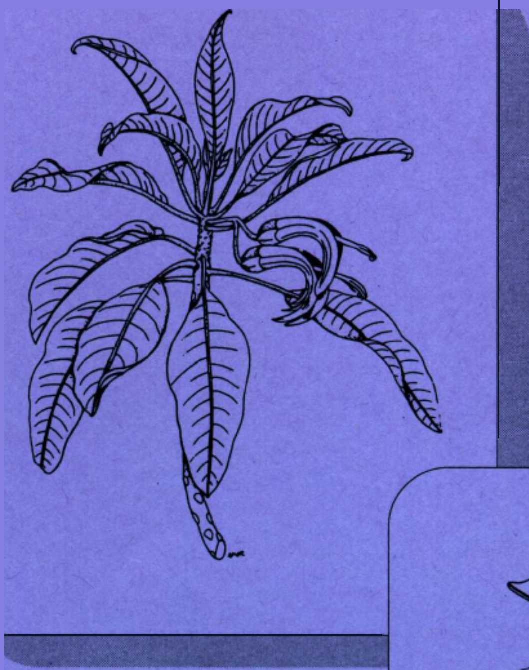
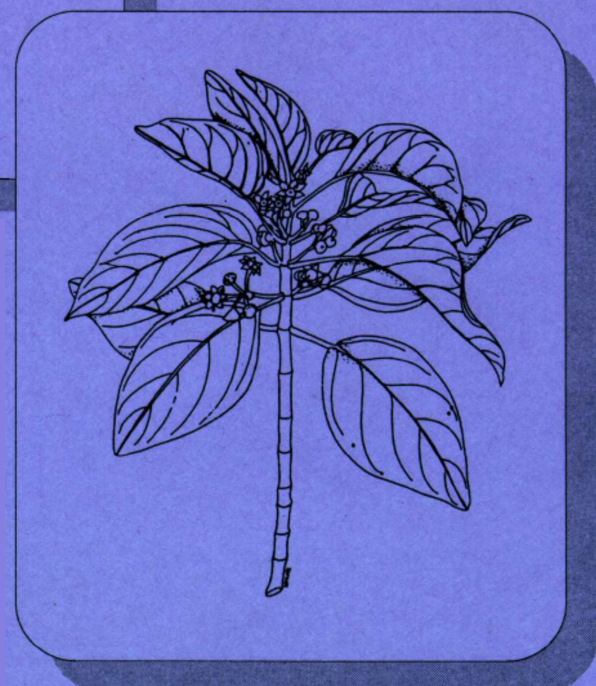
# RECOVERY PLAN FOR THE BIG ISLAND PLANT CLUSTER

SEPTEMBER, 1996





Clermontia peleana (left) and Colubrina oppositifolia (right), two of the 22 plant species in the Big Island Plant Cluster (from Wagner et al.

U.S. Fish and Wildlife Service, Pacific Region

*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.*

# BIG ISLAND PLANT CLUSTER RECOVERY PLAN

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## EXECUTIVE SUMMARY

Current Status of the Taxa: The Big Island Plant Cluster Recovery Plan addresses 22 plant taxa from the island of Hawaii (Big Island) in the State of Hawaii. Twenty taxa are listed as endangered, one is proposed for endangered status, and one is listed as threatened under the Endangered Species Act of 1973, as amended. The endangered taxa in the Big Island Plant Cluster are as follows (# known populations, # known individuals, # outplanted individuals): *Clermontia lindseyana* (12, 400-430), *Clermontia peleana (*subsp. *peleana,* subsp. *singuliflora)* (4, 8), *Clermontia pyrularia* (1-2, 3, 30), *Colubrina oppositifolia* (10, 300, 64), *Cyanea copelandii* subsp. *copelandii* (1, undetermined), *Cyanea hamatiflora* subsp. *carlsonii* (3, 14, 51), *Cyanea shipmanii* (4, <10), *Cyanea stictophylla* (3, <20, 46), *Cyrtandra giffardii* (11, >1,000), *Cyrtandra tintinnabula* (3, 18), *Delissea undulata* (subsp. *niihauensis*, subsp. *kauaiensis*, subsp. *undulata*) [proposed] (1, 1, 50), *Ischaemum byrone* (17, several thousand), *Isodendrion pyrifolium* (1, 50-60), *Mariscus fauriei* (4, 45-60), *Nothocestrum breviflorum* (6, undetermined), *Ochrosia kilaueaensis* (1, undetermined), *Plantago hawaiensis* (8, >5,000), *Portulaca sclerocarpa* (12, >1,000), *Pritchardia affinis* (8, 50-65), *Tetramolopium arenarium* (subsp. *arenarium* var. *arenarium*, subsp. *arenarium* var. *confertum*, subsp. *laxum)* (3, <400), and *Zanthoxylum hawaiiense* (11, >250). The threatened taxon in the Big Island Plant Cluster is *Silene hawaiiensis* (11, ~11,000). Twelve of the 22 taxa are endemic to the Big Island, while an additional 4, which originally had a wider distribution, are now confined to the Big Island. Other taxa currently persist on the islands of Kauai, Oahu, Molokai, Lanai, and/or Maui as well as the Big Island.

Habitat Requirements and Limiting Factors: The island of Hawaii is the largest, highest, and youngest of the Hawaiian Islands, and was built by at least six volcanic mountains. As a result, the taxa included in this plan grow in a variety of vegetative communities (grassland, shrubland, and forests), elevational zones (coastal to alpine), and moisture regimes (dry to wet). They and their habitats are currently threatened by one or more of the following: habitat degradation by feral or domestic animals (goats, pigs, deer (on Maui and Molokai), cattle and sheep); competition for space, light, water, and nutrients by introduced vegetation; fire, a threat which is exacerbated by introduced grasses; direct human perturbation such as recreational and military activities; pest invertebrates; disease; and vulnerability to random events and genetic limitations due to small population size.

Recovery Objectives: The ultimate objective for all taxa is delisting. Interim, downlisting, and delisting criteria are provided. It is suggested that recovery of Big Island Plant Cluster taxa be pursued via the establishment of management units in order to make the most efficient use of available resources and to conserve not only these taxa, but their habitats.

Recovery Criteria:

The following criteria may be revised as more information is obtained about specific taxa.

Interim

The interim objective is to stabilize all existing populations of the Big Island Plant Cluster. To be considered stable, each taxon must be managed to control threats (e.g. fenced) and be represented in an *ex situ* (at other than the plant's natural location, such as a nursery or arboretum) collection. In addition, a minimum total of three populations of each taxon should be documented on the Big Island and, if possible, at least one other island where they now occur or where they occurred historically. Each of these populations must be naturally reproducing and increasing in number, with a minimum of 25 mature individuals per population (minimum of 75 mature plants) for long-lived perennials, and a minimum of 50 mature individuals per population (minimum of 150 mature plants) for short-lived perennials.

Downlisting

For downlisting, a total of five to seven populations of each taxon should be documented on the Big Island and at least one other island where it now occurs or occurred historically, if it is not endemic to the Big Island. Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials, and a minimum of 300 mature individuals per population for short-lived perennials. Each population should persist at this level for a minimum of 5 consecutive years before downlisting is considered.

Delisting

For delisting, a total of 8 to 10 populations of each taxon should be documented on the Big Island and at least1 other island where they now occur or occurred historically, if it is not endemic to the Big Island. Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials, and a minimum of 300 individuals per population for short-lived perennials. Each population should persist at this level for a minimum of 5 consecutive years.

Actions Needed:

1. Protect current populations and manage threats.
2. Conduct essential research.
3. Expand existing wild populations, as necessary.
4. Create new populations within historical range, as necessary.
5. Evaluate and validate recovery objectives.

Total Estimate Cost of Recovery ($1,000):

| Year | Need 1 | Need 2 | Need 3 | Need 4 | Need 5 | Total |
|---|---|---|---|---|---|---|
| 1996 | 279 | 0 | 91 | 146 | 0 | 516 |
| 1997 | 539 | 0 | 91 | 146 | 0 | 776 |
| 1998 | 537 | 0 | 91 | 146 | 0 | 774 |
| 1999 | 470 | 0 | 91 | 146 | 0 | 707 |
| 2000 | 468 | 0 | 91 | 146 | 0 | 705 |
| 2001 | 375 | 200 | 76 | 58 | 0 | 659 |
| 2002 | 318 | 200 | 76 | 58 | 0 | 602 |
| 2003 | 318 | 200 | 76 | 58 | 0 | 602 |
| 2004 | 233 | 200 | 76 | 58 | 30 | 547 |
| 2005 | 233 | 200 | 76 | 58 | 30 | 547 |
| 2006 | 233 | 0 | 18 | 42 | 35 | 323 |
| 2007 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2008 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2009 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2010 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2011 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2012 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2013 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2014 | 233 | 0 | 18 | 42 | 0 | 293 |
| 2015 | 233 | 0 | 18 | 42 | 0 | 293 |
| Total | 6,100 | 1,000 | 1,015 | 1,440 | 95 | 9,395 |

Projected Date of Recovery: 2015

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# I. INTRODUCTION

## BRIEF OVERVIEW

The Hawaiian Islands are classified as a distinct floristic region by phytogeographers because of their unique flora (Takhtajan 1986). Plants ancestral to Hawaii arrived by long distance dispersal, colonizing the islands at a rate of about one species per 70,000 years over a 70 million year history (Carlquist 1970). Isolation by about 2,500 miles (mi) (4,000 kilometers (km)) of water and a conducive climate created biological vacancies. Over millions of years of evolution, Hawaiian ecosystems became diverse in plant taxa. Today's 1,817 native Hawaiian plant species (1,963 taxa) probably adapted and diversified from 272 original colonists (Fosberg 1948, Wagner *et al.* 1990).

In the fourth century, the aboriginal Hawaiians arrived in the Hawaiian Islands. These people brought numerous animals, including dogs, pigs, rats, and chickens, as well as plant species necessary for agriculture (Cuddihy and Stone 1990). The clearing and burning of native vegetation for agriculture, particularly at lower elevations, may have been the greatest cause of environmental change from that time to the arrival of Europeans (Kirch 1982).

The arrival of Captain James Cook in 1778 and subsequent settlement of Europeans and Americans brought further significant changes to the natural environment of Hawaii. Eventually, pasture grasses, trees for timber production, more agricultural and horticultural species, cattle, sheep, and goats were introduced to accommodate ever-increasing demands. Today, more land is used for cattle ranching than for crop production in Hawaii, with more than 25% of the land in the State dedicated to ranching (Hugh *et al.* 1986). Clearing of land, grazing, urbanization, and fire created ideal conditions for weed establishment. Alien plant invasion rapidly accelerated after the arrival of Captain Cook (Cuddihy and Stone 1990). By the end of the 19th century, alien plant introduction increased to about five per year (Cuddihy and Stone 1990).

The demise of native taxa by agricultural and urban developments, unnatural fires, timber harvests, livestock and feral animal grazing, and alien plant intrusion is of grave concern. A large portion of the Hawaiian endemics are now either extinct, listed as endangered or threatened, or species-at-risk (M. Bruegmannn, U.S. Fish and Wildlife Service, personal communication 1995). Immediate actions are necessary to avert the extinction of numerous taxa and their unique habitats.

The Big Island Plant Cluster Recovery Plan addresses plant taxa from the island of Hawaii (Big Island) in the State of Hawaii (Figure 1). Twenty of these taxa were listed as endangered and one listed as threatened under the Endangered Species Act of 1973, as amended, on March 4, 1994 (59 FR 10305). Another taxon addressed in this plan, *Delissea undulata*, was proposed for endangered status on June 27, 1994 (59 FR 32946). Critical habitat was not designated for any of the taxa addressed in this plan. Such designation was found not to be prudent because publication of precise maps and descriptions of critical habitat in the *Federal Register* would increase the degree of threat to these plants from take or vandalism. The taxa included in this plan are listed in Table 1.

Table 1. List of federally endangered and threatened plant taxa included in the Big Island Plant Cluster Recovery Plan.

| Taxon (Common name) | FAMILY | LISTING | DATE |
|---|---|---|---|
| *Clermontia lindseyana* Rock (oha wai) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Clermontia peleana* Rock (oha wai) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Clermontia pyrularia* Hillebr. (oha wai) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Colubrina oppositifolia* Brongn. *ex* H. Mann (kauila) | Rhamnaceae | 59 FR 10305 | 94/03/04 |
| *Cyanea copelandii* Rock subsp. *copelandii* (haha) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Cyanea hamatiflora* Rock subsp. *carlsonii* (Rock) Lammers (haha) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Cyanea shipmanii* Rock (haha) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Cyanea stictophylla* Rock (haha) | Campanulaceae | 59 FR 10305 | 94/03/04 |
| *Cyrtandra giffardii* Rock (haiwale) | Gesneriaceae | 59 FR 10305 | 94/03/04 |
| *Cyrtandra tintinnabula* Rock (haiwale) | Gesneriaceae | 59 FR 10305 | 94/03/04 |

| Taxon (Common name) | FAMILY | LISTING | DATE |
|---|---|---|---|
| *Delissea undulata* Gaud. (No Common Name (NCN)) | Campanulaceae | Proposed 59 FR 32946 | 94/06/27 |
| *Ischaemum byrone* (Trin.) Hitchc. (Hilo *ischaemum*) | Poaceae | 59 FR 10305 | 94/03/04 |
| *Isodendrion pyrifolium* A. Gray (wahine noho kula) | Violaceae | 59 FR 10305 | 94/03/04 |
| *Mariscus fauriei* (Kükenthal) T. Koyama (NCN) | Cyperaceae | 59 FR 10305 | 94/03/04 |
| *Nothocestrum breviflorum* A. Gray (aiea) | Solanaceae | 59 FR 10305 | 94/03/04 |
| *Ochrosia kilaueaensis* St. John (holei) | Apocynaceae | 59 FR 10305 | 94/03/04 |
| *Plantago hawaiiensis* (A. Gray) Pilger (laukahi kuahiwi) | Plantaginaceae | 59 FR 10305 | 94/03/04 |
| *Portulaca sclerocarpa* A. Gray (poe) | Portulacaceae | 59 FR 10305 | 94/03/04 |
| *Pritchardia affinis* Becc. (loulu) | Arecaceae | 59 FR 10305 | 94/03/04 |
| *Silene hawaiiensis* Sherff (NCN) | Caryophyllaceae | 59 FR 10305 | 94/03/04 |
| *Tetramolopium arenarium* (A. Gray) Hillebr. (NCN) | Asteraceae | 59 FR 10305 | 94/03/04 |
| *Zanthoxylum hawaiiense* Hillebr. (ae) | Rutaceae | 59 FR 10305 | 94/03/04 |

Twelve of the 22 taxa addressed in this plan are endemic to the Big Island. Other taxa are known from the islands of Kauai, Oahu, Molokai, Lanai, and/or Maui as well as the Big Island. Four of these taxa are now found only on the Big Island. Figure 2 exhibits the cultural (human) features on the Big Island of Hawaii for reference as distribution of each taxon is discussed in the text.

The listing of the 22 Big Island plant cluster taxa affords them the protection of the Endangered Species Act of 1973, as amended. State law protects federally listed endangered and threatened species automatically (Hawaii Revised Statutes Chapter 1950). Currently, State law prohibits the taking of endangered plant taxa and encourages conservation by government agencies.

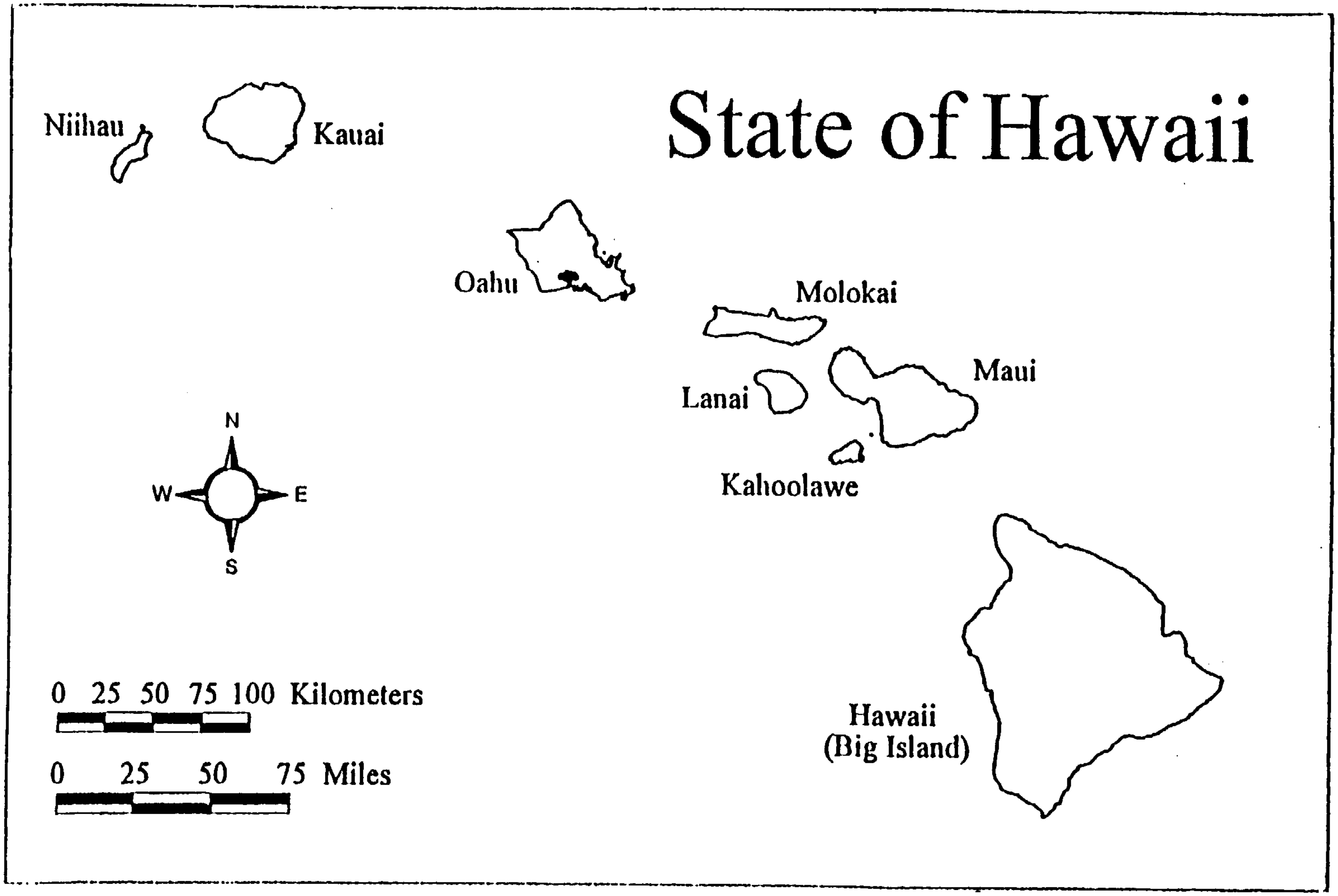


Figure 1. The 8 main Hawaiian Islands.

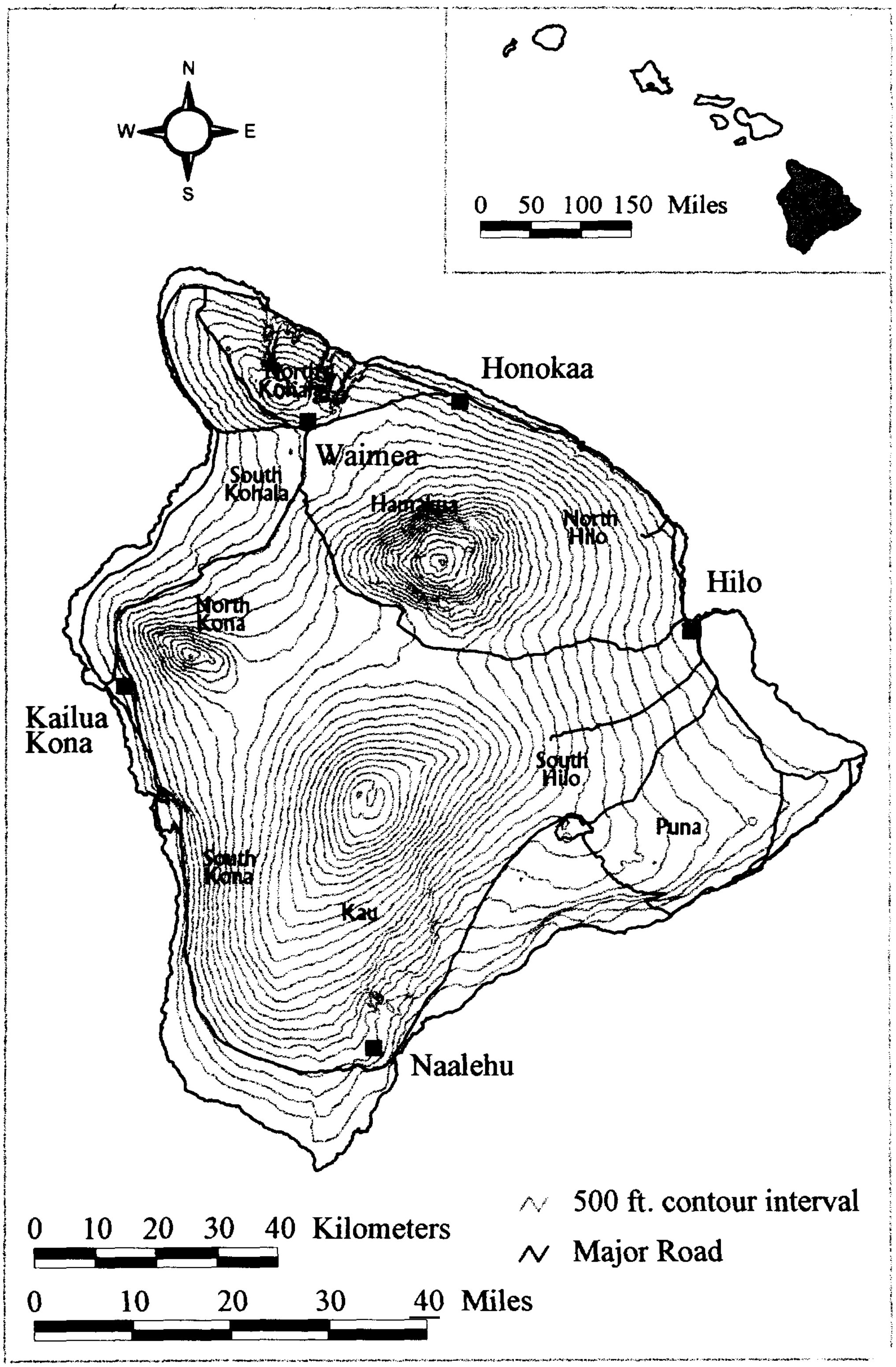


Figure 2. Cultural Features of the Island of Hawaii

## BACKGROUND

### Geology

The island of Hawaii is the largest, highest, southern-most, eastern-most, and youngest of the eight major islands. Rising from the Pacific Ocean between 18°45' and 20°15' north latitude, the island remained isolated from the nearest continental land mass by more than 2,500 miles (4,000 km), until colonized by humans in the recent past. The Big Island was built by at least six volcanic mountains, one of which has been buried by more recent eruptions. The remaining five are relatively young; three have erupted in historic time, according to potassium-argon methods for determining rock age (MacDonald *et al.* 1983) (Figure 3).

The Kohala mountains at the northeastern portion of the island are the oldest (formed 0.33-0.45 million years ago (mya)) (Holmes 1965, MacDonald *et al.* 1983). Formed from moderately violent eruptions from two rift zones, the shield volcano reaches an elevation of about 4,408 feet (ft) (1,344 meters (m)) above sea level. The northwestern and northeastern sides of the volcano differ strikingly in topography. The northwestern side is little eroded and is composed of the original land surface, while the northeastern, windward side is deeply eroded and the original surface is cut away (MacDonald *et al.* 1983). Four huge valleys dissect the windward slope.

Approximately 0.1-0.5 mya, another vent opened in the ocean floor (Holmes 1965, MacDonald *et al.* 1983) at what is presently the south end of the island to build Ninole, a shield volcano about 8,200 ft (2,500 m) in elevation. Lava flows from the Ninole volcano (Ninole series) experienced steam erosion; the original topography has been inundated by flows from Mauna Loa (MacDonald *et al.* 1983). Mauna Kea is the third oldest volcano (0.1-0.5 mya) and rises to 13,792 ft (4,205 m) (MacDonald *et al.* 1983). The latest eruption occurred in the last 2,000 years. Very likely, Mauna Kea was the only mountain on the Big Island to be covered by glaciers during the ice age (Wentworth and Powers 1941). Erosion and climate drastically influenced Mauna Kea's topography. The dry western slope is little eroded while the eastern, windward side of the volcano is deeply scarred with numerous canyons and gulches, some with large rivers and streams

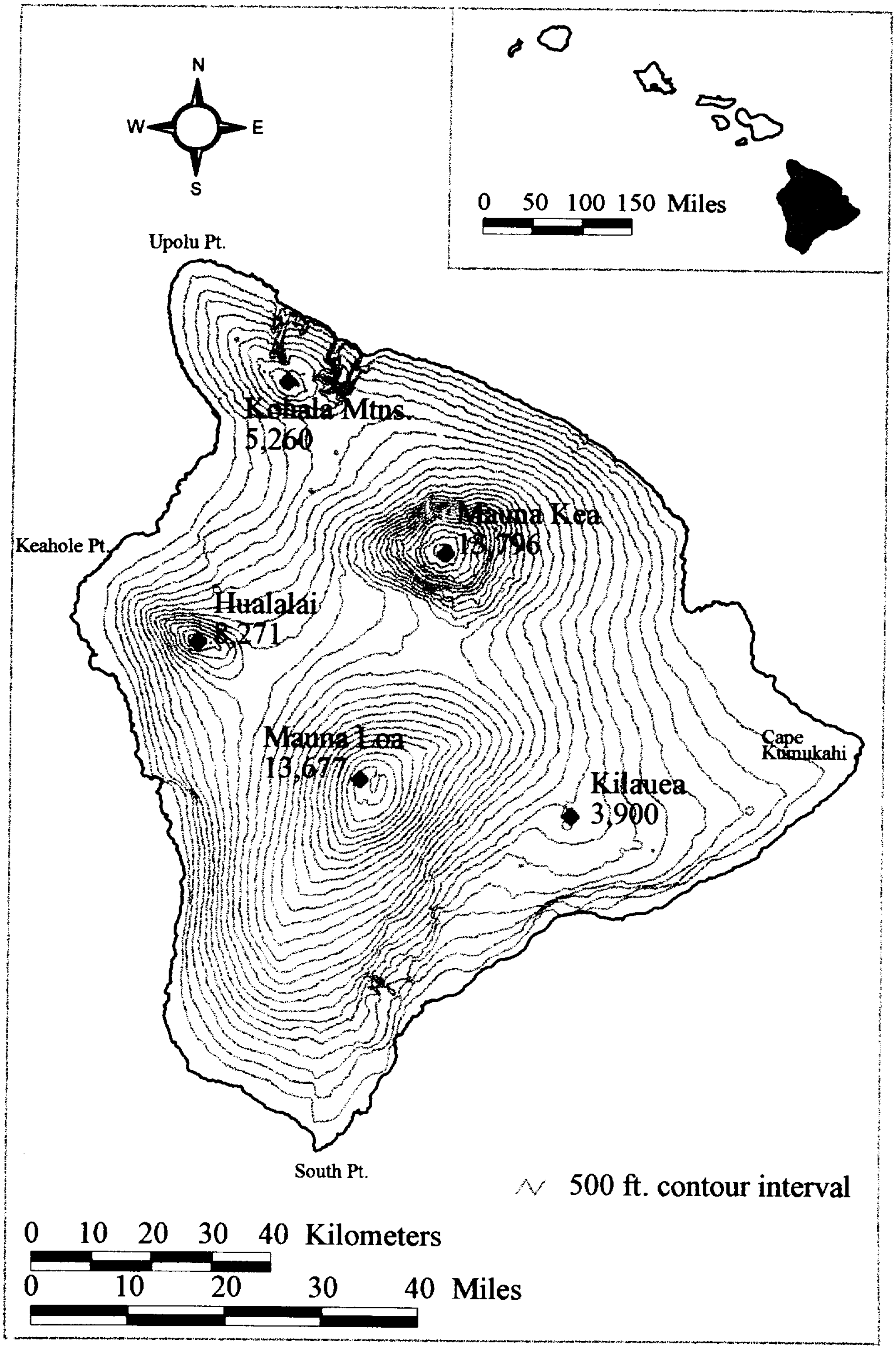


Figure 3: Geologic Features of the Island of Hawaii

(MacDonald *et al.* 1983). Erosive action of these waterways altered the topography over time.

Hualalai volcano is located on the western side of the island and last erupted in 1800-1801 (MacDonald *et al.* 1983). Although its magmatic core is still active, the volcano was built from less explosive eruptions than those of Kohala and Mauna Kea (McDonald *et al.* 1983). Hualalai rises to an elevation of 8,269 ft (2,521 m). The volcano is somewhat protected from erosion (MacDonald *et al.* 1983). Its lava flows intertwine with those of Mauna Loa.

Mauna Loa volcano rises 13,674 ft (4,169 m) above sea level and is currently active. There is little evidence of erosion between successive flows, with the exception of the Wailuku River, which cuts a shallow gorge only to be filled repeatedly with lava that is then degraded (MacDonald *et al.* 1983). The volcano appears to comprise two shield volcanos, Ninole and Mauna Loa.

Kilauea volcano has an elevation of 4,093 ft (1,248 m) and is currently erupting and adding land mass. Presently the Hawaiian hot spot, this volcano is located at the southeastern part of the island and is one of the most active volcanic areas on earth.

Pahala ash was deposited intermittently throughout geologic history by Mauna Kea, Hualalai, Mauna Loa, and Kilauea volcanos (Wagner *et al.* 1990). Ash was deposited at various depths on the northern, northeastern, and southeastern sides of the island. Probably the greatest ash deposition arose from the late Hamakua and Laupahoehoe cones on Mauna Kea and lava fountains of Kilauea (MacDonald *et al.* 1983).

## Climate

The Big Island lies within the trade wind belt (Fosberg 1961, Mueller-Dombois *et al.* 1981). Moisture derived from the Pacific Ocean is carried to the island by north-easterly trade winds. Heavy rains fall when the moisture in clouds makes contact with windward mountain slopes (Fosberg 1961, Wagner 1990) (Figure 4). Considerable moisture reaches the leeward slopes of the saddle, but dries out rapidly as elevation increases. The orographic effect reaches an elevation of about 6,500 to 9,850 ft (2,000 to 3,000 m) and tends to go around rather than over

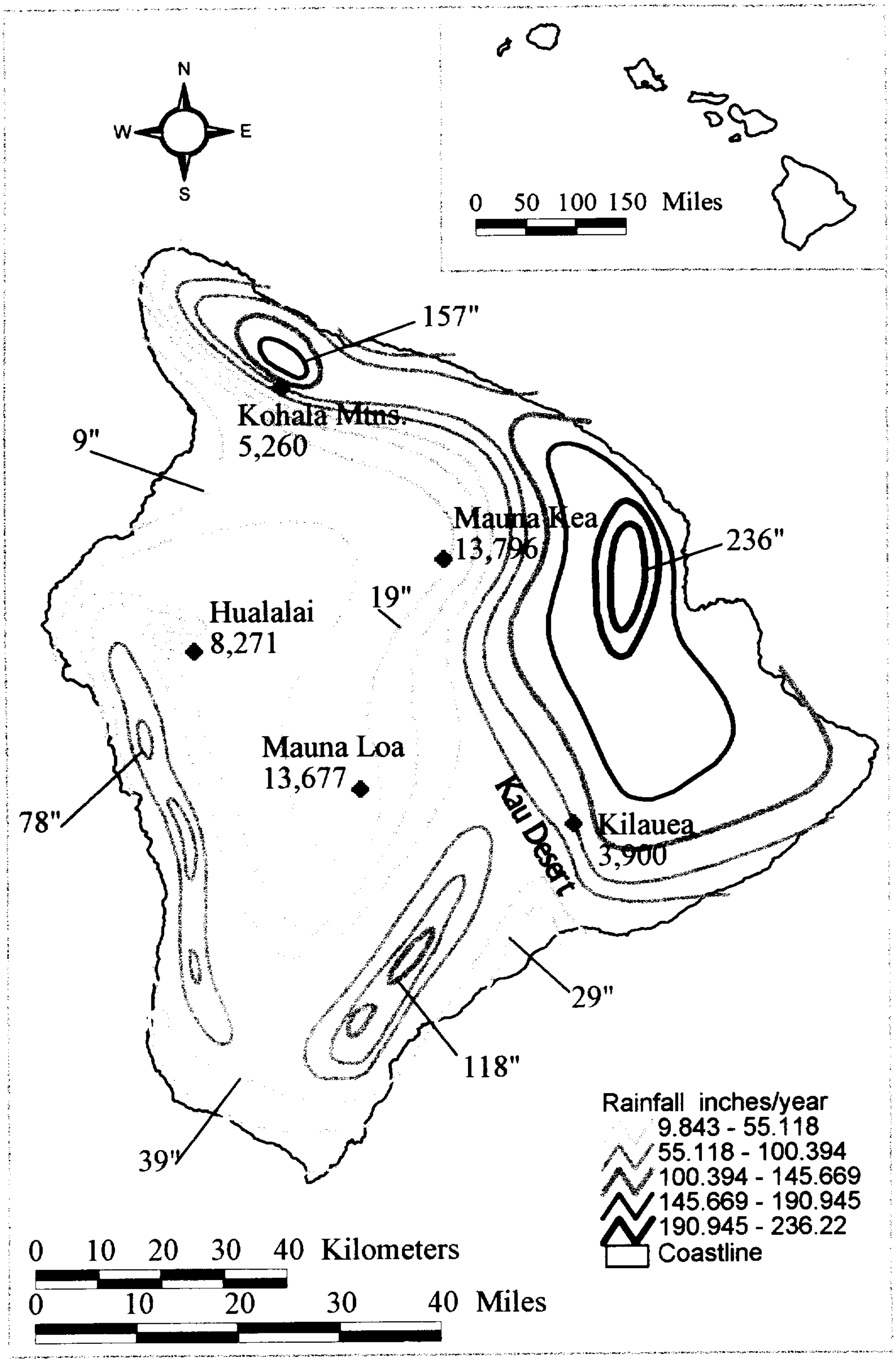


Figure 4: Rainfall on the Island of Hawaii

the high mountains. Thus, leeward and saddle areas of Mauna Kea and Mauna Loa tend to be dry.

A rain shadow effect is created by Mauna Kea and Mauna Loa on the leeward side of the island, removing the Kona coast from trade winds. However, warm air generated from the island land mass rises and condenses, resulting in convectional showers. A major source of rainfall is provided by winter storms which develop south of the island. Kona storms impact the Big Island when trade winds subside during the winter months. Areas of the saddle are protected from these storms by Hualalai volcano and, therefore, droughts in the saddle area are common (Mueller-Dombois *et al.* 1981, Wagner *et al.* 1990).Fog drip, the condensation of moisture on vegetation, can be a significant source of precipitation as well as an effective contributor in reducing evapotranspiration losses, especially in dry areas. Fog drip can equal rainfall amounts in some areas (Sato *et al.* 1973). Fog generally develops in late winter and early spring from either east or west. Fog is more common during the afternoon and occurs as warm air rises up mountain slopes.

At higher elevations, both Mauna Kea and Mauna Loa periodically receive snowfall, that may persist for several months a year. Gregory and Wentworth (1937) indicated that the upper elevations of Mauna Kea experienced glaciationon the summit on four occasions, and glacial deposits date from about 280,000 years ago. No evidence of glaciation is reported for Mauna Loa, indicating the volcano did not reach a significant height to be influenced by glaciation or that glacial deposits were buried beneath more recent lava flows. Gregory and Wentworth (1937) reported reduced sea levels during glaciation resulted in the formation of one large island comprising four islands: Molokai, Lanai, Kahoolawe, and Maui. However, because of the depth of the ocean floor between the Big Island and Maui, the Big Island remained its own entity (Porter 1979, Wagner *et al.* 1990).

The Kau Desert is located on the southeastern side of the Big Island and leeward to the slopes of Kilauea volcano. Lying in the volcano's rain shadow, Kau Desert receives less than 47 inches (in) (1,200 millimeters (mm)) of moisture per year. However, the barren conditions are not attributed to lack of moisture but, rather, to acid rain-forming sulphur dioxide vented from the caldera (Wagner *et al.* 1990).

Small seasonal variation in temperature occurs on the Big Island. Average daily temperatures differ between the warmest and the coolest day only by about 4° C. However, daily extremes are pronounced, reflecting time of day, elevation, and weather. Wagner *et al.* (1990) reported that night is winter in Hawaii. The highest recorded temperature of 100° F (37.7° C) occurred at Pahala and the lowest of 9° F (-12.7° C) on Mauna Kea (Wagner *et al.* 1990).

Vegetation

Climatic contrasts, topography, substrate, geological history, and isolation from continental land masses resulted in a native flora so unique that the mosaic of vegetation patterns are as numerous and diverse as those of continental areas (Wagner *et al.* 1990). Mueller-Dombois *et al.* (1981) stated that nearly all major plant formations occur in Hawaii.

Hawaiian plant communities are based on elevation, moisture and "physiognomy" (i.e., physical structure of the plant community) (Cuddihy 1989, Wagner *et al.* 1990).

For classification, the communities are first placed in one of five elevational bands:

1) coastal -- 0-985 ft (0-300 m);
2) lowland -- 50-6,560 ft (15-2,000 m);
3) montane -- 1,640-8,855 ft (500-2,700 m);
4) subalpine -- 5,575-9,840 ft (1,700-3,000 m);
5) alpine -- 9,840 ft and over (3,000 m and over).

Subsequently, these bands are separated by moisture constants:

1) dry < 47 in (< 1200 mm);
2) mesic 47-98 in (1200-2500 mm); and
3) wet > 98 in (> 2500 mm).

Ultimately the classification is based on physiognomy:

1) herbland -- > 40% herbaceous species;
2) grassland and sedgeland -- > 40% grass and sedge species;
3) shrubland -- > 40% shrubs;

4) forests -- > 40% trees;

5) mixed communities -- > 40% plant codominants of different physiognomic classes.

On the Big Island, all 5 elevational bands are present, 12 of the 13 moisture elevation regions occur, and 30 of the 38 physiognomic classes are present.

## REASONS FOR DECLINE AND CURRENT THREATS

### Agriculture

Kirch (1985) indicated that the greatest force leading to environmental change between the original settlement of the Hawaiian Islands and the arrival of Europeans was agriculture. He recounted that the major impact was experienced at lower elevation and resulted from clearing and burning of native vegetation (Kirch 1982), in addition to the introduction of plant species necessary for agriculture. After the arrival of non-Hawaiians, the number of crops increased with the continual introduction of new cultivated plants by new residents and crews of sailing vessels, and the development of regular trade in agricultural products with European and American ships (Cuddihy and Stone 1990). By the mid-19th century, land reform laws "provided the impetus for rampant clearing of upland forests" (Culliney 1988). Large-scale commercial ventures began to develop in agriculture, logging, and cattle production. The direct loss of individual plants, loss of habitat, introduction and establishment of alien plants, and introduction of ungulates and other non-native animals are all a legacy of this time.

### Alien Plants

The introductions of more than 800 alien plant taxa presently in Hawaii have brought aggressive, vigorous competitors that are displacing native plant populations. Because most alien plant taxa have evolved highly competitive survival strategies and Hawaiian taxa did not evolve under such environmental pressures, Hawaii's native ecosystems and species face an increasingly serious challenge to their survival (Cuddihy and Stone 1990).

Aggressive alien plant taxa in Hawaii are not restricted to one growth form or habitat. They exist as herbs, vines, shrubs, and trees in all disturbed habitats from coastal to alpine regions (Smith 1989, Cuddihy and Stone 1990). Also, exotic plants and animals exhibit mutualistic relationships. Alien plants are a food source for feral animals, resulting in distribution of seeds to new areas (Cuddihy and Stone 1990). The following principal weeds appear to be exceptionally invasive and/or disruptive to native ecosystems: *Pennisetum clandestinum* (kikuyu grass); *Pennisetum setaceum* (fountain grass); *Andropogon virginicus* (broomsedge or yellow bluestem); *Digitaria ciliaris* (Henry's crabgrass, kukaepuaa); *Oplismenus hirtellus* (basketgrass, honohono kukui, honohono maoli); *Melia azedarach* (China berry, pride of India, inia, ilinia); *Leucaena leucocephala* (koa haole, ekoa, lilikoa); *Schinus terebinthifolius* (Christmas berry, wilelaiki, naniohilo); *Lantana camara* (lantana, lakana, laau kalakala, lanakana, mikinolia hihiu, mikinolia hohono, mikinolia kuku); *Polygonum punctatum* (watersmart); *Ardisia elliptica* (shoebutton ardisia); *Casuarina* spp. (ironwood); *Heterotheca grandiflora* (telegraph weed); and *Cannabis sativa* (marijuana). For further information on each of these species, refer to Appendix A.

Domestic and Feral Animals

Dogs, pigs, Pacific rats, and chickens were introduced to Hawaii by Polynesian immigrants about 1,500 years ago (Cuddihy and Stone 1990). European explorers in the late 1700s introduced cattle, goats, deer, sheep, mouflon, and several species of rats and mice, all of which have increased in number during the past 200 years (Stone 1985). Introduced animals are a contributing factor to native plant and animal extinction in lowlands and a primary cause of these losses in uplands (Vitousek *et al.* 1987). Introduction of pigs, cattle, goats, sheep, mouflon, axis deer, and rats have made a major contribution to the demise of many native plant taxa. Alien species of birds compete with and displace native birds. Ungulates degrade native ecosystems by foraging, trampling, and digging, and create eroded and degraded habitats conducive to alien seedling establishment (Stone 1985, Cuddihy and Stone 1990). Rats and mice consume fruits and flowers and strip bark from many native taxa. Of the four rodent species introduced to the Hawaiian Islands, the arboreal roof or black rat (*Rattus rattus*) has the greatest impact on native vegetation and animals (Stone and Loope 1987). Also, rats, mongoose, and feral cats predate on native birds. For further information on each of these species, refer to Appendix B.

Invertebrates

Over 2,000 alien invertebrate species occupy almost all habitats on the Big Island (Howarth and Medeiros 1989). Many alien invertebrates feed on native vegetation, affecting host survival, or prey upon on native invertebrate pollinators (Howarth and Medeiros 1989). Alien species invasions are insidious, pervasive, and usually irreversible (Vitousek *et al.* 1987). Many invertebrates were introduced as biological controls for other alien pests. Howarth (1983) indicated that biological control is unpredictable and should be used with considerable restraint.

One example of a pest invertebrate is the black twig borer (*Xylosandrus compactus*), a serious problem to numerous native taxa in Hawaii (Obata 1973, Gagne 1976, Hara and Beardsley 1979, Samuelson 1981). The black twig borer is a small beetle that bores into branches and lays its eggs. A pathogenic fungus is introduced as a food source by the borer for its larvae (Gagne 1976). As a result, damage to native trees and shrubs can be extensive.

Fire

Although Vogl (1969) suggested that natural fires were an important factor in the development of the original Hawaiian flora, Cuddihy and Stone (1990) stated that, unlike other terrestrial environments on earth, Hawaiian plants are not well adapted to cope with fire. Cuddihy and Stone (1990) contend that fire may have played a less important role in the evolutionary history of native plant taxa because native Hawaiian taxa were historically subjected only to fire resulting from volcanic activity and lightning strikes. Lightning is uncommon on the islands because of their small land mass (Mueller-Dombois 1981).

Native plant communities lack adequate fuel load capacity to maintain fires started by volcanoes or lightning (Mueller-Dombois 1981, Cuddihy and Stone 1990). However, the introduction of alien plant taxa, particularly grasses (*Andropogon virginicus, Pennisetum clandestinum, P. setaceum*), has increased both frequency and size of wildfires (Smith 1985, Cuddihy and Stone 1990). A particularly noxious weed on the dry west side of the Big Island, *P. setaceum* or fountain grass, is adaptable, unpalatable to herbivores, and spreading east. Continuous clumps of highly flammable material are produced as it dries, and fire spreads rapidly and uncontrollably in heavily infested areas. Native plants and dormant seeds in the seed bank are killed by hot fires while fountain grass resprouts quickly at the base, again forming dense clumps and readily producing seeds. Native plant germination and seedling establishment are precluded while ever more dense monotypic stands of fountain grass develop. Although a few native taxa respond to fire by resprouting or producing abundant seeds (*Acacia koa, Dodonaea viscosa*), fire is not a necessary life cycle element (Cuddihy and Stone 1990). The fire cycle may be repeated, ultimately eliminating native flora.

Today, fires are mainly human caused. The effects on vegetation are usually deleterious (Cuddihy and Stone 1990). On the Island of Hawaii, vegetation on the dry slopes of Mauna Kea is particularly vulnerable. Lower elevations are ranched (Parker Ranch), whereas upper elevations are managed for recreational hunting and military activity (Pohakuloa Training Area). These upland areas are heavily infested with kikuyu grass (*Pennisetum clandestinum*) and fountain grass, and are highly susceptible to fire. In 1993, a fire from an unknown source spread rapidly onto Pohakuloa Training Area. The fire burned for several days, enveloping Kipuka Kalawamauna (a critical plant habitat set aside by the military for the protection of sensitive plant taxa), threatening numerous populations of rare plants.

Efforts must be maintained to eliminate and or control fire in all habitats, particularly dry shrubland forests where water is unavailable or limited. The areas most affected by and susceptible to fire are, unfortunately, habitats where the majority of native taxa still persist.

Direct Human Impacts

Most sensitive taxa occur in habitats that are exceptionally fragile. Development, collection of plants for horticultural purposes, and excessive visits by the public may adversely impact taxa that have only a few populations or individuals. Uprooting, collecting and/or trampling of these plants in any degree would cause damage. In addition, research must be carefully planned and executed with discretion to ensure that rare taxa are not "studied to death".

Random Events and Small Population Size

Taxa that occur in small numbers and/or few populations are in jeopardy of extinction from random, events. These events include landslides, flooding, volcanic activity and drifting sand, or human-induced, such as unnatural fires or introduction of disease. Drastic declines in population size also reduce genetic variability and may result in a genetic "bottleneck", leading to possible extirpation or extinction (Carson 1989). Inbreeding depression, for example, may reduce reproductive vigor resulting in even further decline in numbers.

Disease

Lethal yellow, which is not presently known to occur in Hawaii, is caused by a bacteria-like organism that devastate some native plant taxa. The disease occurs in many palms and is considered a potential threat if introduced on plant material into Hawaii (Hull 1980). Other plant diseases could also be introduced to Hawaii and become threats to native taxa.

Avian diseases have had a devastating effect on many endemic Hawaiian forest birds that seem to have little or no resistance. Avian pox (Poxvirus avium) causes lesions on the feet, legs, and bills, and is transmitted by physical contact or vectored by mosquitoes. Avian malaria (Plasmodium relictum capistranoae) is vectored by the southern house mosquito (Culex quinquefasciatus), and clearly limits the lower elevational distribution of many Hawaiian forest birds. The loss and reduction of forest bird pollinators has contributed to the decline of bird-pollinated plants. Table 2 provides a summary of threats.

Table 2. Summary of threats to taxa in the Big Island Plant Cluster.

| Species | Cattle | Deer | Goats | Pigs | Rats | Sheep | Disease Insects | Alien Plants | Fire | Limited Numbers | Human Impact |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Clermontia lindseyana* | X | | X | X | P | | | X | | | |
| *Clermontia peleana* | | | | X | X | | | | | X1,3 | X |
| *Clermontia pyrularia* | | | | | P | | | X | | X1,3 | P |
| *Colubrina oppositifolia* | | | | X | | | X | X | X | | P |
| *Cyanea copelandii* subsp. *copelandii* | | | | | P | | | | | X1,3 | P |
| *Cyanea hamatiflora* subsp. *carlsonii* | X | | | | P | | | X | | X2,3 | |
| *Cyanea shipmanii* | | | | X | P | | | | | X1,3 | |
| *Cyanea stictophylla* | X | | | X | P | | | | | X2,3 | |
| *Cyrtandra giffardii* | | | | X | | | | X | | | |
| *Cyrtandra tintinnabula* | | | X | X | | | | | | X2,3 | P |
| *Delissea undulata* | X | | X | X | X | X | | X | X | X1,3 | X |
| *Ischaemum byrone* | | P | P | | | | | X | P | | X |
| *Isodendrion pyrifolium* | | | | | | | | X | X | X2,3 | X |
| *Mariscus fauriei* | | X | X | | | | | X | | X2,3 | |
| *Nothocestrum breviflorum* | X | | | | | X | | X | X | ? | X |

Table 2. Summary of threats to taxa in the Big Island Plant Cluster.

| Species | Cattle | Deer | Goats | Pigs | Rats | Sheep | Disease Insects | Alien Plants | Fire | Limited Numbers | Human Impact |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ochrosia kilaueaensis* | | | X | | P | | | X | X | X1,3 | P |
| *Plantago hawaiensis* | | | | | | | | | | | |
| *Portulaca sclerocarpa* | | | X | X | | X | | X | X | | P |
| *Pritchardia affinis* | | | | | X | | P | X | X | X2 | X |
| *Silene hawaiiensis* | | | X | X | | X | | X | X | | P |
| *Tetramolopium arenarium* | | | X | X | | X | | X | X | X3 | P |
| *Zanthoxylum hawaiiense* | X | P | X | | | X | | X | X | | P |

Key
X = Immediate and significant threat
P = Potential threat
1 = Fewer than 10 known individuals
2 = Fewer than 100 known individuals
3 = Fewer than 5 known populations

TAXON ACCOUNTS

The following are individual taxon accounts for the Big Island Plant Cluster Recovery Plan. Each taxon is presented here with its recovery priority number and taxon specific information. The recovery priority number is assigned according to the Recovery Priority System which rates the recovery priority of a taxon on a scale of 1-18 according to its degree of threat, recovery potential and taxonomy. This system is briefly reviewed in Appendix C. The general strategy for the recovery of these taxa can be found in the Overall Recovery Strategy section.

**Campanulaceae (Bell Flower Family)**
A family of cosmopolitan distribution, Campanulaceae is composed of 70 genera and 2,000 species (Lammers 1990). The family is broken into two subfamilies: Campanuloideae and Lobelioideae. In Hawaii, the Campanuloideae are represented by two introduced genera each with one species and the Lobelioideae are represented by eight genera (six endemic (native to Hawaii and not found elsewhere), one indigenous (native to Hawaii and found elsewhere), and one introduced) (Lammers 1990).

Hillebrand (1888) referred to endemic Lobelioideae as "the pride of our flora" because of the extreme morphological diversity. The Lobelioideae are indeed most intriguing because the amazing diversity arose from five colonization instances (Rock 1919a). Endemic nectar-feeding birds and Lobelioideae appear to have coevolved, thus affecting the pollination of the taxon and leading to the evolutionary development of this extraordinary diversity (Lammers and Freeman, 1986). Unfortunately, at least 25% of these taxa have been extirpated in the past century, since Hillebrand (1888) commented on this diverse subfamily.

***Clermontia* (oha wai)**
*Clermontia* Gaud., an endemic genus comprised of 22 species and 11 subspecies, is divided into 2 sections: *Clermontioideae* with 7 species and *Clermontia* with 15 species (Lammers 1990). The calyx of *Clermontioideae* is green and triangular while the calyx of *Clermontia* is similar to the corolla, which lends to a doubled flowered appearance. Both sections are represented on the Big Island, *Clermontioideae* with four species and two subspecies and *Clermontia* with seven

species (Lammers 1990). On the Big Island, the following two species (including two subspecies) in section *Clermontioideae* and one species in section *Clermontia* are endangered. Two taxa, which occur on Molokai, Lanai, and Maui, are endangered as well (Lammers 1990).

***Clermontia lindseyana*** **(oha wai)** - Recovery Priority #2

Description

*Clermontia lindseyana* Rock is a small, branched tree that grows 8.2 to 20 ft (2.5-6 m) tall (Lammers 1990). A perennial, the taxon is either terrestrial or epiphytic, living on the surface of other plants. Oblance-shaped leaves are 5-9 in (13-24 centimeters (cm)) long and 1.5-2.6 in (3.8-6.5 cm) wide. The upper surface is dark green while the lower is pale green or purplish and hairy. Leaf stalks are 1-2.8 in (2.5-7 cm) long and hairy. Two flowers arise from the tip of the main flower stalk which is 1-6 in (2.5-4 cm) long. The spreading sepals and petals are similar in shape, texture and size, 2.2-2.6 in (5.5-6.5 cm) long and 0.35-0.7 in (0.9-1.8 cm) wide, green or purplish on the outside and whitish on the inside. They are fused at the base into a hemispherical or ob-oval tube, which is 0.47-0.79 in (1.2-2 cm) long and 0.39-0.87 in (1-2.2 cm) wide. Berries are 1-1.6 in (2.5-4 cm) wide, almost round, and orange.

*Clermontia lindseyana* is easily separable from the other taxa within this genus by several characters: much larger leaves and flowers, similar petals and sepals, and spreading floral lobes (Cuddihy *et al.* 1983, Lammers 1990, 1991). Rock (1962) commented on the leaves being conspicuously hairy beneath.

Taxonomy

In 1957, J.F. Rock made this taxon a variety of *Clermontia hawaiiensis* and named it *Clermontia hawaiiensis* (Hillebr.) Rock var. *grandis* Rock, based on incomplete specimens collected on the Big Island in the 1950s. Rock (1962) recounted that, at the time, he was unable to study the specimens at length, as he was preparing for a trip to Europe. After review, Rock renamed the taxon *Clermontia lindseyana*, in honor of Thomas Lindsey and his wife who first found it. At this time, he also described variety *livida* Rock. St. John (1987a) described the two new species *Clermontia albimontis* St. John and *C. viridis* St. John. However, Lammers (1990, 1991) concluded that these two species were within the range of *C. lindseyana*. Lammers recognized no subspecific taxa.

Historic Distribution

Historically *Clermontia lindseyana* was known on Maui from the southern slope of Haleakala and the eastern portion of the island. On the Big Island, populations were known from the eastern slope of Mauna Kea and eastern, southeastern, and southwestern slopes of Mauna Loa (Table 3) (HHP 1991a1-a13, 59 FR 10305). Known elevation ranged from 4,300 ft (1,311 m) to 7,041 ft (2,150 m).

Table 3. Historic (H) and current distribution of *Clermontia lindseyana*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Maui (H) | E. Maui, Kaupo Nahiki | Not Available (N/A) | N/A | N/A | N/A | 1910 |
| Maui (H) | E. Maui, Haleakala, Lualailua Hills | N/A | N/A | N/A | Forbes | 1920 |
| Hawaii (H) | N. Hilo, Honohina | N/A | N/A | N/A | St. John | 1938 |
| Hawaii (H) | S. Hilo, Papaikou, Puu Akala | N/A | 4,500-6,000 ft (1,370-1,830 m) | Private | N/A | 1957 |
| Hawaii (H) | S. Hilo, Makahanaloa | 2 | 5,800-6,000 ft (1,800-1,830 m) | Private | Rock | 1960 |
| Hawaii (H) | Kau, Kahuku | N/A | 5,900 ft (1,800 m) | State | St. John | 1971 |
| Hawaii (H) | N. Hilo, Maulua Nui | N/A | N/A | N/A | Bird Survey | 197? |
| Hawaii | N. Hilo, Piha | N/A | 5,460 ft (1,660 m) | State | Warshauer | 1977 |
| Hawaii | N. Hilo, Laupahoehoe | N/A | 5,480-5,520 ft (1,670-1,680 m) | State | N/A | 1977 |
| Hawaii | N. Hilo, Piha | N/A | 5,280-5,360 ft (1,610-1,634 m) | State | N/A | 1977 |
| Hawaii | S. Hilo, Makahanaloa | N/A | 5,240 ft (1,600 m) | Private | Warshauer | 1977 |
| Hawaii | S. Kona, Kukuiopae | N/A | 4,800 ft (1,500 m) | State | Warshauer | 1978 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | N. Hilo, Puu Oo | N/A | 7,040 ft (2,150 m) | State | Stephens N/A | 1957 1987 |
| Hawaii | Kulani Correctional Facility | 9 | 5,340-5,360 ft (1,627-1,634 m) | State | Duvall | 1987 |
| Maui | E. Maui, Kahikinui Wailaulau | 330 | 4,500 ft (1,370 m) | State | Hobdy and Medeiros | 1995 |
| Hawaii | Kulani, nr. Boys Home | 3 | 5,639 ft (1,719 m) | Federal | Perlman | 1991 |
| Hawaii | S. Hilo, Kau | 37 | 4,680-6,200 ft (1,430-1,890 m) | State | Clarke, Cuddihy | 1952 1981-1983 |
| Hawaii | Kapapala and Kau Forest Reserves | 27 | 5,150-5,900 ft (1,570-1,800 m) | State | Cuddihy | 1981-1983 |
| Hawaii | S. Kona Hakalau NWR | 10 | N/A | Federal | Jeffrey | 1995 |

Current Distribution

Since 1975, 12 populations of *Clermontia lindseyana* have been identified, 1 on private, 9 on State and 2 on Federal land. One of these is on Maui and 11 are on the Big Island (HHP 1991a1 to 1991a13, 59 FR 10305). Although the total number of extant individuals on the Big Island is unknown, approximately 86 individuals are thought to persist (HHP 1991a1-13). The Maui population is located on State-owned land between Wailaulau Gulch and Manawainui Gulch, and estimated to consist of about 330 individuals (Art Medeiros, National Biological Service, in lit., 1995). Populations on the Big Island occur in or near Piha, Laupahoehoe, Makahanaloa, Kukuiopae, Puu Oo, Kulani Correctional Facility, Kahikinui, Kulani Boys Home, Kau Forest Reserve, and Hakalau National Wildlife Refuge (Table 3). Observations indicate that most of the individuals are in "excellent vigor" (HHP 1991a1 to 1991a13). The elevation ranges from 4,680 ft (1,570 m) to 6,200 ft (1,800 m).

Linda Pratt (National Biological Service, pers. comm., 1995) has indicated that about 37 individuals currently persist on transects in Kilauea Forest (10), Keauhou Ranch (20), and Kulani project (7) in South Hilo. In addition, 19 individual plants were observed in the northeastern corner of the Kau Forest Reserve and eight were observed nearby on permanent transects in the Kapapala Forest Reserve.

Jack Jeffrey (U.S. Fish and Wildlife Service, Hakalau National Wildlife Refuge, pers. comm., 1995) has indicated that 10 plants recently discovered at Hakalau National Wildlife Refuge occur in a gulch that "looked like a lost world". This and another endangered taxon, *Cyanea shipmanii,* grow within 328 ft (100 m) of each other. Six plants of *Clermontia lindseyana* grow in close proximity while the others are scattered. The population appears healthy.

Life History

This species was observed in fruit from June to October, and in flower from February to August (HHP 1991a2, a3, a10). No other life history information is currently available.

Habitat Description

The extant populations grow in mesic forest on the leeward slopes. On the Big Island, the habitat is montane mesic forest dominated by *Acacia koa* A. Gray (Fabaceae) (koa), and *Metrosideros polymorpha* Gaud. (Myrtaceae) (ohia), (Gagne and Cuddihy 1990, Lammers 1990, Lammers 1991, HHP 1991a1-a13, NTBG 1991a). Associated native taxa include the following native trees and shrubs: *Ilex anomala* Hook. & Arnott (Aquifoliaceae), *Coprosma* J.R. Forster & G. Forster (Rubiaceae) (pilo), and *Myrsine* L. (Myrsinaceae) (kolea) (HHP 1991a2, 1991a5; NTBG 1991a; Fern Duvall, Hawaii Division of Forestry and Wildlife, Maui District, pers. comm., 1992).

Reasons for Decline

Among the major threats to *Clermontia lindseyana* are trampling and grazing by cattle, trampling and browsing by goats, and rooting and trampling by pigs (Cuddihy *et al.* 1983; NTBG 1991a; Pratt and Cuddihy 1991; F. Duvall, pers. comm., 1992; A. Medeiros, pers. comm., 1992; L. Pratt, pers. comm., 1995).

Trampling and feeding on this taxon not only decimate the population, but create disturbed areas for non-native plant invasion (L. Pratt, pers. comm., 1995).

Accompanying feral and domestic animal activity are significant loss of plant cover, disturbance, and an increase in bare ground. Progressive intrusion of *Pennisetum clandestinum* and *Passiflora mollissima* presents a formidable threat to this endangered taxon. These invasive taxa outcompete both adults and seedlings, reducing their reproductive potential (L. Pratt, pers. comm., 1995).

Although undocumented, consumption of berries, flowers, and vegetation by *black rats* may damage and contribute to the decline of this taxon. The rat may be a limiting factor to the taxon's survival by decreasing plant viability and depressing reproductive capabilities.

<u>Conservation Efforts</u>
Volcano Rare Plant Facility, Hilo, Hawaii, has successfully germinated *Clermontia lindseyana* from seed (Patty Moriyasu, Volcano Rare Plant Facility, pers. comm., 1995). Currently, six individuals persist in the greenhouse and three are continuing to grow in the garden. Lyon Arboretum, Honolulu, Oahu, has not been able to germinate the taxon because seeds were immature (Greg Koob and Charles Lamoureaux, Lyon Arboretum, pers. comm., 1995).

<u>Needed Recovery Actions</u>
Current populations of this species should be protected from ungulates wherever possible, and their habitat managed for deterrence of non-native plant invasions.

***Clermontia peleana* (oha wai)** - Recovery Priority #5
<u>Description</u>
*Clermontia peleana* Rock is an epiphytic shrub or tree that grows between 5-20 ft (1.5-6 m) tall (Figure 5) (Lammers 1990). *Clermontia peleana* grows on *Metrosideros polymorpha, Acacia koa, Cheirodendron trigynum* (Gaud.) A. Heller, and *Sadleria* spp. (amau). Alternate oblong to elliptic leaves with blades 3-8 in (8-20 cm) long and 1.2-2 in (3-5 cm) wide are attached to leaf stalks 1.2-2.4 in (3-6 cm) long. Single or paired flowers are attached to a flower stalk 1.2-1.8 in (3-4.5 cm) long and then to a main stalk 0.3-0.7 in (0.8-1.7 cm) long. The calyx and petals are fused into a tube (hypanthium) 0.4-0.6 in (1.0-1.5 cm) long

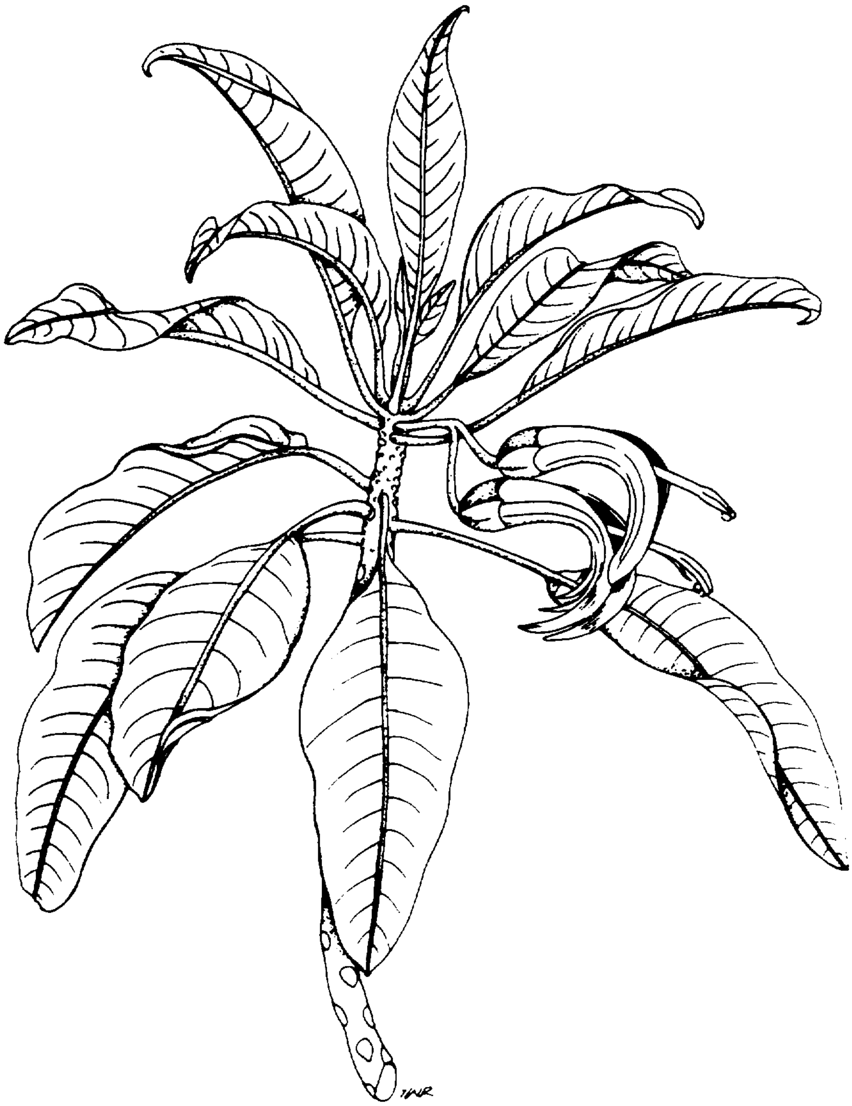

Figure 5: *Clermontia peleana* subsp. *peleana* (from Wagner *et al.* 1990)

and 0.4-0.6 in (l-l.5 cm) wide. The tip of the green calyx is 5-lobed and each lobe is triangular. The petals are fused 3/4 to 4/5 of their lengths above the hypanthium, and all are curved down, such that the flower appears1-lipped. The black-purple or green-white petals measure 2.0-2.8 in (5-7 cm) long and 0.3-0.5 in (0.8-1.3 cm) wide. Anthers extend beyond the petals. Berries are orange and about 1.2 in (2.5-3.0 cm) long and wide. Two subspecies are separated on the basis of flower color: *Clermontia peleana* subsp. *peleana* Rock is black-purple while *C. p.* subsp. *singuliflora*, presumed extinct, is green-white. The species can be separated from other Hawaiian members of the genus by its epiphytic growth, small triangular green calyx lobes, and1-lipped flowers (Lammers 1990, 1991).

Taxonomy

John Lydgate first found this taxon on the Big Island at Hamakua, and Hillebrand (1888) thought it was an unknown variety of *Clermontia gaudichaudii* Hillebr., a 5: *Clermontia peleana* (from Wagner *et al.* 1990) similar taxon now known as *C. clermontioides* (Gaud.) A. Heller. Rock (1913) later collected the same taxon near Kilauea and gave it the specific epithet *peleana* in honor of goddess Pele. *Clermontia peleana* has been known by several other names including: *C. gaudichaudii* Hillebr. var. *singuliflora* Rock (Rock 1919a), *C. singuliflora* (Rock) Rock (Rock 1919a), *C. gaudichaudii* Hillebr. var. *barbata* Rock (Rock 1919a), *C. clermontioides* (Gaud.) A. Heller var. *singuliflora* (Rock) Hochr. (Hochreutiner 1934), *C. clermontioides* (Gaud.) A. Heller var. *mauiensis* Hochr. *nom. illeg.*, and *C. clermontioides* (Gaud.) A. Heller var. *barbata* (Rock) St. John (St. John 1973). Lammers (1991), in the most recent treatment, recognized two subspecies: *C.p. peleana;* and *C.p. singuliflora*. *C.p. singuliflora* is presumed extinct.

Historic Distribution

*Clermontia peleana* subsp. *peleana* is known only from the island of Hawaii, where it was found on the northeastern and southeastern slopes of Mauna Kea and from the eastern slopes of Mauna Loa (Table 4) (Lammers 1991).

Table 4. Historic (H) and current distribution of *Clermontia peleana* subsp. *peleana*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Government Road, Kilauea | Not Available (N/A) | 3,800 ft (1,158 m) | N/A | Rock | 1911-1912 |
| Hawaii (H) | Olaa Flume | N/A | N/A | N/A | Forbes | 1915 |
| Hawaii (H) | Hale Louolu, Wailuku River | N/A | N/A | N/A | N/A | 1915 |
| Hawaii (H) | S. Hilo | N/A | 3,500 ft (1,060 m) | State | Rock | 1957 |
| Hawaii (H) | Kilauea Volcano | 2 | 2,500-3,000 ft (760-910 m) | State | Rock<br>Lindsey | 1911<br>1957 |
| Hawaii (H) | Volcanoes National Park | N/A | N/A | Federal | Mueller-Dombois | 1966 |
| Hawaii | N. Hilo, Keanakolu | N/A | 3,790 ft (1,160 m) | Federal | Warshauer | 1977 |
| Hawaii | N. Hilo, Papaaloa | 2 | 1,820 ft (555 m) | State | Warshauer | 1977 |
| Hawaii | S. Hilo, Upper Piihonua | 2 | 3,600 ft (1,100 m) | State | Warshauer | 1977 |
| Hawaii | S. Hilo, Piihonua Wailuku River | 2 | 2,840-2,900 ft (870-880 m) | State | Wagner<br>N/A | 1983<br>1985 |

*Clermontia peleana* subsp. *singuliflora* was known from the northwestern slope of Haleakala on Maui, and the northern slope of Mauna Kea on the Big Island (Table 5). Last collected on Maui in 1920 (and on the Big Island in 1909), this subspecies is presumed extinct.

Table 5. Historic distribution of *Clermontia peleana* subsp. *singuliflora.*

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Maui (H) | E. Maui, Hamakua | Not Available (N/A) | N/A | N/A | Lydgate | 18?? |
| Maui (H) | E. Maui | N/A | N/A | N/A | Forbes | 1920 |
| Hawaii (H) | Mauna kea, Paauhau | N/A | 3,500-4,000 ft (1,070-1,200 m) | N/A | Rock | 1909 |

Current Distribution

Since 1975, four populations of *Clermontia peleana* subsp. *peleana* have been identified at Keanakolu, Papaaloa, Piihonua, and upper Piihonua on the eastern side of the Big Island (Table 4). The populations are located on State and federally owned lands. Eight individuals are thought to persist although exact numbers are unknown (HHP 1991b1 to 1991b7).

Life History

This species was observed in flower during June and November 1957 (HHP 1991b1, b7), and in fruit during November 1977 (HHP1991b3). No other life history information is currently available.

Habitat Description

*Clermontia peleana* is an epiphyte of montane wet forests on windward slopes of Mauna Kea and Mauna Loa. Rock (1913) commented that "the very handsome species" was associated with *Clermontia hawaiiensis* (Hillebr.) Rock, *Cheirodendron gaudichaudii* (DC.) Seem. [*C. trigynum* (Gaud.) A. Heller], *Cyrtandra* sp., and *Cibotium* sp. Currently, the taxon grows in rain forests dominated by *Acacia koa, Metrosideros polymorpha, Cibotium* subsp. and/or *Sadleria* spp. (tree ferns) at elevations between 1,800 and 3,800 ft. (530-1,600 m) (HHP 1991b1-1991b4, 1991b6, 1991b7; Lammers 1990, 1991). Other native species that grow in association with *Clermontia peleana* are *Melicope clusiifolia* (A. Gray) T. Hartley & B. Stone (kolokolo mokihana) and *Scaevola chamissoniana* Gaud. (naupaka kuahiwi) (HHP 1991b1).

Reasons for Decline

Major habitat destruction resulting from ungulates, particularly pigs, is a primary cause of the decline of this taxon. Cultivation of *Cannabis sativa* (marijuana) has also disturbed areas which might be suitable habitat for *Clermontia peleana* subsp. *peleana*. Roof or black rats may limit fruit production. Loss of pollinators may limit *C. peleana* subsp. *peleana*'s reproductive capability, making recovery difficult or impossible; however, little information is available regarding the relationship between *C. peleana* subsp. *peleana* and nectar-feeding birds and/or other suitable pollinators. Natural events such as fire and flooding may severely inhibit the survivability of the taxon.

Small numbers of individuals and the scattered distribution of populations are significant threats, not only because they limit the gene pool and further depress reproductive vigor, but because a single natural or human-induced disturbance may be catastrophic and lead to the extirpation of the taxon. Unwarranted visits could adversely impact the populations.

Conservation Efforts

Volcano Rare Plant Facility germinated one individual from seed acquired in 1992 (P. Moriyasu, pers. comm., 1995). The National Tropical Botanical Garden (NTBG) has germinated seeds and propagated the taxon (Diane Ragone, NTBG, pers. comm., 1995). Lyon Arboretum has been successfully cloning *Clermontia peleana* subsp. *peleana* using leaf tissue and has about 300 plants in the greenhouse. There have been no attempts to outplant the taxon at this point because these clones are not considered representative of the population and thus not useful for conservation purposes (G. Koob and C. Lamoureaux, pers. comm., 1995). Material from bud tissue is needed (G. Koob, pers. comm., 1995).

Needed Recovery Actions

In order to prevent possible extinction of this taxon, maintenance of *ex situ* (at other than the plant's natural location, such as a nursery or arboretum) genetic stock is necessary. The eight known plants should be protected from ungulates, particularly pigs, via fencing or other means. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of plants for recovery within the taxons's four known locations, and a fifth population will need to be established.

***Clermontia pyrularia* (oha wai)** - Recovery Priority #2

Description

*Clermontia pyrularia* Hillebr. is a tree that grows to about 13 ft (3-4 m) tall (Lammers 1990). Narrowly elliptic leaf blades are 5.9-11 in (15-28 cm) long and 1-2 in (2.5-5 cm) wide, finely toothed, alternate, dark green on the upper surface, and light green beneath. The leaf blades are attached to winged stalks 0.8-1.4 in (1.5-3.5 cm) long. Two, three, or sometimes five flowers are attached to a flower cluster stalk (inflorescence) 1.1-2.4 in (2.8-6 cm) long. Each flower is subtended (supported) by a flower stalk 0.3-0.8 in (0.8-2 cm) long. The calyx and petals are fused at the flower's base into a tube 0.4-0.7 in (1-1.8 cm) long and 0.7-4.7 in (0.8-12 cm) wide. The calyx is small and its lobes are triangular, 0.1-0.2 in (0.3-0.5 mm) long and 0.4-0.8 in (1-2 cm) wide. Petals, 1.6-1.8 in (4-4.5 cm) long, are fused into a tube 0.2-0.3 in (5-8 mm) wide, which is 2-lipped and curved. Five white or green-white petals are finely hairy, lobed and spreading. Berries, 0.7-1.1 in (1.8-2.8 mm) long and 0.6-0.9 in (1.5-2.4 cm) wide, are ob-oval or ob-pear-shaped and orange.

This species is separated from the other taxa in the genus that occur on the Big Island by winged leaf stalks (petioles), 2-lipped flowers, green-white petals, and a pear-shaped berry (Lammers 1990, 1991).

Taxonomy

*Clermontia pyrularia* was first collected during the U. S. Exploring Expedition of 1840-1841 on the slopes of Mauna Kea, Hawaii. Based on this sterile specimen, Gray (1861a) named the taxon *Delissea obtusa* A. Gray var. *mollis* A. Gray. Hillebrand (1888) and Rock treated the name as a synonym for a taxon from Maui, *Cyanea obtusa* Hillebr., although neither saw the type specimen. Later, Hillebrand (1888) collected fertile specimens and named the taxon *Clermontia pyrularia* after the pear (*pyrus*) because of the shape of fruits.

Historic Distribution

*Clermontia pyrularia* is known only from the Big Island, where it occurred on the western and northeastern slope of Mauna Kea, the western slope of Mauna Loa and the saddle between the two (59 FR 10305, HHP 1991d1-d6) (Table 6).

Table 6. Historic (H) and current distribution of *Clermontia pyrularia.*

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Hamakua | Not Available (N/A) | N/A | N/A | N/A | 18?? |
| Hawaii (H) | Mauna Kea, Puu Huluhulu | N/A | N/A | N/A | Forbes | 1915 |
| Hawaii( H) | N. Hilo, Humuula, Hinahina | N/A | 6,200 ft (1,900 m) | N/A | Hosaka | 1939 |
| Hawaii (H) | S. Kona, Kealakekua Papaloa | N/A | 3,937 ft (1,200 m) [Possible error - 5,100 ft?] | Private | N/A | 1949 |
| Hawaii (H) | S. Kona Kealakekua | N/A | 3,000 ft (910 m) | State | | |
| Hawaii (H) | N. Hilo, Maulua Nui | N/A | 6,167-6,200 ft (1,880-1,890 m) | Federal | Rock | 1957 |
| Hawaii | N. Hilo Laupahoehoe | N/A | 5,900 ft (1,800 m) | State | N/A Warshauer | 1949 1978 |
| Hawaii | N. Hilo Piha Hakalau NWR | 3 30 (outpl.) | 6,240 ft (1,900 m) | State, Federal | Bruegmann Jeffrey | 1992 1995 |

Current Distribution

Since 1975, two populations have been identified on State and Federal lands in N. Hilo at elevations of 5,900 to 6,240 ft (1,800 to 1.900 m) (Table 6) (HHP 1991d2 to 1991d5; Lammers 1990, 1991; M. Bruegmann, pers. comm., 1992). One population consisted of an individual previously found near Laupahoehoe Natural Area Reserve; the plant is now dead and this population may be extirpated. The second population consists of three plants found on State land at Piha, adjacent to the Hakalau National Wildlife Refuge (NWR). Although this second population also originally consisted of one plant that eventually died, three more plants were recently discovered (J. Jeffrey, pers. comm., 1995). In addition, approximately 30 individuals grown from seeds of the original plant were outplanted in 2 exclosures at Hakalau NWR by refuge staff in December of 1990 and June and July of 1992.

Life History

This species was observed in fruit and flower during December 1978 (HHP 1991b3) and November 1957 (HHP 1991b4). No other life history information is currently available.

Habitat Description

The habitat for *Clermontia pyrularia* is wet montane forest dominated by *Acacia koa* and/or *Metrosideros polymorpha*, and subalpine dry forest dominated by *M. polymorpha*, at elevations between 3,000 to 7,000 ft (910 and 2,130 m) (HHP 1991d1-d2, 59 FR 10305). Associated taxa are *Lythrum maritimum* Kunth (pukamole), *Rubus hawaiensis* A. Gray (kala), and *Hedyotis* (HHP 1991d1-d2).

Reasons for Decline

Alien grasses, shrubs, and vines, particularly banana poka (*Passiflora mollissima*), negatively impact *Clermontia pyrularia*. Jack Jeffrey (pers. comm., 1995) indicated that the canopy of banana poka is shading out seedlings in Piha and must be controlled. By rooting and trampling native vegetation and eliminating juveniles, pigs also appear to be a major contributor to the taxon's demise (J. Jeffrey, pers. comm., 1995). Jeffrey also indicated that pigs are attracted by the fruits of *Passiflora mollissima*. Fruits are dispersed in their digestive tracts, hooves, and hair.

Predation on fruits and seeds of *Clermontia pyrularia* by black rats may limit the successful establishment of new plants. Scattered distribution, few populations, and small number of individuals make this taxon highly vulnerable to random events and human impacts, and may also affect reproductive vigor. The plant originally known from Piha rapidly died from unknown causes in 1995 and there was no indication of natural reproduction even though viable seeds for the outplants were produced. The general decline of the environment may have eliminated or reduced native vectors and thereby precluded or lessened pollination. Other individuals known from the Piha area disappeared a few years ago, probably eaten by cattle. The area is pasture land and is heavily grazed (M. Bruegmann and J. Jeffrey, pers. comm., 1995).

Conservation Efforts
Volcano Rare Plant Facility at the Volcano Agricultural Station has successfully germinated *Clermontia pyrularia* and currently has approximately 50 seedlings growing in the greenhouse (P. Moriyasu, pers. comm., 1995). Lyon Arboretum has successfully cloned the taxon and has about 100 seedlings in the greenhouse (G. Koob, pers. comm., 1995).

Approximately 30 individuals have been outplanted and are growing in 2 exclosures at Hakalau NWR. Seeds were acquired from the wild plant at Piha that succumbed in 1989. The individuals grown from seed are healthy and two or three have flowered. Jeffrey (pers. comm., 1995) indicated that there are plans to fence the three remaining wild plants in the near future.

Needed Recovery Actions
The known remaining individuals should be protected from ungulates and encroachment of alien plants. In order to prevent possible extinction of this taxon, maintenance of *ex situ* genetic stock is necessary. Propagation and outplanting of *ex situ* stock will be needed in order to establish a sufficient number of populations and plants for recovery. Research into the taxon's pollination vectors may be necessary.

***Cyanea* (haha)**
The genus *Cyanea* Gaud. is endemic to Hawaii. It contains 52 species and 17 subspecies and is the largest genus of *Campanulaceae* in Hawaii (Lammers 1990). The Big Island supports 11 species and 5 subspecies from the genus. Of these, three taxa are presumed extinct and four are endangered. The four endangered plants listed in this plan are *Cyanea copelandii* subsp. *copelandii*, *Cyanea hamatiflora* subsp. *carlsonii*, *Cyanea shipmanii*, and *Cyanea stictophylla*.

***Cyanea copelandii* subspecies *copelandii* (haha)** - Recovery Priority #5
Description
*Cyanea copelandii* Rock subsp. *copelandii* is a small epiphytic shrub that grows 1-6.7 ft (0.3-2 m) tall (Lammers 1990). Rooting at the nodes, its weak stems clamber on rocks and tree trunks. Oblance-shaped leaf blades 4.9-10.6 in (10-27 cm) long and 1.4-3.3 in (3.5-8.5 cm) wide are dark green on the upper surface and hairy on the lower surface. Leaf blade margins have small teeth and the base

of the blade is attached to a leaf stalk that is 1-3.9 in (2.5-10 cm) long. Clusters of 5 to 12 flowers are attached to a main flower cluster stalk (peduncle) 0.8-1.8 in (2-4.5 cm) long. Each flower is then attached to a flower stalk (pedicel) 0.2-0.6 in (0.4-1.6 cm) long. The calyx and the petals are fused at the base into a tube 0.2-0.4 in (0.6-1 cm) long. Calyx lobes are small and triangular, 0.08-0.2 in (2-4 mm) long. The petals, 1.5-1.7 in (3.7-4.2 cm) long, are yellowish but appear rose because of long dark red hairs that cover the surface. Five spreading petal lobes are fused into a tube. Berries are ob-oval, 0.3-0.6 in (0.7-1.5 cm) long and dark orange.

Lammers (1990) distinguishes this species from other members of the genus by the size, shape and dark red hairs of the petals and by the reclining habit. This taxon is easily separated by its narrow leaves from the only other subspecies, *Cyanea copelandii* subsp. *haleakalaensis* (St. John) Lammers, which is relatively prolific on Maui.

Taxonomy

*Cyanea copelandii* was named by Rock in 1917 in honor of his friend and collecting companion, M. L. Copeland. On a trip to the Big Island, Copeland and Rock collected the taxon in 1914 (Rock 1917a). The validity of the characters used to separate *Cyanea* and *Delissea* as entities (Hillebrand 1888, Rock 1919a) was questioned by St. John and Takeuchi (1987) and the two genera were merged. The species was assigned to *Delissea,* the older of the two generic names, resulting in *Delissea copelandii* (Rock) St. John. The merger was not accepted because it failed to provide a more natural classification and was based on a limited understanding of both genera (Lammers 1990). The current treatment of the family by Lammers (1990) recognizes the original separation of the two genera. Also, he regarded the taxon as *Clermontia copelandii* subsp. *copelandii*, segregating it from a taxon that is relatively common on Maui, *C. c.* var. *haleakalaensis.*

Historic Distribution

*Cyanea copelandii* subsp. *copelandii* was first collected at two sites on the southeastern slope of Mauna Loa, near Glenwood, Hawaii. It was last collected in 1957 by an unknown collector (Table 7).

Table 7. Historic distribution of *Cyanea copelandii* subsp. *copelandii*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | Puna, Glenwood | Not Available (N/A) | 2,400 ft (730 m) | State | Rock | 1914 1918 |
| Hawaii | N/A | N/A | N/A | N/A | N/A | 1957 |

Current Distribution

Although it was last collected in 1957, the population is still thought to be extant (Table 7) (Lammers 1990). The number of individuals currently present is undetermined (HHP 1991f).

Life History

This taxon was observed in fruit and flower during December 1914 (HHP 1991f1). No other life history information is currently available.

Habitat Description

The habitat of *Cyanea copelandii* subsp. *copelandii* is montane wet forest dominated by *Cibotium* spp., at elevations between 2,200 to 5,232 ft (660 to 1,600 m) (Lammers 1990). The Hawaiian Heritage Program (1991f) gives 2,200 to 2,900 ft (660 to 880 m) as the elevational range of this taxon. *Cibotium* is the only genus recorded as an associate of this taxon (HHP 1991f).

Reasons for Decline

*Cyanea copelandii* subsp. *copelandii* has been particularly impacted by the grazing of feral ungulates. Black rats may also constitute a threat by consuming fruits and seeds, and thereby reducing reproductive and establishment success. The loss of Hawaiian honeycreepers has likely resulted in elimination of the bird pollinator for this plant. Because only one small plant population may exist, reduction in reproductive vigor and susceptibility to random extinction are threats.

Conservation Efforts

At this time, neither the Volcano Rare Plant Facility nor Lyon Arboretum are attempting to germinate and/or grow individuals from tissue culture (P. Moriyasu and G. Koob, pers. comm., 1995). Since the last plant specimen was collected in 1957, the availability of plant materials is the present constraint. If materials are obtained, attempts will be made to grow and outplant individuals.

Needed Recovery Actions

This taxon should be located in the wild, and seeds and/or tissue collected for propagation and maintenance of *ex situ* genetic stock. Additional populations will need to be established and, along with the extant population, protected from ungulates and other threats.

***Cyanea hamatiflora* subspecies *carlsonii* (haha)** - Recovery Priority #5

Description

*Cyanea hamatiflora* Rock subsp. *carlsonii* (Rock) Lammers is a palm-like tree that grows 9.8-26 ft (3-8 m) tall and has tan sap (Lammers 1990). The leaf blades are 20-31 in (50-80 cm) long and 3-5.5 in (8-14 cm) wide and are without a leaf stalk. Five to 10 flowers are in clusters at the end of a main cluster stalk (peduncle) 0.6-1.2 in (1.5-3 cm) long. Each flower is subtended by a stalk (pedicel) 0.2-0.5 in (0.5-1.2 cm) long. The sepals and the petals are fused at the base into an ob-oval tube (hypanthium) 0.5-1.2 in (1.2-3 cm) long and 0.2-0.5 in (0.6-1.2 cm) wide. The calyx has five narrowly oblong lobes 1.2-1.8 in (3-4.5 cm) long and 0.2 in (0.5 cm) wide. Magenta petals are fused into a tube 2.3-3.1 in (6-8 cm) long and 0.2-0.4 in (0.6-1.1 cm) wide, which is down-curved. The top of the tube is1-lipped with five down-curved lobes. Berries are red and ob-oval, 1.2-1.8 in (3-4.5 cm) long and 0.8-1.0 in (2-2.7 cm) wide.

The species is composed of two subspecies: *Cyanea hamatiflora* subsp. *carlsonii* is an endangered taxon endemic to the Big Island; *Cyanea hamatiflora* subsp. *hamatiflora* occurs only on East Maui and is relatively common. *C. h.* subsp. *carlsonii* is distinguished from other taxa in the genus by calyx lobes that are longer and wider (Lammers 1990).

## Taxonomy

Rock (1957) originally named the taxon *Cyanea carlsonii* Rock in honor of Norman K. Carlson. When Rock first collected the taxon with Carlson and L. W. Bryan the specimen was sterile. Rock (1962) later described the fruits and flowers from specimens acquired from Carlson's garden. Along with the other members of the genus, the validity of the characters used to separate *Cyanea* and *Delissea* as separate genera (Hillebrand 1888, Rock 1919a) were questioned, and the two taxa were merged by St. John (St. John 1987b, St. John and Takeuchi 1987), resulting in the name *Delissea carlsonii* (Rock) St. John. In a current treatment by Lammers (1990), St. John's nomenclature is disregarded and the two genera are accepted. Lammers (1990) recognizes the two infraspecific taxa *Clermontia hamatiflora* subsp. *carlsonii* and *C. hamatiflora* subsp. *hamatiflora*.

## Historic Distribution

*Cyanea hamatiflora* subsp. *carlsonii*, known only from the west side of the Big Island, is a fairly recent discovery by Rock and Carlson (1957) (Table 8).

Table 8. Historic (H) and current distribution of *Cyanea hamatiflora* subsp. *carlsonii*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | S. Kona, Keokea | 3 | 4,000-4,300 ft (1,220-1,310 m) | Private | Rock<br>Rock | 1957<br>1969 |
| Hawaii | Hualalai | 3 | 5,220 ft (1,600 m) | State | NTBG | 1990 |
| Hawaii | Hualalai<br>PuuWaawaa | 1<br>6 (outpl.) | 5,220 ft (1,600 m) | State | NTBG<br>Giffin | 1990<br>1996 |
| Hawaii | Hualalai, Honualua | ca. 10<br>45 (outpl.) | 5,700 ft (1,740 m) | State | Davis et al.<br>Pratt, Bergfeld | 1980<br>1995 |

## Current Distribution

Since 1975, *Cyanea hamatiflora* subsp. *carlsonii* has been identified at three sites on the western slopes of Hualalai, Hawaii. There are approximately 14 known individuals (Table 8) (HHP 1991g1-g2, NTBG 1991c1-c3). In addition, 45 plants were outplanted on the Honualua Forest Reserve (Steve Bergfeld, Hawaii

Division of Forestry and Wildlife (DOFAW), pers. comm., 1995) and 6 plants were outplanted at Puu Waawaa (Jon Giffin, DOFAW, pers. comm., 1996).

Life History

This taxon was observed in flower during December 1980 (HHP1991g1) and August 1995 (C. Corn, DOFAW, pers. comm., 1996). Seeds were collected by Hawai DOFAW in October 1991 and November 1995. No other life history information is currently available.

Habitat Description

The habitat of *Cyanea hamatiflora* subsp. *carlsonii* is mesic montane forest dominated by *Metrosideros polymorpha* at elevations between 4,000 to 5,700 ft (1,220 to 1,740 m) (Lammers 1990, HHP 1991g1-g2). Associated native plants include *Myoporum sandwicense* A. Gray (naio), *Hedyotis* (pilo), and *Zanthoxylum* (a'e).

Reasons for Decline

Alien plant invasion represents a serious threat to the long term survival of *Cyanea hamatiflora* subsp. *carlsonii*. Banana poka (*Passiflora mollissima)*, an invasive alien weed, negatively impacts *C. hamatiflora* by competing for nutrients, water, and light. Grazing and trampling by domestic and escaped cattle and rooting by pigs degrade the habitat and open conducive sites for alien plant establishment. Rats and alien birds may eat the juicy fruits, reducing the potential numbers of successive individuals. The small remaining numbers of individuals and their limited and scattered distribution are serious threats because a single natural or human-induced event may have catastrophic effects on the few surviving plants. Seeds collected by Hawaii DOFAW in 1991 had little or no insect damage, but seeds collected in 1995 were heavily damaged by an undetermined species of caterpillar (C. Corn, pers. comm., 1996). Reproductive vigor may be depressed by a limited gene pool.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon (D. Ragone, pers. comm., 1995). Seeds planted at Volcano Rare Plant Facility have not germinated (P. Moriyasu, pers. comm., 1995), and seeds acquired by Lyon Arboretum from storage were not viable. Attempts are being made to obtain new seed (G. Koob, pers. comm., 1995). Steve Bergfeld (pers. comm., 1995) has indicated that, in 1993, 22 and 27 individuals were planted within 2 exclosures at Honuaula Forest Reserve. Currently, 21 plants remain alive in the first and 23 in the second. One individual was planted outside the exclosures and is surviving. Three unhealthy plants were planted near Honomalino, but all died. Of several individuals planted at Puu Waawaa, six have survived (J. Giffin, DOFAW, pers. comm., 1996)

Needed Recovery Actions

Current populations need to be protected from ungulates, and banana poka and other alien species controlled, to the extent possible, within the taxon's habitat. Propagation and outplanting efforts should be encouraged and continued.

***Cyanea shipmanii* (haha)** - Recovery Priority #2

Description

*Cyanea shipmanii* Rock is a small unbranched or sparsely branched shrub 8-13 ft (2.5-4 m) tall (Lammers 1990). Young plants often have sharp outgrowths on the stem. Leaves are divided 3/4 to 7/8 of the distance to the midrib into 20 to 30 segments. The blades are 6.7-12 in (17-30 cm) long and 2.8-5.7 in (7-14 cm) wide. The leaf stalk (petiole) is 1.2-2.2 in (3-5.5 cm) long and is also muricate (spiny). Ten to 15 flowers are in a cluster at the tip of a main flower cluster stalk (peduncle) 0.4-1.2 in (1-3 cm) long. Each flower is subtended by a stalk (pedicel) 0.4-0.6 in (1-1.5 cm) long. The calyx and the petals are fused at the base into a tube (hypanthium) 0.16-0.2 in (4-6 mm) long and 0.12-0.16 in (3-4 mm) wide. The calyx has five small oblong lobes 0.12-0.2 in (0.3-0.6 cm) long and 0.02-0.04 in (0.5-1 mm) wide. Five lobed green-white petals 1.2-1.4 in (3-3.6 cm) long are fused below into a curved tube 0.1-0.2 in (3-4 mm) wide. The berry is elliptic, 0.5-0.6 in (1.2-1.5 cm) long, and 0.5 in (1.3 cm) wide. This taxon is easily distinguishable from other members of the genus by its small flowers, slender stems, and stalked and divided leaves (Lammers 1990).

Taxonomy

*Cyanea shipmanii* was originally described by Asa Gray (1861a) as *Cyanea grimesiana* Gaud. var. *citrullifolia* A Gray, based on sterile specimens collected on the U. S. Exploring Expedition of 1840-1841. Juvenile leaves collected at the same time were later thought to be specimens of *C. tritomantha* A. Gray (Rock

1919a). However, Rock and Shipman re-collected the taxon in 1955. Rock (1957) named the species in honor of his traveling companion, Herbert Shipman, resulting in the name, *Cyanea shipmanii*.

Historic Distribution

*Cyanea shipmanii* is known only from the eastern slopes of Mauna Kea, Hawaii (Table 9). When first collected in 1840-1841, a total of 50 or fewer individuals were observed in the population (Lammers 1990, HHP 1991h). Only one was a mature plant.

Table 9. Historic (H) and current distribution of *Cyanea shipmanii*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Eastern Mauna Kea | <50 | Not Available (N/A) | Private | N/A | 1840 |
| Hawaii | S. Hilo, Papaikou | 3 | 5,400-6,000 ft (1,650-1,830 m) | Private | N/A | 1955 1993 |
| Hawaii | N. Hilo, Upper Waiakea Forest Reserve | 1 | 5,860 ft (1,786 m) | State | Pratt | 1994 |
| Hawaii | S. Hilo, Kulani, nr. Mauna Loa Home for Boys | N/A | N/A | Private? | Katahira | 1995 |
| Hawaii | Hakalau Forest | 4 | N/A | Federal | Jeffrey | 1995 |

Current Distribution

Since 1975, four populations of *Cyanea shipmanii* have been identified on State, Federal, and private land (Table 9). The total number of extant individuals is unknown, but fewer than 10 are estimated to exist (L. Pratt, pers. comm., 1995).

Life History

No life history information is currently available for this species.

Habitat Description

The habitat of *Cyanea shipmanii* is montane mesic forest dominated by *Metrosideros polymorpha* (ohia) on the windward slopes of the island, at elevations between 5,400 and 6,200 ft (1,650 and 1,900 m) (HHP 1991h, 59 FR 10305). Associated native plants include *Zanthoxylum*, *Myrsine* (kolea), *Acacia koa* (koa) and *Metrosideros polymorpha* (L. Pratt, pers. comm., 1995). The four individuals in Hakalau Forest National Wildlife Refuge are growing with *Clermontia lindseyana* (J. Jeffrey, pers. comm., 1995).

Reasons for Decline

Recent pig rooting of tree ferns and other native taxa was evident at the Upper Waiakea Forest population (L. Pratt, pers. comm., 1995). Small numbers of extant individuals and localized distribution may result in a limited gene pool and reduced reproductive vigor, as well as vulnerability to extirpation by random events. Small population size probably affects vector and flower relationships, precluding or reducing effective pollination, and reduction in the number of endemic nectar feeding birds may have disrupted their fundamental role in pollination.

Conservation Efforts

Seeds have been germinated at Volcano Rare Plant Facility at the Volcano Agricultural Station. About 10 plants are growing in the garden and four in the greenhouse (P. Moriyasu, pers. comm., 1995). Lyon Arboretum has cloned about 300 individuals from immature seed (G. Koob, pers. comm., 1995). An individual found in 1994 by Thane Pratt in a shaded ravine south of Powerline Road in the Upper Waiakea Forest Reserve is now protected from feral pigs by a small fence built by the DOFAW. The individual appears healthy.

Needed Recovery Actions

Propagation and maintenance of *ex situ* stock should be continued, and current populations protected from pigs and augmented. One new population will need to be established and numbers increased in order to meet recovery criteria.

***Cyanea stictophylla* (haha)** - Recovery Priority #2

Description

*Cyanea stictophylla* Rock is a small tree or shrub 2-20 ft (0.6-6 m) tall (Lammers 1990). The stems are sparsely branched and occasionally equipped with sharp outgrowths. The leaves are long and narrow with toothed or lobed blades, 7.8-15 in (20-38 cm) long and 1.6-3.1 in (4-8 cm) wide. Leaf stalks (petioles) are 0.6-1.4 in (1.5-3.5 cm) long. Five or six flowers form a cluster at the tip of the main flower cluster stalk, which is 0.3-0.9 in (0.7-2.2 cm) long. The calyx and petals are fused at the base into an oval, sparsely hairy tube (hypanthium) about 0.2 in (5-6 mm) long. At the tube tip, five triangular calyx lobes are 0.1-0.2 in (2-4 mm) long and 0.04-0.1 in (1-2 mm) wide. Sparsely hairy, spreading, deeply-lobed petals, 1.4-2 in (3.5-5 cm) long, are fused into an arched tube about 0.2 in (5-6 mm) wide. The five petals are yellow-white or purple. Berries are orange and round.

*Cyanea stictophylla* is distinguished from other taxa within the genus by its large, deeply lobed flowers and small calyx lobes (Lammers 1990).

Taxonomy

In 1912, Rock first collected *Cyanea stictophylla* on the slopes of Mauna Loa. Rock described the taxon in 1913 based on these specimens. The specific epithet refers to the leaves, which are long and narrow. Other authors recognized the following synonyms: *Cyanea palakea* C. Forbes (Forbes 1916), *C. quercifolia* (Hillebr.) F. Wimmer var. *atropurpurea* F. Wimmer (Wimmer 1953), *C. stictophylla* var. *inermis* Rock (Rock 1957), and *C. nelsonii* St. John (St. John 1976). St. John (1987b) and St. John and Takeuchi (1987), disregarding the separation of the genera *Cyanea* and *Delissea*, merged the two into the genus *Delissea*, resulting in the new combinations of *Delissea palakea* (C. Forbes) St. John, *D. quercifolia* (Hillebr.) St. John var. *atropurpurea* (F. Wimmer) St. John, *D. stictophylla* (Rock) St. John, *D. stictophylla* var. *inermis* (Rock) St. John, and *D. nelsonii* (St. John) St. John. However, Lammers (1990) recognized the generic distinction and retained both genera.

## Historic Distribution

*Cyanea stictophylla* is known historically from the western, southern, southeastern, and eastern slopes of Mauna Loa on the Big Island (Table 10) (Lammers 1990).

Table 10. Historic (H) and current distribution of *Cyanea stictophylla*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kau, Kaiholena | Not Available (N/A) | 6,000 ft (1,800 m) | N/A | Rock | 1912 |
| Hawaii (H) | N. Kona, Puu Hualalai, Puu Waawaa | N/A | 5,906 ft (1,800 m) | N/A | St. John *et al.* | 1931 |
| Hawaii (H) | S. Kona | N/A | 3,500-4,300 ft (1,070-1,300 m) | Private | Rock | 1957 |
| Hawaii | Kau, Keauhou | 7<br>6 (outpl.) | 5,200 ft (6,200 m) | Private, State | Clarke *et al.*<br>Bergfeld | 1980<br>1996 |
| Hawaii | S. Kona, Kohae | N/A | 4,700 ft (1,430 m) | Private | Duvall | 1987 |
| Hawaii | N. Kona, Puu Waawaa | 1<br>40 (outpl.) | 5,500 ft (1,800 m) | State | N/A | 1996 |

## Current Distribution

Since 1975, the taxon has been identified near Keauhou, Kohae, and on Puu Waawaa (Table 10) in 3 populations thought to comprise fewer than 20 individuals (HHP 1991i1-i3). In addition, approximately 46 outplanted individuals persist in exclosures on Puu Waawaa and Kau Forest Reserve (J. Giffin and S. Bergfeld, pers. comm., 1996).

## Life History

This species was observed in flower during March 1987 (HHP 1991i3). No other life history information is currently available.

Habitat Description

The habitats of *Cyanea stictophylla* are lowland to montane, mesic to wet forest dominated by *Acacia koa* and *Metrosideros polymorpha*. Populations grow between 3,500 to 6,400 ft (1,070 to 1,950 m) in elevation (Lammers 1990, HHP 1991il-i3). Associated native species include *Melicope volcanica* (A. Gray) T. Hartley & B. Stone (alani) and *Urera glabra* (Hook. & Arnott) Wedd. (opuhe) (HHP 1991il-i3).

Reasons for Decline

The primary reasons for decline of this species are destruction of former habitat by cattle grazing and degradation of current habitat by feral pigs. In addition, the small number of plants and the scattered distribution of populations may limit the gene pool, resulting in decreased reproductive vigor, and make them vulnerable to extirpation by random events.

Conservation Efforts

The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995). Patty Moriyasu has has been attempting to acquire seed of *Cyanea stictophylla* to begin germination work at Volcano Rare Plant Facility (pers. comm., 1995). The single, wild individual on Puu Waawaa has been fenced. Seeds from this wild plant were germinated, and approximately 68 individuals were planted about 3 years ago within a separate exclosure on Puu Waawaa (S. Bergfeld and J. Giffin, pers. comm., 1995). Of these individuals, about 40 have survived. Seeds from the same wild individual at Puu Waawaa were used to establish six individual plants in an enclosure on the Kau Forest Reserve (Steve Bergfeld, pers. comm., 1996).

Needed Recovery Actions

Propagation and maintenance of *ex situ* stock are necessary and efforts to do such should be encouraged. Current populations should be protected from ungulates and augmented, where possible. At least two new populations will need to be established and numbers increased to meet recovery criteria.

***Delissea***

*Delissea* Gaud., an endemic genus comprising nine species and five subspecies, was named in honor of a physician from Mauritius who served on the

D'Entrecasteaux Expedition to the South Pacific in 1800-1804 (Lammers 1990). The genus is divided into two sections *Delissea* and *Macranthae* (Hillebr.) Rock. All but four of the nine species are presumed extinct. Two species (*Delissea fallax* Hillebr. and *D. undulata* Gaud.) were known to occur on the Big Island, the former being endemic to the Big Island and the latter endemic to the Hawaiian Islands. *D. fallax* is considered extinct. *D. undulata* consists of only one known wild individual.

***Delissea undulata*** - Recovery Priority #5

Description

*Delissea undulata* is an unbranched, palm-like, woody-stemmed tree, 6-32 ft (2-10 m) tall (Lammers 1990). A dense cluster of leaves occurs at the stem tip. Leaf blades are elliptic to narrowly lance-shaped, 2-8 in (5-21 cm) long and 1-4 in (3.5-10 cm) wide. Leaf edges are wavy or flat and toothed. Leaf stalks are 0.8-5.9 in (2-15 cm) long. Flower clusters are subtended by a main stalk 2-20 in (5-50 cm) long. Each cluster is composed of about 5-20 flowers. The calyx and petals are fused at the base to form an oval tube 1.2-2.7 in (3-7 mm) long. Calyx lobes are awl- or triangular-shaped 0.04-0.08 in (0.1-2 mm) long. Petals are green-white and slightly down-curved, 0.6-1 in (1.6-2.5 cm) long. One or two knoblike structures often occur on the back of the flower tube. Fruits are oval or round, purple berries 0.2-0.48 in (6-12 mm) long.

Lammers (1990) separates this taxon from the other closely related members of the genus by its large flowers and berries and broad leaf bases. Three subspecies, all but the last of which are considered extinct, may be separated on the basis of leaf shape and margin characters: *Delissea undulata* var. *kauaiensis* Lammers (leaf blades are oval and flat-margined with sharp teeth), *D. u.* var. *niihauensis* (St. John) Lammers (leaf blades are heart shaped and flat-margined with shallow, rounded teeth) and *D. u.* var. *undulata* (leaf blades are elliptic to lance-shaped and wavy-margined with small, sharply pointed teeth (Lammers 1990).

Taxonomy

This taxon was originally described by Charles Gaudichaud-Beaupre from specimens he collected in the Hawaiian Islands in 1819. Based on a 1911 collection by J.F. Rock from Kanahaha, near Kona, Hawaii, F.E. Wimmer (1943) named the taxon *Cyanea argutidentata* F. Wimmer. However, the taxon was moved to *Delissea* by St. John and called *D. argutidentata* (F. Wimmer) St. John (St. John 1959). In 1968, St. John collected another specimen from the southern Kona district and named it *Delissea konaensis* St. John (St. John 1986). *Delissea niihauensis* St. John, *D. undulata* var. *argutidentata* (F. Wimmer) St. John, and *Lobelia undulata* (Gaud.) Endl. are regarded as synonyms of *D. undulata* by Lammers (1988, 1990). The specific epithet refers to the wavy leaf margins. In his most recent treatment, Lammers (1990) recognizes three subspecies: *Delissea undulata* subsp. *niihauensis* (St. John) Lammers, *D. u.* subsp. *kauaiensis* Lammers, and *D. u.* subsp. *undulata*. Only the last of these is extant.

Historic Distribution

*Delissea undulata* subsp. *kauaiensis* is known from Kauai. In 1895, A.A. Heller collected the taxon west of the Hanapepe River (Heller 1897) (Table 11). However, individuals have not been observed again, and the subspecies is considered extinct (Lammers 1988, HHP 1991a).

Table 11. Historic distribution of *Delissea undulata* subsp. *kauaiensis*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Kauai | West of Hanapepe R. | Not Available (N/A) | N/A | N/A | Heller | 1895 |

*Delissea undulata* subsp. *niihauensis* is known from the island of Niihau where it was collected in the late 1800s. This taxon has not been observed since that time and is also considered extinct (Table 12) (Lammers 1990; HHP 1991a, 1991b).

Table 12. Historic distribution of *Delissea undulata* subsp. *niihauensis*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Niihau | Niihau | Not Available (N/A) | N/A | N/A | Mann and Brigham | 1850 |

*Delissea undulata* subsp. *undulata* was observed in the late nineteenth century on southwestern Maui in four valleys, and in the early twentieth century on western Hawaii in North and South Kona (Table 13) (HHP, no reference number). It was observed in South Kona at Puu Lehua in 1971, but was later thought to be extirpated (Lammers 1990; HHP, no reference number).

Table 13. Historic (H) and current distribution of *Delissea undulata* subsp. *undulata*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Maui (H) | W. Maui, Oloalu | Not Available (N/A) | N/A | N/A | Hillebrand | 1870 |
| Maui (H) | W. Maui, Lahaina | N/A | N/A | N/A | Hillebrand | 1870 |
| Maui (H) | W. Maui, Waikapu | N/A | N/A | N/A | Hillebrand | 1870 |
| Maui (H) | W. Maui, Waihee | N/A | N/A | N/A | N/A | N/A |
| Hawaii (H) | N. Kona, Puu Waawaa | N/A | 2,953-3,000 ft (900-914 m) | N/A | N/A | 1909 |
| Hawaii (H) | S. Kona, Puu Lehua | N/A | 5,000-6,000 ft (1,524-1,829 m) | N/A | N/A<br>Herbst | 1912,<br>1971 |
| Hawaii (H) | Kona, Hualalai, Hanehane | N/A | N/A | N/A | Forbes | 1911 |
| Hawaii (H) | N. Kona, Kanakaha | N/A | N/A | N/A | Forbes | 1911 |
| Hawaii | N. Kona<br>Puu Waawaa | 1<br>50 (outpl.) | 3,520 ft (1,072 m) | N/A | Rock<br>N/A<br>Giffin | 1909<br>1992<br>1995 |

Current Distribution

*Delissea undulata* subsp. *kauaiensis* and *D. undulata* subsp. *niihauensis* are considered extinct. In 1992, a single individual of *D. undulata* subsp. *undulata* was rediscovered at Puu Waawaa (Table 13) (J. Giffin, pers. comm., 1993). The single known individual adult occurs at the edge of a collapsed lava tube in a thin substrate, at an elevation of 3,520 ft (1,070 m) (59 FR 32946). Since then, approximately 50 individuals have been outplanted within 3 exclosures at Puu Waawaa, Waihou Forest Reserve (J. Giffin, pers. comm., 1995).

Life History

The remaining wild individual was observed in flower and (immature) fruit in August 1992 and outplanted individuals were observed in flower in July 1995 (M. Bruegmann, pers. comm., 1995). No other life history information is currently available.

Habitat Description

*Delissea undulata* occurs in dry and mesic forests at elevations of about 3,300-5,700 ft (1,000-1,750 m) in open *Sophora chrysophylla* (mamane) and *Metrosideros polymorpha* (ohia) forest. Taxa that are associated with *D. undulata* also include *Santalum ellipticum* Gaud. (iliahi) and *Acacia koa* (koa). Another endangered taxon, *Nothocestrum breviflorum,* grows in the area where the single individual was found in 1992.

Reasons for Decline

Damage from feral and domestic animals and the degradation from grazing, browsing and trampling by cows, sheep, goats, and pigs are threats. Although palatability of the taxon is not documented, lack of seedling establishment and low numbers of individuals suggest that the taxon may be negatively impacted by these animals. Three alien plant taxa pose a threat to *Delissea undulata*. Two vines, *Passiflora mollissima* and *Senecio mikanioides* Otto *ex* Walp. (German ivy), and a noxious grass, *Pennisetum clandestinum* (kikuyu grass), compete with *D. undulata* for light, nutrients, and space, and therefore limit or preclude reproductive success (Cuddihy and Stone 1990, O'Connor 1990). Fire is potentially a threat, although fuel loads from *P. clandestinum* are minimized by heavy grazing by cattle (J. Giffin, in lit. 1993; pers. comm., 1995). Predation of the fleshy fruits by black rats and introduced game birds is a threat to *D. undulata* (J. Giffin, in lit. 1993; J. Giffin, pers. comm., 1995). Because only one remaining wild adult plant known, *D. undulata* is threatened by extinction due to random events. For instance, natural changes to the habitat may threaten the preservation of this individual as it grows in a collapsing lava tube. Obviously a limited gene pool exists.

Conservation Efforts

Seeds were obtained from the Puu Waawaa plant and germinated. Approximately 50 individuals were outplanted within 3 exclosures at Puu Waawaa, Waihou Forest Reserve (J. Giffin, pers. comm., 1995).

Needed Recovery Actions

The propagation and maintenance of *ex situ* genetic stock for this taxon is necessary in order to protect it from the serious threat of extinction by random event. Protection and outplanting efforts should be encouraged and continued.

**Rhamnaceae (Buckthorn Family)**

Rhamnaceae is most common in tropical and subtropical regions, but is relatively cosmopolitan in distribution. Comprising about 55 genera and 900 species worldwide, the family is represented in Hawaii by 4 genera and 7 species (Wagner *et al.* 1990). Five species are endemic to the Hawaiian Islands, one is indigenous, and one naturalized.

***Colubrina* (kauila)**

*Colubrina* Rich *ex* Brongn., nom. cons., is distributed primarily from the western United States to South America and the West Indies, and contains 31 species (Wagner *et al.* 1990). The genus is divided into 2 subgenera: *Colubrina* (leaf margins with less than 10 teeth) and *Serrataria* (leaf margins with more than 10 teeth) (Johnston, 1971). Hawaiian *Colubrina* are represented by two taxa: *C. asiatica* (L.) Brongn., an indigenous taxon in subgenus *Serrataria*, and *C. oppositifolia* Brongn. *ex* H. Mann, an endangered endemic in subgenus *Colubrina*.

***Colubrina oppositifolia* (kauila, kauwila)** - Recovery Priority #5

Description

*Colubrina oppositifolia* is a tree approximately 16-40 ft (5-13 m) tall, with extremely hard red wood (Figure 6) (Wagner *et al.* 1990). Opposite, oval-shaped leaf blades are 2.4-4.7 in (6-12 cm) long and 1.2-2.8 in (3-7 cm) wide. Leaf blades are thin, dull green on the upper surface, and olive green beneath. Two kinds of glands occur on the lower surface: small black glands near the margin and small glandular projections in the axil of the leaf vein. Leaf stalks are 0.6-1.2 in (1.4-3 cm) long. Lance-shaped stipules are fused at the base of each pair of

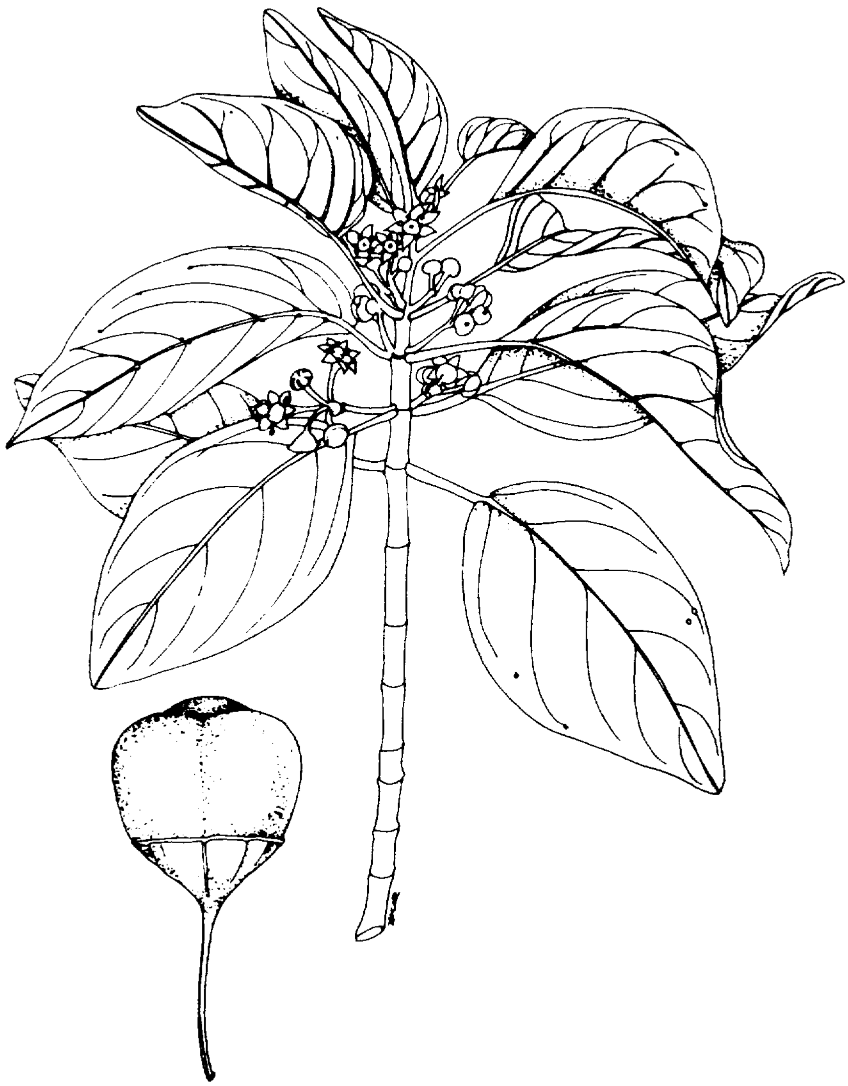

Figure 6: *Colubrina oppisitifolia* (from Wagner *et al.* 1990)

leaves. Ten to 12 flowers are arranged on a flower cluster stalk 0.1-0.3 in (3-8 mm) long. Each flower is subtended by a flower stalk 0.07-0.1 in (2-3 cm) long, which increases in length as the fruit matures. Five sepals are triangular and about 0.06-0.08 in ( 1.5-2 mm) long. Five green-yellow petals are about 0.06 in (1.5 mm) long. Fruits are brown, almost round, about 0.3-0.4 in (8-11 mm) long, and explosively split apart, discharging oval or oblong, black, shiny, hump-back seeds, 0.2-0.3 in (6-8 mm) long and 0.1-0.2 in (4-5 mm) in diameter.

This species is readily distinguished from the other species in Hawaii by several characters: opposite leaf position, dull leaf surface, and entire leaf margins (Wagner *et al.* 1990).

Taxonomy

*Colubrina oppositifolia* was first collected by Remy in the 1850s. Adolphe Theodore Brongniart (Mann 1867) described Remy's collection and named the taxon, with the specific epithet referring to the position of leaves. St. John (1979) designated a variety resulting in *Colubrina oppositifolia* var. *obatae* St. John. However, no varietal taxa are recognized in the current treatment by Wagner *et al.* (1990).

Historic Distribution

*Colubrina oppositifolia* is known from Oahu, Maui and the Big Island. Historic populations are known from the central and southern Waianae mountains on Oahu, and from the Kohala mountains; western, southwestern, and southern slopes of Mauna Loa; and northern slopes of Hualalai on the Big Island (Table 14). The taxon was recently discovered on Maui.

Table 14. Historic (H) and current distribution of *Colubrina oppositifolia*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Oahu (H) | Waianae Mts | Not Available (N/A) | N/A | N/A | Hillebrand | 18?? |
| Hawaii (H) | Volcanoes Nat'l. Park | N/A | N/A | N/A | N/A | 19?? |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kona | 2 | 1,920 ft (590 m) | N/A | Degener and Wiebke | 1926 |
| Hawaii (H) | Kau | N/A | N/A | N/A | Degener | 1929 |
| Hawaii (H) | Kohala Mts., Waimea | 1 | 3,018 ft (920 m) | N/A | Fosberg | 1933 |
| Oahu (H) | Makua Valley | N/A | N/A | State | Judd | 1930<br>1950 |
| Oahu (H) | Waianae Mts. | N/A | 1,500 ft (460 m) | Private | Korte | 1954 |
| Oahu (H) | Waianae Mts. | N/A | 1,200-1,600 ft (370-490 m) | State | N/A<br>Obata | 1950<br>197? |
| Oahu (H) | Waianae Mts. | N/A | 1,600 ft (490 m) | State | Obata<br>N/A | 19??<br>1986 |
| Oahu | Waianae Mts. | >40 | 1,250-1,600 ft (380-490 m) | State | Perlman | 1989 |
| Hawaii | S. Kona, Kapua | 1 | 800-950 ft (240-290 m) | Private | Nagata | 1984 |
| Hawaii | N. Kona, Kaupulehu | Occasional | 2,000 ft (610 m) | Private | St. John;<br>Lorence, Flynn | 1947<br>1987 |
| Hawaii | Kau | <50 | 800-1,000 ft (240-300 m) | State | Higashino<br>Perlman | 1989<br>1991 |
| Hawaii | N. Kona | 1 | 1,900 ft (580 m) | State | Webster, Gankin, Herbst;<br>Perlman | 1968<br>1992 |
| Hawaii | N. Kona<br>Puu Waawaa | 150<br>64 (outpl.) | 1,850-3,000 ft (560-910 m) | State | Lau<br><br>Bergfeld | 1909<br>1992<br>1996 |
| Hawaii | Kau, Kamaoa-Puueo | 1 | 1,040 ft (310 m) | Private | N/A<br>Perlman | 1991<br>1992 |
| Maui | Kapunakea Preserve | 1 | 1,640 ft (500 m) | Private | Bily | 1992 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Oahu | Waianae Mts., Kamananui Kamokunui | 1 | 1,700 ft (520 m) | State | St. John<br>Fenste-macher | 1955<br>1994 |

Current Distribution

Since 1975, 10 populations have been identified: 3 on Oahu, 6 on the Big Island, and 1 on Maui (Table 14). Approximately 300 individuals are known to occur (HHP 1991e1-e2, 1991e5, 1991e9-e12).

The Oahu populations are known from the Waianae mountains, where an undetermined number of individuals are known to exist.

The six populations on the Big Island are distributed on the northern slope of Hualalai and near the extreme southern part of the island, on State and privately owned land (HHP 1991e3, 1991e4, 1991e6 - 1991e8, 1991e13 - 1991e16). Approximately 185 to 205 individuals occur within these populations (HHP 1991e3-e4, 1991e6-1991e8, 1991e13-1991e16; 59 FR 10305).

A single plant was discovered on Maui in the Kapunakea Preserve in 1992.

Life History

This species was observed in fruit and flower during September 1929 (HHP 1991e8) and June 1968 (HHP 1991e12), and in flower during December 1947 (HHP 1991e4) and January 1984 (HHP 1991e9). No other life history information is currently available.

Habitat Description

Habitats of *Colubrina oppositifolia* are lowland dry and mesic forests. The dominant species of these forests is *Diospyros sandwicensis.* Individuals are found at elevations between 800 and 3,000 ft (240-910 m), sometines on a'a lava flows and associated with *Canthium odoratum* (G. Forster) Seem. (alahe'e) and *Reynoldsia sandwicensis* A Gray (ohe) (HHP 1991e3, 1991e8, 1991e15, 1991e16, NTBG 1991b).

Reasons for Decline

Major concerns are habitat destruction by feral pigs and the introduction of aggressive alien plant taxa, particularly *Lantana camara* (lantana), *Pennisetum setaceum* (fountain grass), and *Schinus terebinthifolius* (Christmasberry). Furthermore, the introduction of *Xylosandrus compactus* (black twig borer) could lead to the demise of *C. oppositifolia* (J. Giffin, pers. comm., 1995). *X. compactus* is actively attacking trunks and twigs of the trees at Puu Waawaa and this population, the largest known for the species, is declining. The insects reduce the individuals' vigor and lead to death. Chinese rose beetles (*Adoretus sinicus*) may also be a threat to the Maui population.

Decimation by fire is a concern because population numbers are small and distributions are limited to concentrated areas, particularly on the dry, leeward sides of islands. Disturbance by military and unauthorized personnel may compromise habitats and jeopardize the survivability of individuals.

Conservation Efforts

The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995). Lyon Arboretum has attempted to clone *Colubrina oppositifolia* from buds and immature seeds with no success (G. Koob and C. Lamoureaux, pers. comm., 1995). Steve Bergfeld (pers. comm., 1996) has indicated that DOFAW is actively propagating the taxon from seed and has outplanted approximately 64 plants into several exclosures on Puu Waawaa.

Needed Recovery Actions

Protecting habitat from ungulates and controlling aggressive alien plant taxa such as lantana, fountain grass and Christmasberry are necessary for recovery of the species, as is reducing the threat of fire. Control of the black twig borer, and research necessary to accomplish this, should be undertaken to stem the species' demise. Steps should be taken to ensure that populations remain viable on each of the islands on which the species presently occurs.

**Gesneriaceae (African Violet Family)**

Gesneriaceae is a pantropical family with only a few temperate species. The family is composed of about 120 genera and 2,500 species (Wagner *et al.* 1990) and is represented by a single genus, *Cyrtandra*, in the Hawaiian Islands.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kona | 2 | 1,920 ft (590 m) | N/A | Degener and Wiebke | 1926 |
| Hawaii (H) | Kau | N/A | N/A | N/A | Degener | 1929 |
| Hawaii (H) | Kohala Mts., Waimea | 1 | 3,018 ft (920 m) | N/A | Fosberg | 1933 |
| Oahu (H) | Makua Valley | N/A | N/A | State | Judd | 1930<br>1950 |
| Oahu (H) | Waianae Mts. | N/A | 1,500 ft (460 m) | Private | Korte | 1954 |
| Oahu (H) | Waianae Mts. | N/A | 1,200-1,600 ft (370-490 m) | State | N/A<br>Obata | 1950<br>197? |
| Oahu (H) | Waianae Mts. | N/A | 1,600 ft (490 m) | State | Obata<br>N/A | 19??<br>1986 |
| Oahu | Waianae Mts. | >40 | 1,250-1,600 ft (380-490 m) | State | Perlman | 1989 |
| Hawaii | S. Kona, Kapua | 1 | 800-950 ft (240-290 m) | Private | Nagata | 1984 |
| Hawaii | N. Kona, Kaupulehu | Occasional | 2,000 ft (610 m) | Private | St. John;<br>Lorence, Flynn | 1947<br>1987 |
| Hawaii | Kau | <50 | 800-1,000 ft (240-300 m) | State | Higashino<br>Perlman | 1989<br>1991 |
| Hawaii | N. Kona | 1 | 1,900 ft (580 m) | State | Webster, Gankin, Herbst;<br>Perlman | 1968<br>1992 |
| Hawaii | N. Kona Puu Waawaa | 150<br>64 (outpl.) | 1,850-3,000 ft (560-910 m) | State | Lau<br><br>Bergfeld | 1909<br>1992<br>1996 |
| Hawaii | Kau, Kamaoa-Puueo | 1 | 1,040 ft (310 m) | Private | N/A<br>Perlman | 1991<br>1992 |
| Maui | Kapunakea Preserve | 1 | 1,640 ft (500 m) | Private | Bily | 1992 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Oahu | Waianae Mts., Kamananui Kamokunui | 1 | 1,700 ft (520 m) | State | St. John Fenste-macher | 1955 1994 |

Current Distribution

Since 1975, 10 populations have been identified: 3 on Oahu, 6 on the Big Island, and 1 on Maui (Table 14). Approximately 300 individuals are known to occur (HHP 1991e1-e2, 1991e5, 1991e9-e12).

The Oahu populations are known from the Waianae mountains, where an undetermined number of individuals are known to exist.

The six populations on the Big Island are distributed on the northern slope of Hualalai and near the extreme southern part of the island, on State and privately owned land (HHP 1991e3, 1991e4, 1991e6 - 1991e8, 1991e13 - 1991e16). Approximately 185 to 205 individuals occur within these populations (HHP 1991e3-e4, 1991e6-1991e8, 1991e13-1991e16; 59 FR 10305).

A single plant was discovered on Maui in the Kapunakea Preserve in 1992.

Life History

This species was observed in fruit and flower during September 1929 (HHP 1991e8) and June 1968 (HHP 1991e12), and in flower during December 1947 (HHP 1991e4) and January 1984 (HHP 1991e9). No other life history information is currently available.

Habitat Description

Habitats of *Colubrina oppositifolia* are lowland dry and mesic forests. The dominant species of these forests is *Diospyros sandwicensis.* Individuals are found at elevations between 800 and 3,000 ft (240-910 m), sometines on a'a lava flows and associated with *Canthium odoratum* (G. Forster) Seem. (alahe'e) and *Reynoldsia sandwicensis* A Gray (ohe) (HHP 1991e3, 1991e8, 1991e15, 1991e16, NTBG 1991b).

***Cyrtandra*** (ha iwale)

Comprising 500 to 600 species, *Cyrtandra* S.R. Forster & G. Forster is polymorphic throughout its range. Its variation in Hawaii renders this genus among the most taxonomically difficult in the islands (Wagner *et al.* 1990). Hawaiian taxa have been revised eight times in the past 100 years (Hillebrand 1888; Rock 1917b, 1918, 1919b, 1919c; St. John 1966; Clarke 1883; Wagner and Herbst 1991). To date, 67 putative hybrids have been described, emphasizing the prolific polymorphism within the Hawaiian genus. *Cyrtandra* is divided by Wagner *et al.* (1990) into six sections: 1) *Verticillatae*, 2) *Cylindrocalyces*, 3) *Crotonocalyces*, 4) *Apertae*, 5) *Macrosepala*, and 6) *Chacoca*. Although the *Manual of the Flowering Plants of Hawaii* (Wagner *et al.* 1990) recognizes 53 species and 4 varieties, a current treatment (Wagner and Herbst 1991) recognizes 54 species and 4 varieties. Of these, only eight species and two varieties grow on the Big Island. All of these are endemic to the Hawaiian Islands, and five are endemic to the Big Island. Of these taxa, one is extinct and two, *Cyrtandra giffardii* and *Cyrtandra tintinnabula*, are endangered.

***Cyrtandra giffardii* (ha iwale)** - Recovery Priority #2

Description

*Cyrtandra giffardii* Rock is a small shrubby tree 10-20 ft (3-6 m) tall (Figure 7) (Wagner *et al.* 1990). Opposite leaves are positioned on the upper nodes of the stem. Toothed, papery-textured elliptic blades, 2.4-4.7 in (6-12 cm) long and 1.0-1.8 in (2.5-4.6 cm) wide, generally have a few brown hairs on the veins. Leaf stalks (petioles) are 0.8-1.6 in (2-4 cm) long. Three to five moderately brown-hairy flowers are in clusters at the tip of the main cluster stalk (peduncle), which is 1-1.4 in (2.5-3.5 cm) long. Each flower is subtended by unequal stalks (pedicels) 0.6-1.2 in (1.5-3 cm) long and two linear bracts 0.25 in (6-7 mm) long. The green calyx, 0.1-0.4 in (3-9 mm) long, is split 0.04-0.08 in (1-2 mm) from its base. Five calyx lobes are narrowly deltate (triangular) and are moderately covered with short brown hairs. The white petals are fused into a cylindrical tube about 0.5 in (1.2 cm) long. Five sparsely hairy lobes are about 0.08-0.1 in (2-3 mm) long. Only immature berries are known, and they are almost round, approximately 0.4 in (1 cm) long, and white.

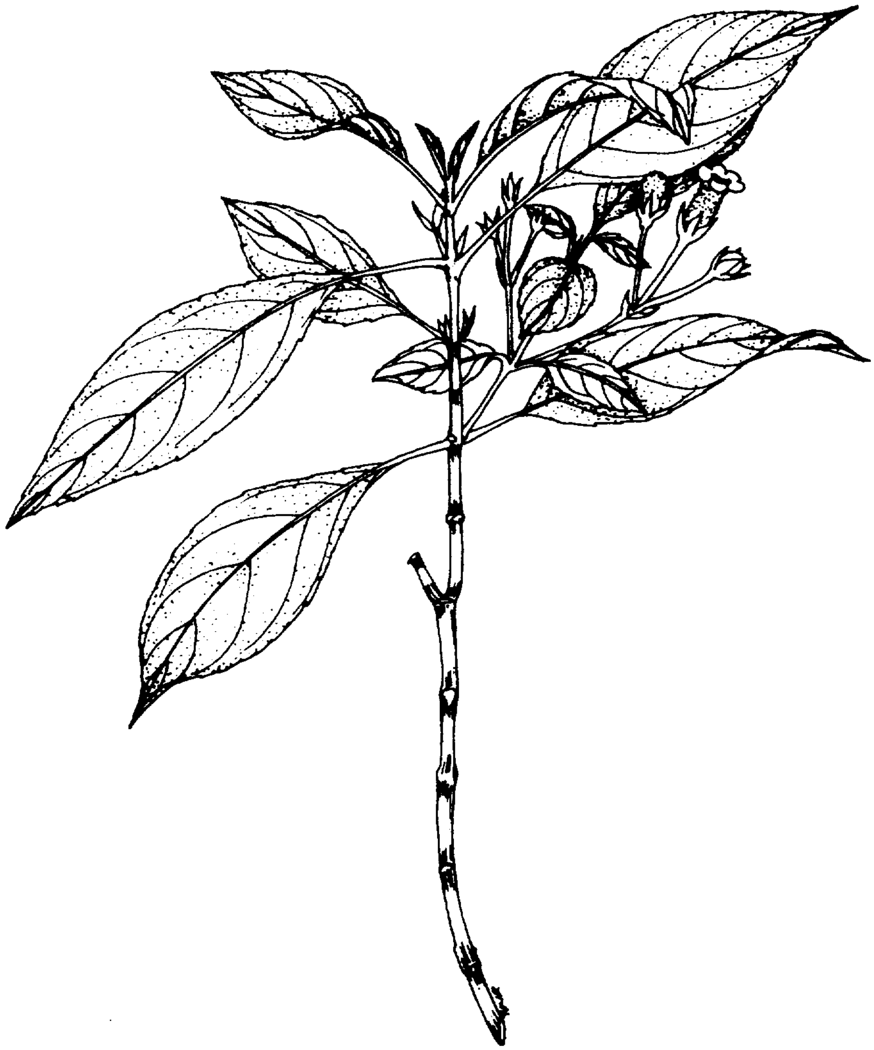

Figure 7: *Cyrtandra giffardii* (from Wagner *et al.* 1990)

*Cyrtandra giffardii* is distinguished from other closely aligned taxa by the combination of the following characters: leaf texture and shape (papery and elliptic), petal shape and size (cylindric and small), calyx shape and size (regular and small), number of flowers per cluster (3-5), presence of hairs (hairs present on leaves and flower clusters), and berry shape (almost round) (Wagner *et al.* 1990).

Taxonomy

*Cyrtandra giffardii* originally was described by Rock based on one specimen collected in 1911. Rock (1919c) named the species in honor of Walter M. Giffard, the collector of the first flowering specimens in 1918. Rock originally placed *C. giffardii* in section *Microcalyces* (=*Apertae*), otherwise known only from Oahu. However, current treatments regard *C. giffardii* to be more closely aligned to *C. menziesii* Hook. & Arnott and, therefore, it is currently placed in section Chactocalyces.

Historic Distribution

*Cyrtandra giffardii* is known from the northeastern slope of Mauna Kea south to the eastern slope of Mauna Loa (Table 15) (Wagner *et al.* 1990).

Table 15. Historic (H) and current distribution of *Cyrtandra giffardii*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kalauilehua Kilauea Crater | 1 | Not Available (N/A) | N/A | Rock | 1911 1918 |
| Hawaii (H) | Olaa Flume, Kipuka | N/A | 2,165 | N/A | Fosberg | 1933 |
| Hawaii | Puna District, Olaa Ahupuaa | N/A | 3,600-3,670 ft (1,100-1,120 m) | State | Warshauer and McEldowney | 1978 1979 |
| Hawaii | Stainback Highway | N/A | 3,281 ft (1,000 m) | State | Wagner *et al.* | 1985 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | Laupahoe-hoe NAR | 100-1000 | 3,000 ft (915 m) | State | Perlman | 1990 |
| Hawaii | Laupahoe-hoe NAR | 2 | 2,350-3,800 ft (720-1,160 m) | State | N/A | 1971<br>1988<br>1991 |
| Hawaii | Laupahoe-hoe NAR | 80-100 | 2,320-2,540 ft (707-717 m) | State | Perlman | 1990<br>1991 |
| Hawaii | Laupahoe-hoe NAR | 50-100 | 2,360-2,520 ft (720-768 m) | State | Perlman | 1991 |
| Hawaii | Laupahoe-hoe NAR | 10-15 | 3,040-3,240 ft (827-988 m) | State | Perlman | 1991 |
| Hawaii | Volcanoes NP Olaa Tract, Koa Unit | 90 | 4,100-4,400 ft (1,250-1,341 m) | Federal | Pratt | 1993-1994 |
| Hawaii | Volcanoes NP Olaa Tract, Puu Unit | 10 | 4,000-4,400 ft (1,220-1,341 m) | Federal | Pratt | 1993 |
| Hawaii | Volcanoes NP Olaa Tract, Ag Unit | 27 | 4,000-4,200 ft (1,220-1,280 m) | Federal | Pratt | 1993 |
| Hawaii | Volcanoes NP Small Tract | 2 | 3,800-3,900 ft (1,160-1,190 m) | Federal | Pratt | 1993 |

Current Distribution

Since 1975, 11 populations have been identified with the total number of individuals estimated to exceed 1,000 (Warren Wagner, Smithsonian Institution, pers. comm., 1995; HHP 1991). These occur near Puu Makaala, Stainback Highway, and Kilau stream in Laupahoehoe Natural Area Reserve on State-owned land, and at Hawaii Volcanoes National Park (Table 15). As of 1994, 55 known individuals occurred in Hawaii Volcanoes National Park on transects in the Koa Unit and 35 additional individuals were identified in another area of the Koa Unit that were not on the transects, 6 occurred on transects in the Puu Unit (2 inside an exclosure and 4 outside), and 27 individuals occurred on transects in the Ag Unit of the Olaa Tract, as well as 2 on transects in the Small Tract.

Life History

This species was observed in fruit and flower during June 1979 (HHP 1991j2) and November 1988 (HHP 1991j3), and in flower during December 1933 (HHP 1991j5) and January 1918 (HHP 1991j4). No other life history information is currently available.

Habitat Description

The habitat of *Cyrtandra giffardii* is wet montane forest dominated by *Cibotium* (tree fern) at elevations between 2,400 and 4,900 ft (720 and 1,500 m) (Wagner *et al.* 1990, HHP 1991j1-j3, NTBG 1991d1-d2, 59 FR 10305). Associated taxa include *Hedyotis* spp., *Perrottetia sandwicensis* A. Gray (olomea), and other species of *Cyrtandra* (HHP 1991j1-j3, 59 FR 10305).

Reasons for Decline

Rooting and trampling by pigs result in profound degradation of the substrate and native vegetation. Habitat destruction inevitably leads to alien plant invasions, particularly *Andropogon virginicus* which, ultimately, becomes a problem (L. Pratt, pers. comm., 1995). Control of alien taxa is imperative and fencing to exclude feral animals and control of alien weeds will assist in preserving *Cyrtandra giffardii* (L. Pratt, pers. comm., 1995). Small numbers of populations and individuals may depress and limit the reproductive potential, and also increase the vulnerability of this taxon to extinction from the occurrence of a catastrophic event (Stone 1985; W. Wagner, pers. comm., 1992).

Conservation Efforts

Attempts have been made at Volcano Rare Plant Facility to germinate seed of *Cyrtandra giffardii* without success (P. Moriyasu, pers. comm., 1995). Further attempts will be pursued when more seed is acquired. All of the Koa Unit and some of the Puu Unit of the Olaa Tract in Hawaii Volcanoes National Park are fenced and have been declared pig-free (L. Pratt, pers. comm., 1995). All but four of the plants in this and Small Tract are within exclosures. The plants appear healthy and are flowering and fruiting. It is undetermined how many juveniles are present because they are difficult to distinguish from other members of the genus when immature (L. Pratt, pers. comm., 1995).

Needed Recovery Actions

Populations outside of Hawaii Volcanoes National Park should be protected from pigs and other ungulates, and fencing should be maintained for those inside the Park. Control of alien plant taxa should also be undertaken.

***Cyrtandra tintinnabula*** (ha iwale) - Recovery Priority #5

Description

*Cyrtandra tintinnabula* Rock is a small shrub 3.3-6.6 ft (1-2 m) tall (Wagner *et al.* 1990). Opposite, elliptic or oval leaf blades are 5-10 in (13-26 cm) long and 2-4.9 in (5-12.3 cm) wide. Papery in texture, the toothed leaf blades are moderately covered with yellow-brown hairs, especially on the lower surface. Stalks of the leaves (petioles) are 2.1-4.1 in (5.3-10.5 cm) long. Three to six flowers are in clusters at the tip of a main cluster stalk (peduncle) 0.4-0.7 in (1-1.8 cm) long. Each flower is subtended by a stalk 0.2-0.6 in (0.5-1.5 cm) long and oval or heart-shaped leaf-like bracts 0.4-0.6 in (0.9-1.5 cm) long. The calyx, 0.4 in (9-10 mm) long, is pale green, bell-shaped and cleft 1/4 to 1/3 of its length. Five reflexed, deltate lobes are densely and softly hairy. Five white petals, 0.1 in (3 mm) long, are fused into a soft-hairy, cylindric tube, about 0.5 in (12 mm) long and 0.2 in (0.5 mm) wide.

*Cyrtandra tintinnabula* is distinguished from the other taxa which occur on the Big Island by a combination of characters such as petal size and shape, calyx size and shape, number of flowers per cluster, and the presence of hairs. The taxon differs from *C. giffardii* by its shrubby habit, larger leaves, and shorter main cluster stalks (peduncles) and flower stalks (pedicels) (Wagner *et al.* 1990, 59 FR 10305).

Taxonomy

*Cyrtandra tintinnabula* was described by Rock from specimens he collected on Mauna Kea, Hawaii, in 1909. Rock (1918) named the specific epithet by describing the bell-shaped calyx of the flower. *C. tintinnabula* was originally placed by Rock in the section Crotonocalyx where it remains today.

Historic Distribution

*Cyrtandra tintinnabula* is known only from three locations on the northeastern slopes of Mauna Kea (Table 16) (HHP 1991k1-k6, 59 FR 10305).

Table 16. Historic (H) and current distribution of *Cyrtandra tintinnabula*

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Hawaii (H) | Hamakua, Paauhau | Not Available (N/A) | 3,000 ft (900 m) | N/A | Rock | 1909 |
| Hawaii (H) | Makahanaloa, Puu Kauku | N/A | N/A | N/A | N/A | 1922 |
| Hawaii (H) | N. Hilo, Honomu | N/A | 1,476 ft (450 m) | N/A | Fosberg | 1933 |
| Hawaii | N. Hilo, Honohina | 1 | 2,130 ft (650 m) | Private | St. John | 1976 |
| Hawaii | W. Kilau Stream | 16 | 2,400 ft (730 m) | State | Warshauer | 1977 |
| Hawaii | Kilau Stream, Laupahoehoe | 1 | 2,940 ft (890 m) | State | Warshauer | 1977 |

Current Distribution

Since 1975, three populations have been identified in the Laupahoehoe area, on State and private land (Table 16). A total of 18 individuals is known in an area of 1 by 6 mi (3 by 10 km) (HHP 1991k1-k6, 59 FR 10305).

Life History

This species was observed in flower during July 1909 (HHP1991k1) and August 1977 (HHP1991k3), and in fruit during December 1933 (HHP1991k2). No other life history information is currently available.

Habitat Description

*Cyrtandra tintinnabula* grows in lowland wet forest dominated by dense *Acacia koa* (koa), *Metrosideros polymorpha* (ohia), and *Cibotium* (tree fern) at elevations of 2,100 to 3,400 ft (650 to 1,040 m) (Wagner *et al.* 1990, HHP 1991k3-k4, 1991k6). Several other *Cyrtandra* (haiwale) and *Hedyotis* (pili) species are associated with *C. tintinnabula* (HHP 1991k3-k6).

Reasons for Decline

Rooting and browsing by feral pigs directly damage and disturb the habitat of *Cyrtandra*, and break its weak and delicate stems (Stone 1985). Indirectly, pigs disturb native vegetation and allow the invasion of alien taxa, which in turn rapidly become established. Continued disturbance exacerbates the alien plant problem and eventually precludes the survivability of native taxa. Because much of the native habitat is lost, appropriate pollinator(s) may be absent as well. The loss of native vectors is a probable cause for the taxon's demise. Small numbers of extant individuals with limited distributions restrict the gene pool and depress reproductive vigor. They also render random events a serious threat.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon (D. Ragone pers. comm., 1995).

Needed Recovery Actions

In order to prevent possible extinction of this taxon, maintenance of *ex situ* genetic stock is necessary. The 18 known individuals should be protected from ungulates, particularly pigs, and encroachment of alien plants. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of populations and plants for recovery. Research should be conducted into the species' pollination vectors.

**Poaceae (Grass Family)**

The grass family is comprised of approximately 600 genera and nearly 10,000 species (Gould and Shaw 1983), and ranks as the third or fourth largest family on earth. Grasses in the State of Hawaii comprise 67 genera and 147 species, including 39 endemic and 8 indigenous species in 19 genera, and 57 genera and 100 species that have become naturalized (O'Connor 1990).

***Ischaemum* (ischaemum)**

*Ischaemum* L., a member of the tribe Andropogoneae, is primarily paleotropical, especially in Asia (O'Connor 1990). Although the genus contains about 60 species, onlyoneis endemic to the State of Hawaii. However, in 1963, *Ischaemum indicum* (Houtt.) Merr. was found to be an introduced taxon on Maui (O'Connor 1990).

***Ischaemum byrone* (Hilo ischaemum)** - Recovery Priority #8

Description

*Ischaemum byrone* (Trin.) Hitchc. is a perennial grass with creeping underground stems and erect stems 16-31 in (40-80 cm) tall (Figure 8) (O'Connor 1990). The lower portion of the leaf that surrounds the stem (sheath) sometimes exhibits long hair near the base, while the upper portion is often inflated and encloses the yellow-brown flower clusters (inflorescences). The flat, hairless leaf blades are 2.8-7.9 in (7-20 cm) long and 1.2-2 in (3-5 cm) wide, decreasing in size toward the top of the plant. Branches of the flower clusters originate at one point in twos and threes (digitate). Two-flowered spikelets (basic units of an inflorescence) are of two types: 1) one unit is sessile with a twisted bristle (awn), 0.9-1.0 in (2.4-2.6 cm) long; and 2) one unit is stalked with a red-brown awn, 0.6-0.8 in (1.5-2 cm), which is twisted toward the base. The fruit is a golden oval grain (caryopsis) about 0.1 in (3 mm) long.

*Ischaemum byrone* can be distinguished from other Hawaiian grasses by its tough outer flower bracts, dissimilar basic flower units, which are awned and 2-flowered, and a 2 or 3-branched digitate inflorescence (O'Connor 1990, 59 FR 10305).

Taxonomy

*Ischaemum byrone* was collected by James Macrae in 1825 during the Blond Expedition near Byron's Bay, now referred to as Hilo Bay, Hawaii. Trinius (1830) named the taxon *Spodiopogon byronis* Trin., the specific epithet honored the collection's location in Byron's bay. Steudel (1855) moved the taxon to the genus *Andropogon* and named it *A. byronis* (Trin.) Steud. In 1889, Hackel redescribed the taxon and placed it in the genus *Ischaemum*, naming it *Ischaemum lutescens* Hack. for the yellow-brown color of the inflorescence. The name was considered superfluous and, in 1922, Hitchcock recognized the original specific

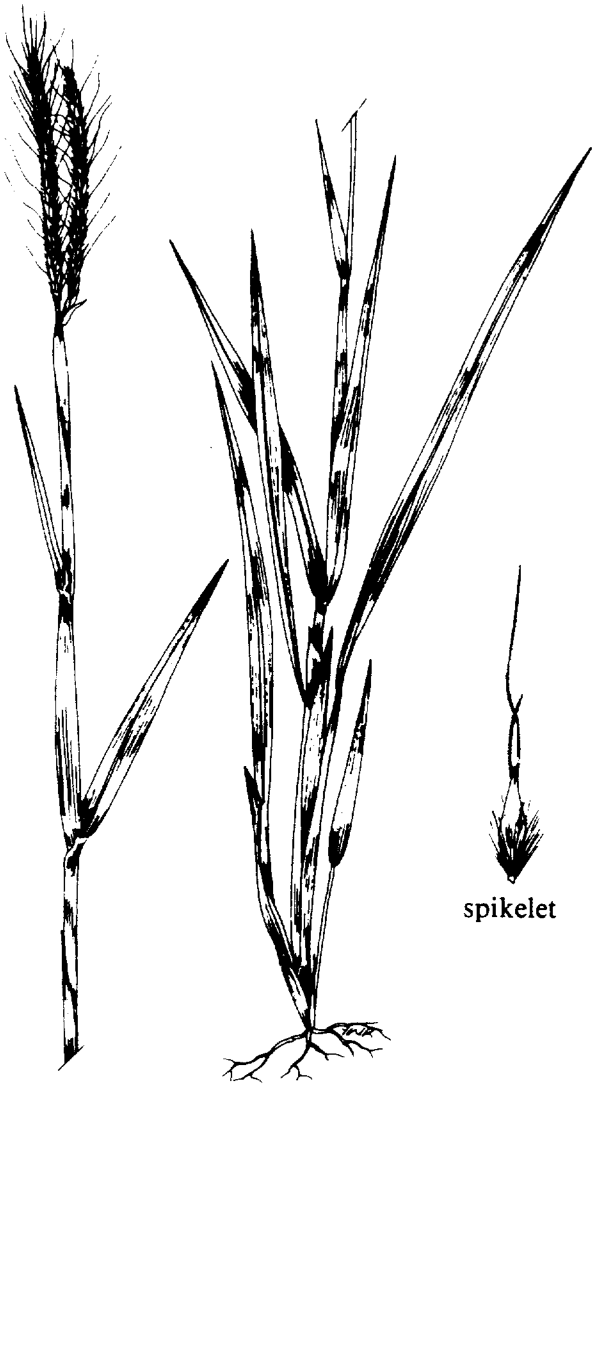


Figure 8: *Ischaemum byrone* (from Wagner *et al.* 1990)

epithet and published the currently accepted nomenclature, *Ischaemum byrone* (O'Connor 1990, 59 FR 10305).

## Historic Distribution

*Ischaemum byrone* was historically distributed over several islands: Oahu; northeastern coast of Molokai; east Maui; the eastern coast and inland portion of the Big Island; and an unspecified island (Table 17) (HHP 1991m5-m11).

Table 17. Historic (H) and current distribution of *Ischaemum byrone*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Oahu (H) | Not Available (N/A) | N/A | N/A | N/A | N/A | 18?? |
| Maui (H) | E. Maui | N/A | N/A | N/A | N/A | 18?? |
| N/A (H) | N/A | N/A | N/A | N/A | N/A | 18?? |
| Molokai (H) | Halawa | N/A | N/A | N/A | Faurie | 1909 |
| Hawaii (H) | Kalapana | N/A | N/A | N/A | Rock | 1917 |
| Hawaii (H) | Rainbow Falls | N/A | N/A | N/A | Hitchcock | 1922 |
| Hawaii (H) | N/A | N/A | N/A | N/A | N/A | 1926 |
| Hawaii (H) | Hilo Bay | N/A | N/A | N/A | Degener and Iwasaki | 1930 |
| Hawaii (H) | Keaau | N/A | 10 ft (3 m) | N/A | Hosaka | 1936 |
| Maui (H) | Kahanu Gardens, Piliani Heiau | Locally common | N/A | Private | Fosberg | 1974 |
| Maui | Pauwalu Point | N/A | 80 ft (24 m) | Private | N/A<br>Davis and Sylva | 1933<br>1978 |
| Maui | Moku Huki | Occasional | 10 ft (3 m) | State | Hobdy | 1981 |
| Maui | Kauiki Head, Puuiki Island | N/A | 250 ft (2-76 m) | Federal | Hobdy | 1982 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Maui | E. Maui, Keopuka Rock | N/A | 100 ft (30 m) | State | Hobdy | 1982 |
| Hawaii | Volcanoes National Park | 50-100 | 20-25 ft (6-8 m) | Federal | N/A<br>Cuddihy | 1965<br>1983 |
| Molokai | Wailau Valley | N/A | 100 ft (30 m) | Private | Higashino and Allen | 1984 |
| Molokai | N. Coast, E. Kikipua | Scattered | N/A | Private | Hobdy | 1984 |
| Hawaii | S. Hilo | N/A | N/A | State | Koske and Genka | 1987 |
| Maui | Wainapanapa State Park, Pailoa Bay, Keawaiki Bay | N/A | 30 ft (9 m) | State | N/A | 1991 |
| Maui | E. Maui, Honokalani, Wainapanapa State Park | 1,000-2,000 | N/A | State | N/A | 1991 |
| Hawaii | Kamoamoa, Puna | N/A | 20-25 ft (6-7 m) | Federal | Lamoureux | 1945<br>1992 |
| Hawaii | Puna, Kikala-Keokea | Locally common | 50 ft (15 m) | N/A | Takeuchi | 1992 |
| Hawaii | Hilo, near Lehia Park | 1,000s | spray zone | Private | HHP | 1992 |
| Hawaii | Puna, Makuu Halona | 50 | N/A | Federal | HHP | 1992 |
| Hawaii | Volcanoes National Park, New Kipuka | 200 | N/A | Federal | Pratt | 1992 |
| Hawaii | Volcanoes National Park | 50 | N/A | Federal | Pratt | 1995 |
| Kauai | Kauapea Beach | ~50 | 6 ft (2 m) | Private | Lorence | 1995 |

## Current Distribution

Since 1975, 17 populations have been identified on Kauai, Molokai, Maui, and Hawaii (Table 17). A small population was recently discovered on the north shore of Kauai. Approximately 50 plants are growing on wet cliff faces on privately owned lands. Several thousand individuals exist, the majority occurring in three of the populations, one on Maui and two on the Big Island. Two populations are distributed on the northeastern coast of Molokai, on privately owned land. These populations occur within 2 mi (3.2 km) and have an undetermined number of individuals. Maui's 6 populations are distributed throughout an area of approximately 16 mi (26 km) on the northeast coast and number 1,000-2,000 individuals or more. On the Big Island, eight populations are known along the east and southern coasts of the island and number in the thousands, with most located in two populations. The populations appear to be healthy and reproducing (Richard Warshauer, National Biological Service, pers. comm., 1995; C. Corn, pers. comm., 1995). At Hawaii Volcanoes National Park, the 200 plants between Kamoamoa and Ka Lae Apuki in a kipuka (an "island" of land formed by the new lava flow) may have been covered by lava since they were identified in 1992 (L. Pratt, pers. comm., 1995). Likewise, the 5 concentrations totalling approximately 50 plants west of Ka Lae Apuki at Lae Apuki at Hawaii Volcanoes National Park, may have been covered by lava since last seen in January of 1995 (L. Pratt, pers. comm., 1995).

Life History

No life history information is currently available for this species.

Habitat Description

The habitat of *Ischaemum byrone* is coastal dry shrubland. The taxon occurs near the ocean, among rocks and cliffs at elevations ranging from 0-250 ft (0-75 m). Associated taxa include *Bidens* L. (ko'oko'olau), *Fimbristylis cymosa* R. Br. (mau'u 'aki'aki), and *Scaevola sericea* Vahl (naupaka kai) (HHP 1991m5, 1991m7, 1991m9, 1991m11, NTBG 1991f, 59 FR 10305).

Reasons for Decline

Aside from the threat of coverage by lava flow on the southeastern portion of the Big Island, the most serious threat to *Ischaemum byrone* is the invasion of alien grasses, particularly *Digitaria ciliaris* (Henry's crabgrass). Other potential threats include grazing and browsing by feral animals (axis deer and goats). Disturbance incurred from these ungulates further promotes introduction and establishment of alien weeds. Lava flowing from Kilauea destroyed about 200 individuals 0.25 mi

(0.4 km) west of Kamoamoa in 1992 (L. Pratt pers. comm., 1995). A few individuals were rescued. Fire in areas infested with alien grasses may be a potential problem, provided enough fuel is present. Some populations are also threatened from residential development.

Conservation Efforts

The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995). Approximately 10-15 plants were rescued from the lava flow at Lae Apuki in Hawaii Volcanoes National Park in 1992. These are presently located at the Park greenhouse.

Needed Recovery Actions

Protection of plants from ungulate (goat and deer) browsing, invasion of alien grasses, fire, and development are necessary for the recovery of this species. Efforts should be made to ensure that populations remain viable on each of the islands on which the species presently occurs.

**Violaceae (Violet Family)**

Violaceae is cosmopolitan in distribution and contains about 16 genera and 800 species. In Hawaii, the family is represented by two genera, *Viola* L., and the endemic genus, *Isodendrion* A. Gray (Wagner *et al.* 1990).

***Isodendrion pyrifolium*** **(wahine nono kula)** - Recovery Priority #2C

Description

*Isodendrion pyrifolium* A. Gray is a small, branched shrub 2.6-6.6 ft (0.8-2 m) tall (Wagner *et al.* 1990). Elliptic to lance-shaped leaf blades are 1-2.6 in (2.5-6.5 cm) long and 0.3-1.3 in (0.8-3.2 cm) wide. The papery-textured blade is moderately hairy beneath (at least on the veins) and stalked. The stalk (petiole) is 0.2-0.4 in (0.5-1 cm) long and is subtended by oval, hairy, bract-like structures (stipules) 0.1-0.2 in (2.8-5 mm) long. Fragrant, bilaterally symmetrical flowers are solitary. The flower stalk (pedicel) is 0.07-0.2 in (1.5-4 mm) long, white-hairy, and subtended by two bracts 0.08-0.1 in (2-3 mm) long. Bracts arise at the tip of the main flower stalk (peduncle) 0.08-0.2 in (2-6 mm) long. The five sepals are lance-shaped 0.1-0.2 in (3.5-5 mm) long, membranous-edged and fringed with white hairs. Five green-yellow petals are somewhat unequal, 0.4-0.6 in (10-15 mm) long and lobed, 0.2 in (5 mm), the upper being the shortest and the lower the longest. The fruit is a 3-lobed, oval capsule, 0.5 in (12 mm) long, which splits to release olive-colored seeds 0.1 in (3-3.2 mm) long and 0.08 in (1.8-2.2 mm) in diameter.

*Isodendrion pyrifolium* is distinguished from other taxa in the genus by its smaller, green-yellow flowers, and hairy stipules and leaf veins (Wagner *et al.* 1990).

Taxonomy

*Isodendrion pyrifolium* was first described by Asa Gray (1852) after its collection on Oahu during the United States Exploring Expedition of 1841. St. John (1952), in his monograph, divided the genus into five species: *I. hawaiiense* St. John, *I. hillebrandii* St. John, *I. lanaiense* St. John, *I. molakaiense* St. John, and *I. remyi* St. John. The current treatment (Wagner *et al.* 1990) recognizes *I. pyrifolium* as the correct name and considers the other names as synonyms. Gray chose the specific epithet, *pyrifolium*, because the shape of the leaf resembles a pear *(pyrus)*.

Historic Distribution

*Isodendrion pyrifolium* is known historically from six of the Hawaiian Islands. Locations of the populations on Niihau, Molokai, and Lanai were unspecified. Specific populations were found in Oahu's central Waianae mountains, Maui's southwestern mountains, and on the western slope of Hawaii's Hualalai mountain (Table 18) (Wagner *et al.* 1990, HHP 1991n1-n5).

Table 18. Historic (H) and current distribution of *Isodendrion pyrifolium*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Niihau (H) | Not Available (N/A) | N/A | N/A | N/A | N/A | 185? |
| Molokai (H) | N/A | N/A | N/A | N/A | N/A | 185? |
| Lanai (H) | N/A | N/A | N/A | N/A | N/A | 1870 |
| Oahu (H) | Waianae Mts. | N/A | N/A | N/A | St. John | 1840 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Oahu (H) | Waianae Mts. | N/A | 1000 ft (300 m) | N/A | St. John | 1869 |
| Hawaii (H) | N. Kona Hualalai | N/A | N/A | N/A | N/A | 1857 |
| Maui (H) | W. Maui, Wailuku Valley | N/A | N/A | N/A | Hillebrand | 1870 |
| Maui (H) | W. Maui, Waihee Valley | N/A | N/A | N/A | N/A<br>St. John | 1870<br>1952 |
| Maui (H) | W. Maui, Oloalu | N/A | N/A | N/A | Hillebrand | 1870 |
| Hawaii | N. Kona, Kealakehe | 50-60 | 270 ft (82 m) | N/A | HHP | 1990<br>1992 |

Current Distribution

Since 1952, only one population of this taxon has been identified. In 1990, four to six individuals were located near Kailua Kona on the Big Island (C. Corn, pers. comm., 1995; F92HHPo9). During a search of the area in 1992-93, 50 to 60 individuals were found in the same area (Table 18) (Evangeline Funk, Botanical Consultants, pers. comm., 1993; C. Corn, pers. comm., 1995). The plants occur on land that is being developed for residential use and a golf course, and fencing is planned for their protection (C. Corn, pers. comm., 1995).

Life History

During periods of drought, this species will drop all but the newest leaves. After sufficient rains, the plants produce flowers with seeds ripening 1 to 2 months later (C. Corn, pers. comm., 1996).

Habitat Description

*Isodendrion pyrifolium* is found in dry to mesic forests at low elevations. This species was formerly associated predominantly with taxa such as *Canthium odoratum* (alahe'e), *Sida fallax* (ilima), *Santalum* (sandalwood, 'iliahi), *Myoporum sandwicense* (naio), *Sophora chrysophylla* (mamane), and *Waltheria indica* L. ('uhaloa) (Paul Weissich, Weissich and Associates, pers. comm., 1992, 1995).

Reasons for Decline

The conversion of this species' natural habitat to residential and recreational developments is of grave concern, as is the presence of the aggressive alien fountain grass (*Pennisetum setaceum*). Drying stands of this and other weedy species greatly increase the fire load and fire potential. Competition for nutrients with alien plant taxa such as koa haole (*Leucaena leucocephala*) is a threat. Although more prolific than once anticipated, numbers of individuals are not abundant enough to maintain reproductive vigor, thus making random extirpation a possibility.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon (D. Ragone, pers. comm., 1995). Lyon Arboretum has attempted to grow *Isodendrion pyrifolium* from immature seed but has had no success (G. Koob, pers. comm., 1995). Carolyn Corn (pers. comm., 1995) mentioned that the seeds appear to germinate slowly. To minimize negative impact to this species by the development of a subdivision in the area, there are plans to fence the remaining wild individuals (C. Corn, pers. comm., 1995).

Needed Recovery Actions

In order to prevent possible extinction of this species, propagation and maintenance of *ex situ* genetic stock is necessary. It is imperative that plans to fence and protect the remaining wild population be carried out. Control of fountain grass and koa haole should be undertaken in the habitat of the wild population. Propagation and outplanting of *ex situ* stock will be needed in order to establish a sufficient number of populations and plants for recovery. Efforts should be made to re-establish the species on Oahu and Maui within its known historical range in order to ensure against random extinction.

**Cyperaceae (Sedge Family)**

Cyperaceae is widely distributed throughout the world in numerous ecological environments and comprises about 70 genera and 4,000 species. All of the 18 genera found in the Hawaiian Islands are indigenous. Within these, there are 41 species that have been introduced and 28 that are indigenous, including 17 species that are endemic (Koyama 1990).

***Mariscus* (no common name)**

The genus *Mariscus* Vahl, nom. cons., occurs predominately in the tropical, subtropical, and temperate regions of the world and is composed of about 200 species. Native Hawaiian *Mariscus* appear to have been introduced by three independent colonizations, resulting in three closely related groups (Koyama 1990). Some authors regard *Mariscus* as a member of *Cyperus* L. because there seems to be a lack of evidence to separate the genera.

In Hawaii, *Mariscus* contains 12 species and 8 subspecies. Of the eight taxa that are endemic to the Hawaiian Islands, five occurred on the Big Island. Of these five taxa, two are endangered, *Mariscus pennatiformis* (subsp. *bryanii* and subsp. *pennatiformis*), and *Mariscus fauriei*.

***Mariscus fauriei* (no common name)** - Recovery Priority #14

Description

*Mariscus fauriei* (Kükenth.) T. Koyama is a perennial herb with tuberous underground stems that are covered with red-brown hairs (Figure 9) (Koyama 1990). Erect 3-angled stems 4-20 in (10-50 cm) tall are either single or several are grouped together. Linear leaves, 0.04-0.1 in (1-3.5 mm) wide, are equal to the stems in length. The basal portion of the leaf, which clasps the stem, (sheath) is red-brown. The flower cluster (inflorescence), 0.8-1.6 in (2-4 cm) long and 1.2-3.9 in (3-10 cm) wide, is subtended by three to five unequal bracts, the lowest being the longest at 2.4-7.9 in (6-20 cm) long. Each flower cluster is composed of 3 to 10 spikes (unstalked flowers in unbranched clusters), which are 0.3-1.2 in (0.8-3 cm) long and 0.3-0.4 in (0.8-1 cm) wide. Each spike is composed of seven to nine small flattened flower units (spikelets) 0.2-0.3 in (4-8 mm) long, which spread with age. Bracts subtending each flower are yellow-brown, with red-brown specks or lines. The unopened fruits are 3-angled and elliptic, 0.05 in (1.2 mm) long and 0.03 in (0.7 mm) wide.

*Mariscus fauriei* is distinguishable from other taxa within the genus in Hawaii by small, narrow, spreading spikelets, relatively soft leaves, and a relatively small stature (Koyama 1990, 59 FR 10305).


Figure 9: *Mariscus fauriei* (from Wagner *et al.* 1990)

Taxonomy

*Mariscus fauriei* was originally described by Kükenthal, based on 1910 collections by Faurie from Molokai (Wagner *et al.* 1989) and named *Cyperus fauriei* Kükenth. in honor of the collector. Koyama (1990) re-evaluated certain taxa within *Cyperus* and placed them in *Mariscus*, including *M. fauriei.*

Historic Distribution

*Mariscus fauriei* is known historically from eastern Molokai; northwestern and southern Lanai; and western Hawaii (Table 19) (HHP 1991o1-o8; NTBG 1991g).

Table 19. Historic (H) and current distribution of *Mariscus fauriei*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Molokai (H) | Kamalo | Not Available (N/A) | 3,281 ft (1,000 m) | N/A | Faurie | 1910 |
| Hawaii (H) | N. Kona, Puu Waawaa | N/A | N/A | N/A | Forbes | 1911 |
| Lanai (H) | S. Lanai | N/A | N/A | N/A | Munro | 1913 |
| Lanai (H) | Miki | N/A | 1,250-1,300 ft (380-400 m) | N/A | Munro | 1929 |
| Lanai (H) | Kaa | N/A | 1,400-1,450 ft (430-440 m) | N/A | Munro | 1930 |
| Hawaii (H) | Mauna Loa, Hualalai | N/A | 6,000 ft (1,830 m) | Private | N/A | 1962 |
| Molokai | Kamiloloa | 20-30 | 2,000 ft (610 m) | State | Hobdy | 1985 |
| Hawaii | South Point, Kamaoa-Puueo | 10 | 1,040 ft (320 m) | State | NTBG | 1991 |
| Hawaii | Kamaoa-Puueo | 12 | 1,040-1,080 ft (320-330 m) | Private | N/A | 1991 |
| Hawaii | N. Kona, Kaloko | ca. 5 | 380 ft (116 m) | N/A | HHP | 1992 |

Current Distribution

The taxon is presumed extinct on Lanai. Since 1975, 4 extant populations have been identified, totalling 45-60 individuals (HHP 1991o1-o8; NTBG 1991g; R. Hobdy, DOFAW, pers. comm., 1992) (Table 19). One population of 20 to 30 plants is extant on a State Forest Reserve, Molokai. Three populations, together consisting of 20-30 plants, are known on the Big Island.

Life History

No life history information is currently available for this species.

Habitat Description

The habitat of *Mariscus fauriei* is lowland dry forest, typically dominated by *Metrosideros polymorpha* ('ohi'a) and *Diospyros* L. (lama) species. The taxon generally occurs on a'a lava substrates at elevations of 380 to 6,000 ft (300 to 1,830 m) (Koyama 1990, HHP 1991o8, NTBG 1991g). Associated native taxa include *Peperomia* Ruiz & Pav. (ala ala), *Capparis sandwichiana* (maia pilo) *Rauvolfia sandwicensis* A. DC. (hao), and *Canthium* Lam., nom. cons. prop. (alahe'e).

Reasons for Decline

Significant browsing and trampling of *Mariscus fauriei* by feral goats and axis deer occur on Molokai and are contributing significantly to the taxon's decline. Disturbance of substrate and understory provide opportunities for invasion of alien taxa.

On the Big Island, competition with alien species, such as the noxious grass *Oplismenus hirtellus*, koa haole (*Leucaena leucocephala*) and a member of the mango family, *Schinus terebinthifolius*, is a major concern because these invasive species are encroaching on habitats of *Mariscus fauriei*. The two aforementioned alien species present a major threat in drier habitats. On Molokai and the Big Island, but particularly the latter, small numbers of widely distributed *M. fauriei* account for a much reduced gene pool, which may negatively affect reproductive vigor. Development and natural and human-caused catastrophic events are grave threats because entire populations may be extirpated (HHP 1991o8; NTBG 1991g; R. Hobdy, pers. comm., 1992; 59 FR 10305).

Conservation Efforts

No conservation efforts are taking place at this time.

Needed Recovery Actions

Propagation and maintenance of *ex situ* genetic stock are necessary. Molokai populations should be protected from deer and goats via fencing or other means. Control of competing alien taxa, specifically *Oplismenus hirtellus, Leucaena luecocephala* and *Schinus terebinthifolius*, is necessary on the Big Island. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of populations and plants for recovery. Efforts should be made to ensure that both Molokai and Big Island populations remain viable.

**Solanaceae (Nightshade Family)**

Solanaceae is a family that is widespread, but occurs primarily in the southern hemisphere. Composed of 90 genera and 2,700 species, this family is represented in Hawaii by 12 genera, 3 of which are native (Symon 1990). Solanaceae is an important contributor of many food sources, as well as weeds.

***Nothocestrum* (aiea)**

*Nothocestrum* A. Gray is endemic to the main Hawaiian Islands. The genus comprises four species, two of which occur on the Big Island with one of these endemic to the Big Island. Both taxa on the Big Island are listed as endangered. *Nothocestrum peltatum* Skottsb. also occurs on Kauai, and is addressed in the Recovery Plan for the Kauai Plant Cluster. *Nothocestrum breviflorum* A. Gray is addressed in this plan (Symon 1990).

***Nothocestrum breviflorum* (aiea)** - Recovery Priority #5

Description

*Nothocestrum breviflorum* is a stout tree 33-39 ft (10-12 m) tall (Symon 1990). The trunk, about 18 in (45 cm) in diameter, has a soft, sappy wood with dark brown bark. Oblong to elliptic, toothless, stalked leaves, 2-4.7 in (5-12 cm) long and 1.2-2.4 in (3-6 cm) wide, are generally confined to the ends of the branches and are seasonally shed. In texture, they are relatively thick and papery. The upper leaf surface is glabrous (smooth) to sparsely whitish pubescent (downy), and the lower surface is often densely whitish pubescent. Several to numerous flowers appear in clusters at the tips of shortened, spur-like branches. Each flower is subtended by its own stalk (pedicel) 0.2-0.4 in (4-10 mm) long. The 4-lobed, tube-shaped calyx, 0.2-0.4 in (6-11 mm) long, is split on one side. Green-yellow, 4-lobed petals are fused at the base and generally are enclosed in the calyx. The lobes are hairy on the outside. Fruits remain enclosed by the calyx and are orange-red, round berries about 0.2-0.3 in (6-8 mm) in diameter.

This species is distinguished from other Hawaiian members of the genus by leaf shape, number of flowers (more than three) in the flower clusters at tips of short spur-like branches, and the fruit remaining enclosed in the calyx (Symon 1990).

Taxonomy

*Nothocestrum breviflorum* was first collected by Charles Pickering during the United States Exploring Expedition of 1840 and 1841. Based on these specimens, Asa Gray (1862) named the taxon *N. breviflorum,* thus referring to the short petals of the flower in this species. Hillebrand (1888), in his *Flora of the Hawaiian Islands*, described a variety, *Nothocestrum breviflorum var. longipes* Hillebr. However, in the most recent treatment, Symon (1990) disregarded varieties of this species.

Historic Distribution

*Nothocestrum breviflorum* is known from the southern Kohala mountains, the western, southern, and eastern slopes of Mauna Loa, and the northern slopes of Hualalai, Hawaii (Table 20).

Table 20. Historic (H) and current distribution of *Nothocestrum breviflorum*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | S. Kohala, Kawaihae Iuka | Not Available (N/A) | N/A | N/A | N/A | 18?? |
| Hawaii (H) | Kau, Kapapala | N/A | N/A | N/A | Forbes | 1911 |
| Hawaii (H) | Kau, Hilea Trail | N/A | N/A | N/A | Rock | 1912 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | N. Kona | N/A | N/A | N/A | Cranwell | 1938 |
| Hawaii (H)? | Kipuka Puaulu | 1 | N/A | Federal | N/A<br>Fagerlund and Mitchell | 1915<br>1943 |
| Hawaii (H) | S. Kona, Kiilae | N/A | 4,000-5,000 ft (1,220-1,520 m) | Private | N/A<br>Baldwin | 1944<br>1959 |
| Hawaii (H) | Kohala Mts., Waimea | N/A | 2,400 ft. (730 m) | Private | N/A<br>Christensen | 1926<br>1963 |
| Hawaii (H) | Naulu | N/A | 1,700-2,100 ft (520-640 m) | Federal | Newell | 1966 |
| Hawaii (H) | N. Kona | 2 | 1,000 ft (300 m) | State | Herbst | 1970 |
| Hawaii | N. Kona Kaupulehu | 4 | 2,000-2,200 ft (607-670 m) | Private | N/A<br>Wagner *et al.*<br>Lorence | 1947<br>1983<br>1995 |
| Hawaii | Kau, Kamaoa-Puueo | 1 | 600 ft (180 m) | State | N/A | 1991 |
| Hawaii | N. Kona, Puu Waawaa | N/A | 900-6,000 ft (580-1,830 m) | State | N/A<br>Takeuchi and Tate | 1909<br>1992 |
| Hawaii | S. Kohala, Kiholo | N/A | N/A | N/A | N/A | 1989<br>1992 |
| Hawaii | N. Kona, Kaloko | 2 | 360 ft (110 m) | N/A | HHP | 1992 |
| Hawaii | N. Kona, Kealakehe | 1 | 260 ft (79 m) | N/A | HHP | 1992 |

## Current Distribution

Since 1975, six populations have been identified on the western side of the Big Island from South Kohala to Kamaoa-Puueo (Table 20) (HHP 1991p1-12; Joel Lau, The Nature Conservancy of Hawaii, pers. comm., 1992; W. Wagner, pers. comm., 1992; J. Giffin, pers. comm., 1995). Four populations consist of one to four plants each, and numbers are unknown for two populations. In addition, plants may have been cultivated at Kipuka Puaulu for ornamental purposes (J. Giffin, pers. comm., 1995). Six individuals may persist at this site, provided they were correctly identified (L. Pratt, pers. comm., 1995). The taxon has not been seen recently at Naulu and is probably extirpated from that location (L. Pratt, pers. comm., 1995).

Life History

This species was observed in flower during February 1970 (HHP 1991p4), and in fruit and flower during December 1991 (HHP 1991p12) and January 1912 (Rock 1913). No other life history information is currently available.

Habitat Description

Habitats of *Nothocestrum breviflorum* are lowland dry forest, montane dry forest, and montane mesic forest dominated by *Metrosideros polymorpha, Acacia koa,* and\or *Diospyros sandwicensis*. Individuals occur on a'a lava substrates at elevations ranging from 260 to 6,000 ft (180 to 1,830 m) (Gagne and Cuddihy 1990; Symon 1990; HHP 1991p1-p2, 1991p5, 1991p7, 1991p12; NTBG 1991h). *Santalum* L. (iliahi), *Caesalpinia kavaiensis* H. Mann (uhiuhi), *Erythrina sandwicensis* Degener (wiliwili) and several other taxa grow in association with *Nothocestrum breviflorum* (HHP 1991p1, 1991p3-p4, 1991p12; NTBG 1991h; W. Wagner, pers. comm., 1992; J. Giffin, pers. comm., 1995). Other endangered taxa, including *Colubrina oppositofolia*, *Kokia drynariodes*, *Hibiscadelphus hualalaiensis*, and *Delissea undulata,* grow in the area where *N. breviflorum* occurs in the Puu Waawaa area.

Reasons for Decline

*Nothocestrum breviflorum* is negatively impacted by cattle and sheep grazing and by the introduction of alien plant taxa such as *Schinus terebinthifolius, Pennisetum setaceum* (fountain grass), *Lantana camara,* and *Leucaena leucocephala* (koa haole). The introduction of these invasive taxa may afford enough fuel to support a destructive fire. Increased residential and recreational developments have reduced available habitat. Population and individual numbers of *Nothocestrum breviflorum* are few enough to face random extinction or reduced reproductive viability (HHP 1991p4, 1991p6, 1991p12; Lamb 1981; J. Giffin, pers. comm., 1995).

Conservation Efforts

The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995). Steve Bergfeld (pers. comm., 1995) has indicated that the taxon germinates and grows well in the greenhouse. However, individuals succumbed when outplanted (J. Giffin, pers. comm., 1995). Six individuals were found at the Kipuka Puaula site, provided they were correctly identified (L. Pratt, pers. comm., 1995).

Needed Recovery Actions

Propagation and maintenance of *ex situ* genetic stock is necessary. Populations should be protected from cattle via fencing or other means, and competing alien plant taxa, specifically *Schinus terebinthifolius*, lantana and fountain grass, should be controlled. Habitat of this species should be protected from residential and recreational development in sufficient area to allow for full recovery of the species.

**Apocynaceae (Dogbane Family)**

Apocynaceae is a widespread, predominately tropical and subtropical family composed of about 200 genera and 2,000 species. In Hawaii, this family is represented by six genera, four of which are native and two of which are introduced (Wagner *et al.* 1990).

***Ochrosia* (holei)**

*Ochrosia* Juss. is a genus of 30 species that occurs from Madagascar to Australia and Polynesia. In Hawaii, four endemic species are recognized tentatively at this time and appear to be derived from a single colonization (Wagner *et al.* 1990). Two of the four taxa occur on the Big Island, and that addressed in this plan, *Ochrosia kilaueaensis*, is endemic to this island. *O. kilaueaensis* is listed as endangered (Wagner *et al.* 1990).

***Ochrosia kilaueaensis* (holei)** - Recovery Priority #5

Description

*Ochrosia kilaueaensis* St. John is a tree with milky sap that grows to about 49-59 ft (15-18 m) tall (Wagner *et al.* 1990). Oblance-shaped to ob-elliptic leaf blades, 2.4-7.5 in (6-19 cm) long and 0.9-2.6 in (2.2-6.5 cm) wide, are arranged three to four at a node. Conspicuous secondary veins are almost perpendicular to the midvein. Numerous flowers are arranged in clusters and subtended by main flower cluster stalks divided into two sections: primary stalks (peduncles), 1.8-2.5 in (4.5-6.3 cm) long; and secondary branch stalks, 0.4-1 in (1.1-2.5 cm) long. Each flower has a flower stalk (pedicel) 0.2-0.3 in (5-7 mm) long. The calyx is deeply 5-lobed and about 0.4 in (1 cm) long. The green-white, trumpet-shaped flowers have five lobes 0.5-0.6 in (12-15 mm) long fused at the base into a cylindric tube 0.3-0.4 in (7-11 mm) long. Lance-shaped fruits, 1.8-1.9 in (4.5-4.9 cm) long and 0.9-1.1 in (2.4-2.5 cm) wide, have a fleshy inner layer, a stony single seed, and may be yellow-brown when mature.

This species can be separated from other Hawaiian taxa of the genus by the greater height of mature trees, open flower clusters, longer flower stalks, and larger calyx and petal lobes (Wagner *et al.* 1990).

Taxonomy

*Ochrosia kilaueaensis* was first collected in 1915 by Forbes at Kilauea Volcano, Hawaii. The taxon was not described until St. John, in 1978, named the species. The specific epithet honors the volcano on which the type collection was made. Based on an earlier collection made by Rock from Kona (1909), St. John (1978) reviewed the nomenclature and assigned the name *Ochrosia konaensis* St. John in reference to its locality. The current treatment of the genus (Wagner *et al.* 1990) recognizes this name as the synonym of *O. kilaueaensis.*

Historic Distribution

*Ochrosia kilaueaensis* is known only from Puu Waawaa and at Kipuka Puaulu, Kilauea, Hawaii (Table 21). This taxon was collected last in 1927 by Giffard at Kilauea and may now be extirpated from there (L. Pratt, pers. comm., 1995).

Table 21. Historic (H) and current distribution of *Ochrosia kilaueaensis.*

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Hawaii (H) | N. Kona, Puu Waawaa | A few | 3,000 ft (914 m) | Not Available (N/A) | Rock | 1909 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H?) | Volcanoes Nat'l Park, Kipuka Puaulu | Several | 3,937-4,265 ft (1,200-1,300 m) | Federal | N/A<br>Giffard | 1911<br>1927 |
| Hawaii | N. Kona, Puu Waawaa | N/A | 2,198-3,000 ft (670-910 m) | State | Tomich | 19?? |

Current Distribution

Possibly the only extant population occurs at Puu Waawaa on state-owned land (Table 21). The population was last collected by Q. Tomich on an unknown date, and it is unknown how many individuals are present in the population, if any (HHP 1991g1-g2). Jon Giffin (pers. comm., 1995) stated that the last known observation of the population was in the 1940s and it may be extinct. The population in Hawaii Volcanoes National Park has not been observed since 1927, although the kipuka was intensively surveyed in 1992 (L. Pratt, pers. comm., 1995).

Life History

No life history information is currently available for this species.

Habitat Description

*Ochrosia kilaueaensis* occurs within montane mesic forest at elevations between 2,200 and 4,000 ft (670 and 1,220 m) (Gagne and Cuddihy 1990; Wagner *et al.* 1990; HHP 1991q1-q2; 59 FR 10305). Associated taxa included *Gardenia brighamii* H. Mann (nanu), *Psychotria hawaiiensis* (A. Gray) Fosb. (kopiko), *Nothocestrum* (aiea), and *Colubrina* (kauila) (HHP 1991q1).

Reasons for Decline

*Ochrosia kilaueaensis* has several major threats to its survivability, provided that the taxon remains extant. Feral goats browse and trample the native vegetation, disturbing substrate and understory and providing ample sites for weedy adventives such as *Pennisetum setaceum* (fountain grass). Competition from alien species is a major source of concern for this rare taxon. Drying stands of grass provide an excellent source for fire. Predation of fruits by black rats is a potential problem.

Provided that this taxon persists, human impacts continue to be a serious threat to the survival of *Ochrosia kilaueaensis*. If this exceedingly rare taxon is extant, the extremely limited number of individuals reduces reproductive rates and increases the probability of extirpation by random events.

Conservation Efforts

There are no conservation efforts for this taxon at this time.

Needed Recovery Actions

A thorough survey of the area where the last known *Ochrosia kilaueaensis* occurred is necessary. If the species is found, genetic material for maintenance of *ex situ* stock should be collected, the existing population protected, and eventual outplanting of propagated material in protected areas within its historic range pursued.

**Plantaginaceae (Plantain Family)**

Plantaginaceae consists of 3 genera and about 250 species. All but four taxa belong to the genus *Plantago* L. and are relatively cosmopolitan in distribution. The family is represented in Hawaii by one genus, *Plantago* (Wagner *et al.* 1990).

***Plantago* (plantain)**

A cosmopolitan genus, *Plantago* L. contains about 250 species. Hawaiian *Plantago* consists of eight species and four varieties. Five species are naturalized and three are endemic (Wagner *et al.* 1990). Two taxa are endemic to all of the Hawaiian Islands and one is found only on the Big Island. The latter, *Plantago hawaiensis*, is listed as endangered.

***Plantago hawaiensis* (laukahi kuahiwi)** - Recovery Priority #2

Description

*Plantago hawaiensis* (A. Gray) Pilg. is a perennial herb with a short stem that is several centimeters long and has red-brown wooly hairs (Wagner *et al.* 1990). Thick leathery basal leaves are narrowly elliptic, 3-8.7 in (7.5-22 cm) long and 0.6-1.3 in (1.5-3.2 cm) wide, usually with five to seven almost parallel nerves. Sessile, ascending flowers are moderately crowded into a spike about 5.9-9 in (15-23 cm) long. The spike of flowers is subtended by a flowering stalk (scape)

7.9-35 in (20-90 cm) long. Each flower has an ovate-elliptic bract at its base, 0.08-0.1 in (2.1-2.6 mm) long. The calyx consists of four subequal, elliptic to oval lobes with thin, translucent margins. The petals are trumpet-shaped with four reflexed lobes, about 0.04 in (1 mm) long. The fruit is longer than the calyx, 0.1-0.2 in (2.6-4 mm) long, dry, and splits apart to release four to six dull black, winged (at one end) seeds, 0.4 in (1 mm) long.

This species is distinguished from other members of the genus in Hawaii by several characters: ascending to suberect flowers; thick leathery leaves; and a fruit that is longer than the calyx (Wagner *et al.* 1990).

Taxonomy

*Plantago hawaiensis* was first collected on the Big Island by members of the United States Exploring Expedition of 1840 and 1841. In 1850, it was collected again by Remy. Gray (1862) gave the specimens two different names, *Plantago pachyphylla* A. Gray var. *hawaiensis* A. Gray (referring to the plant's location and based on the Exploring Expedition's collection) and *P. pachyphylla* var. *hawaiensis* subvar. *gracilis* A. Gray, based on Remy's collection. The assumption that these taxa were varieties of *P. pachyphylla* was understandable as they are closely related to this polymorphic taxon. In 1911, Leveille published another name, *P. gaudichaudiana* H. Lev., based on another specimen from elsewhere on the island. In 1923, Pilger elevated the varietal level of *P. p.* var. *hawaiensis* to specific rank, resulting in *Plantago hawaiensis*. Pilger (1937) later also recognized a new variety, *Plantago hawaiensis* var. *laxa* Pilger. However, Pilger's varietal addition is not recognized by the latest revision of Wagner *et al.* (1990). Therefore, *Plantago hawaiensis* stands.

Historic Distribution

*Plantago hawaiensis* is known only from the Big Island. It occurred on the southern slope of Mauna Kea, northeastern, southeastern and southern slopes of Mauna Loa, and the western slope of Hualalai (HHP 1991r1-r6) (Table 22).

Table 22. Historic (H) and current distribution of *Plantago hawaiensis*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kau, Kapapala | Not Available (N/A) | N/A | N/A | Forbes | 1911 |
| Hawaii (H) | Kona, Kukui-o-Pii | N/A | N/A | N/A | N/A | 1911 |
| Hawaii (H) | Kipuka Ahiu | N/A | N/A | N/A | N/A | 1915 |
| Hawaii (H) | N. Kona, Hualalai | N/A | 6,000-6,562 ft (1,830-2,000 m) | N/A | N/A<br>Rock | 1909<br>1922 |
| Hawaii (H) | Kau, Keapohina | N/A | 6,000+ ft (1,830+ m) | Private | Meinicke | 1963 |
| Hawaii | S. Hilo, Puu Oo Trail | 2 | 5,640 ft (1,720 m) | State | Warshauer | 1977 |
| Hawaii | N. Hilo, Humuula | 2 | 6,200-6,400 ft (1,890-1,950 m) | State | N/A<br>Warshauer and McEldowney | 1935<br>1979 |
| Hawaii | S. Hilo, Waiakea, Kipuka | N/A | 5,260 ft (1,600 m) | State | Clarke | 1981 |
| Hawaii | Volcanoes Nat'l Park, Kipuka Kulalio | 360 | 7,000 ft (2,134 m) | Federal | Pratt | 1994 |
| Hawaii | Volcanoes Nat'l Park; Kipuka Maunaiu | 270 | 7,000 ft (2,134 m) | Federal | Pratt | 1994 |
| Hawaii | Upper Waiakea Forest Reserve | Scattered | N/A | State | Pratt | 1994 |
| Hawaii | Kau, Kapapala | 5,000 | 7,800-8,040 ft (2,377-2,450 m) | State | N/A | 1995 |
| Hawaii | Puu Waawaa | 2 | N/A | State | Giffin | 1995 |

Current Distribution

Since 1975, eight populations have been identified in North and South Hilo, Waiakea Forest Reserve, Hawaii Volcanoes National Park, Kapapala and Puu Waawaa (Table 22). The populations are found on state, Federal and privately owned lands. The total number of individuals present is not known; however, estimates exceed 5,000. Two plants were discovered in Puu Waawaa around 1990, and the presence of additional plants is suspected (J. Giffin, pers. comm., 1995). The Volcanoes populations are flowering, fruiting, and reproducing (L. Pratt, pers. comm., 1995). A few scattered plants have been observed in the Upper Waiakea Forest Reserve near Powerline Road and the Kau Silversword Bog (L. Pratt, pers. comm., 1995).

Life History

No life history information is currently available for this species.

Habitat Description

The habitat of *Plantago hawaiensis* is somewhat variable. The taxon grows either in montane wet sedgeland with mixed sedges and grasses, or in montane mesic forest growing with stunted *Acacia koa* and *Metrosideros polymorpha*, often growing in cracks of lava. *Plantago hawaiensis* occurs at elevations of 5,900 to 8,040 ft (1,800 to 2,450 m) mainly on the leeward side of the island (Wagner *et al.* 1990; HHP 1991r1-r2, 1991r4, 1991r6).

Reasons for Decline

Feral goats and mouflon sheep are problems for the two populations that occur on Kipuka Kulalio and Kipuka Maunaiu in Hawaii Volcanoes National Park. These individuals grow at an elevation of 7,000 ft (2,134 m). They occupy an area outside the Mauna Loa strip goat fence and, therefore, are unprotected from these feral animals. Browsing by goats and mouflon sheep may affect the viability of these plants, preclude the establishment of juveniles, and damage the habitat, thereby opening suitable sites for the inevitable establishment of alien weeds.

Reproductive ability may be decreased because of limited numbers of individuals in most populations, and widely scattered distibution of these few populations, resulting in the demise of the taxon. Random extinction from natural phenomena and human interference is possible.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon (D. Ragone, pers. comm., 1995). Four plants are located at the greenhouse at Hawaii Volcanoes National Park.

Needed Recovery Actions

Steps should be taken to fence known populations to protect them from ungulates and encourage regeneration. Research as to additional causes for decline may also be necessary. Ownership of the large population at Kapapala should be determined and the site protected.

**Portulacaceae (Purslane Family)**

Portulacaceae is relatively cosmopolitan, but is most prolific in western North America and the Andes mountains of South America. A family containing 20 genera and 500 species, the Hawaiian Portulacaceae is represented by 2 genera, *Talinum* and *Portulaca* (Wagner *et al.* 1990).

***Portulaca* (purslane)**

*Portulaca* L. is a subtropical and pantropical genus. In Hawaii, the genus comprises seven species: three endemic, one indigenous, and three introduced (Wagner *et al.* 1990). Native Hawaiian taxa appear to have arisen from two separate colonizations. *Portulaca sclerocarpa* is listed as endangered.

***Portulaca sclerocarpa* (poe)** - Recovery Priority #2

Description

*Portulaca sclerocarpa* A. Gray is a perennial with a fleshy, tuberous taproot that becomes woody with maturity (Figure 10) (Wagner *et al.* 1990). Stems, 7.9 in (20 cm) long, are prostrate or ascending. Leaves, 0.3-0.5 in (8-12 mm) long and 0.06-0.1 in (1.5-2.5 mm) wide, are narrowly oblance-shaped to linear, almost round in cross-section, succulent, grey-green, and stalkless. Dense tufts of yellow-brown hairs, about 0.1-0.2 in (3-6 mm) long, occur in the axil between stem and leaf. Three to six flowers occur at the end of the stem and form a dense flower cluster. The flower clusters are subtended by dense tufts of hair, 0.2-0.3 in (5-8 mm) long and by several leaf-like bracts 0.06 in (1.5 mm) long. Sepals, 0.2

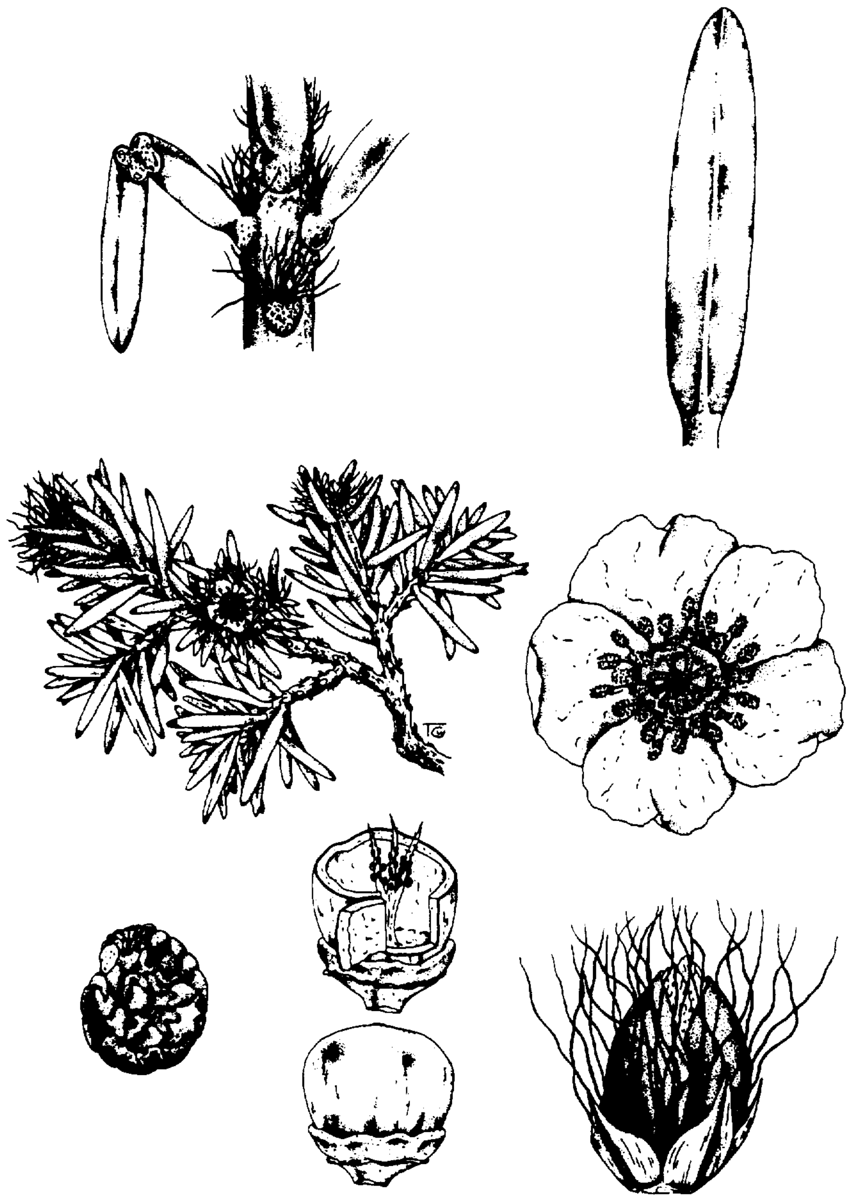

Figure 10: *Portulaca sclerocarpa* (Tracy Wager, CEMML, CSU)

in (5 mm) long, have edges that are transparent and thin. Five ob-oval white, pink, or pink with white base petals, 0.4 in (10 mm) long, surround 30 stamens and an ovary with an 8-branched style. Fruits are almost round 0.2 in (4 mm) long, with an outer hard wall 0.01-0.02 in (0.18-0.5 mm) thick. The fruit may break apart, with the top portion separating 1/3 of its length from the base at maturity. Seeds are about 0.02 in (0.4-0.6 mm) long and are glossy and red-brown. *Portulaca sclerocarpa* is distinguished from other species of the genus in Hawaii by its woody taproot, narrow leaves, and petal and seed color. It is readily separated from two other taxa, *P. villosa* Cham. and *P.* sp. A, both of which may occur on the Big Island. *Portulaca villosa* has thin-walled fruits and *P.* sp. A's taproot is not woody (Wagner *et al.* 1990).

Taxonomy

*Portulaca sclerocarpa* was originally collected during the United States Exploring Expedition of 1840 and 1841. Gray (1854) named the species in reference to the hard, bony fruit.

Historic Distribution

*Portulaca sclerocarpa* is known from the islands of Lanai and Hawaii. Populations were found on an islet off of the south coast of Lanai, and the Kohala mountains, the northern slopes of Hualalai, the northwestern slopes of Mauna Loa, and near Kilauea Crater on the Big Island (Table 23).

Table 23. Historic (H) and current distribution of *Portulaca sclerocarpa*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | S. Kohala, Waimea | Not Available (N/A) | N/A | N/A | U.S. Exploring Expedition | 1841 |
| Hawaii (H) | Kau, Kanehaha | N/A | N/A | N/A | N/A | 1911 |
| Hawaii (H) | Kau, Kau Desert | N/A | N/A | N/A | Degener | 1929 |
| Hawaii (H) | Kau, Kilauea, Kilauea Iki | N/A | 3,939 ft (1,200 m) | N/A | St. John *et al.* | 1931 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kau, Kilauea, Hilena Pali Rd. | N/A | 3,400 ft (1040 m) | N/A | St. John *et al.* | 1937 |
| Hawaii (H) | Kau, Kilauea, Keanakakoi Crater | N/A | N/A | N/A | St. John *et al.* | 1937 |
| Hawaii (H) | Volcanoes National Park, Footprints Trail | <10 | N/A | Federal | Pratt | 1970 |
| Hawaii | Pohakuloa Training Area | 1 | 5,100 ft (1,550 m) | Federal | N/A<br>N/A | 1977<br>1991 |
| Hawaii | Parker ranch | 80 | 2,400-3,060 ft (732-933 m) | Private | Cuddihy | 1981-1983 |
| Lanai | Poopoo Islet | 10 | N/A | N/A | Hobdy | 1982 |
| Hawaii | N. Kona, Keauhou | N/A | 5,020 ft (1,530 m) | Private | Jacobi | 1978 |
| Hawaii | N. Kona, Puu Anahulu | 3 | 4,300-4,810 ft (1,310-1,470 m) | Private | Warshauer, McEldowney<br>Giffin | 1978<br>1995 |
| Hawaii | N. Kona, Keauhou | 2 | 5,350 ft (1,630 m) | Private | Warshauer, McEldowney | 1978 |
| Hawaii | N. Kona, Keauhou | 6 | 4,700 ft (1,430 m) | Private | Warshauer, McEldowney | 1978 |
| Hawaii | Volcanoes National Park, Hilina Pali Rd. | <10 | N/A | Federal | Pratt | 1987 |
| Hawaii | Volcanoes National Park, Keanakakoi Crater | <10 | N/A | Federal | N/A | 1992 |
| Hawaii | Volcanoes National Park, Fumarole Area | 970 | 3,600 ft (1,100 m) | Federal | Fosberg<br>Pratt<br>Pratt | 1977<br>1983<br>1993 |
| Hawaii | Pohakuloa Training Area | <15 | N/A | Federal | CEMML-CSU | 1993-1995 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | Pohakuloa Training Area | <25 | N/A | Federal | CEMML-CSU | 1994-1995 |

<u>Current Distribution</u>

Since 1975, 1 extant population which consists of 10 individuals is known to occur off the coast of Lanai on Poopoo Islet (R. Hobdy, pers. comm., 1992) and 11 extant populations, numbering over 1,000 plants, are known to occur on Federal, State and private lands on the Big Island (Table 23) (Cuddihy *et al.* 1983; HHP 1991S1-12; Robert B. Shaw, Director, Center for Ecological Management of Military Lands (CEMML), Colorado State University (CSU), pers. comm., 1992; Shaw, in press).

Individuals were found on three puu (hills) on the Parker Ranch in the early 1980s. The individuals appeared healthy, but not in flower or fruit (L. Pratt, pers. comm., 1995). The populations within Hawaii Volcanoes National Park occur primarily in the Puhimau geothermal (fumarole) area. In 1983, approximately 4,300 plants were counted but, in 1993-94, the number had declined to 970. The reason for this decline is unknown. The taxon is currently known at 2 other locations in the Park: Keanakakoi Crater Rim (< 10 plants), and Hilina Pali Road (< 10 plants) (L. Pratt, pers. comm., 1995). The Footprints Trail population in the Kau Desert consisted of fewer than 10 plants in the 1970s, but has not been observed recently.

In 1991, CEMML-CSU found a single individual growing on the western portion of the Pohakuloa Training Area (PTA). In 1993 and 1994, two more populations were discovered in the southwestern portion of PTA. The populations occur approximately 1.5 miles (2 kilometers) apart and grow in pockets of eroded pahoehoe lava. Individuals in both populations were healthy, flowering and producing seed. Numerous juveniles were present in both populations. In 1995, Jon Giffin and CEMML-CSU found two plants on the 1859 lava flow in the Puuanahulu area. One plant was producing seed.

Life History

This species was observed in flower during March 1977 (HHP 1991s1), December 1937 (HHP 1991s2), and June 1978 (HHP 1991s12). The presence of juveniles indicates that pollination and germination are occurring.

Habitat Description

The habitat of *Portulaca sclerocarpa* is montane dry shrubland. The taxon often is found on bare cinder, near steam vents, and in open *Metrosideros polymorpha* dominated woodlands, at elevations between 3,380 and 5,340 ft (1,030 to 1,630 m) (Gagne and Cuddihy 1990, Wagner *et al.* 1990). Associated taxa are *Sophora chrysophylla*, *Metrosideros polymorpha*, and *Myoporum sandwicense* (HHP 1991s1-s8, 1991s10, 1991s12; NTBG 1991I; 59 FR 10305).

Reasons for Decline

A major threat to *Portulaca sclerocarpa* is competition from alien grasses such as *Pennisetum setaceum* (fountain grass) and *Andropogon virginicus*. Although no browsing has been observed, goats, pigs and sheep trample and disturb the habitat, damaging the understory and providing suitable sites for noxious invaders such as *Heterotheca grandiflora*. Fire is also a pervasive problem in such dry habitat. The unknown reason for the decrease in numbers from 4,300 in 1983 to 970 in 1994 in the Puhimau geothermal (fumarole) area within Hawaii Volcanoes National Park is of concern. Small numbers of populations and individuals and their scattered distributions decrease reproductive viability and increase vulnerability to random events.

Conservation Efforts

The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995). CEMML staff at CSU germinated seeds in 1993-94. The individuals flowered and set seed.

Needed Recovery Actions

Propagation and maintenance of *ex situ* genetic stock should continue. Habitat of this species must be protected from feral ungulates, and competition from alien grasses controlled. Research into the cause of decline in the fumarole area of Hawaii Volcanoes National Park should be undertaken. Efforts should be made to ensure that both Lanai and Big Island populations remain viable. Outplanting of propagated plants may be necessary in order to augment populations.

**Arecaceae (Palm Family)**

A tropical or subtropical family, Arecaceae consists of about 212 genera and 2,600 species (Read and Hodel 1990). In Hawaii the family is represented by four genera, of which three monotypic genera are introduced and one genus is endemic (*Pritchardia*) (Read and Hodel 1990).

***Pritchardia* (loulu)**

*Pritchardia* Seem. & H.A. Wendl., nom. cons., is a complex genus occurring in tropical Pacific islands and is composed of 25 species. In the Hawaiian Islands, the highly variable, poorly described genus is represented by 19 endemic species (Read and Hodel 1990). Four species are endemic to the Big Island. One of these four species, *Pritchardia affinis*, is listed as endangered.

***Pritchardia affinis* (loulu)** - Recovery Priority #5

Description

*Pritchardia affinis* Becc. is a palm tree that grows from 33-82 ft (10-25 m) tall (Read and Hodel 1990). Its orbicular and wedge-shaped, hairless leaf blades are green on the upper surface and pale green on the lower surface, with a few yellow scales. Pale, long, soft, tangled hairs extend along the fan-like folds of the leaf segments to the leaf stalk. One or more hairless flower clusters are branched and rebranched. Each flower cluster is subtended by a main flower cluster stalk (peduncle) that has bracts at the base. Upper flower cluster branches also are subtended by small membranous bracts bearing a single flower. The calyx is cup-shaped and 3-lobed. Three petals are fused at the base to the stamen tube, which is comprised of six stamens. The immature fruit has a 3-lobed stigma. The fruit is brown to black, almost round and about 0.9 in (2.3 cm) in diameter.

This taxon can be distinguished from other species of *Pritchardia* by several characters: long tangled hair on the lower blade surface and leaf stalk, stout hairless flower clusters borne among wedge-shaped leaves, and an almost round fruit that is smaller than fruits of other species (Read and Hodel 1990).

## Taxonomy

*Pritchardia affinis* was first collected by Rock on the island of Hawaii. Based on these collections, Beccari named three varieties: *Pritchardia affinis* Becc. var. *rhopalocarpa* Becc., *P. affinis* Becc. var. *halophila* Becc., and *P. affinis* Becc. var. *gracilis* Becc. (Beccari and Rock 1921). *P. affinis* var. *halophila* was published incorrectly as *P. affinis* var. *holaphila*, a spelling error. These three varieties of *P. affinis* appear to represent ecological variation and genetic plasticity within the species; therefore, Read and Hodel (1990) recognize no varietal taxa.

## Historic Distribution

*Pritchardia affinis* is known only from the Kohala mountains, and along the southeastern and western coasts of the Big Island (HHP 1991t1-t6) (Table 24).

Table 24. Historic (H) and current distribution of *Pritchardia affinis*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kohala Mts. | Not Available (N/A) | N/A | N/A | Hillebrand | 18?? |
| Hawaii (H) | S. Kona, near Kealia | N/A | 1,969 ft (600 m) | N/A | N/A | 19?? |
| Hawaii (H) | Punaluu | N/A | N/A | N/A | Hodel | 19?? |
| Hawaii (H) | S. Kona, Kealakekua | N/A | 2,000 ft (6,100 m) | N/A | Rock | 1917 |
| Hawaii (H) | S. Kona, Kaohe | N/A | N/A | N/A | N/A | 1920 |
| Hawaii (H) | N. Kona | 17 | N/A | N/A | Degener | 1926 |
| Hawaii | Volcanoes National Park, Kalapana | N/A | 1,000 ft (305 m) | Federal | Rock<br>Pratt | 19??<br>1994 |
| Hawaii | Kihilo | N/A | N/A | N/A | N/A | N/A |
| Hawaii | Kukio | N/A | N/A | N/A | N/A | N/A |
| Hawaii | Palani Road | N/A | N/A | N/A | N/A | N/A |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | Kailua | N/A | N/A | N/A | N/A | N/A |
| Hawaii | Captain Cook | N/A | N/A | N/A | N/A | N/A |
| Hawaii | Milolii | N/A | N/A | N/A | N/A | N/A |
| Hawaii | Punaluu | N/A | N/A | N/A | N/A | N/A |

Current Distribution

According to the listing notice in 1994, there are 8 or more populations, which comprise a total of 50 to 65 extant individuals, scattered along the western coast of the Big Island and within Hawaii Volcanoes National Park (59 FR 10305; Hodel 1982; Norman Bezona, Hawaii Cooperative Extension Service, pers. comm., 1992; Brian Meilleur and P. Weisich, Amy Greenwell Ethnobotanical Garden, pers. comm., 1992) (Table 24). Individuals are scattered in urban areas near Kihilo, Kukio, Palani Road, Kailua, Captain Cook, Milolii, and at Punaluu at unspecified sites (Hodel 1992). Linda Pratt (pers. comm., 1995) has indicated that the taxon also occurs along the eastern portion of Hawaii Volcanoes National Park. Three trees still survive along Kalapana Trail at about 1,000 ft (305 m). These individuals appear to have been planted. Several other individuals were planted near Wahaula, but were destroyed by lava in the 1980s.

Life History

No life history information is currently available for this species.

Habitat Description

The habitat of *Pritchardia affinis* is coastal mesic forest on the leeward side of the Big Island, possibly near or in brackish water, at elevations of 0 to 2,000 ft (0 to 610 m) (Read and Hodel 1990; HHP 1991t2; C. Corn, pers. comm., 1992 and 1995). The trees occur in cultivated and/or developed sites, perhaps planted by Hawaiians, or may occur naturally. Because land was cleared for cultivation, native associates are now unknown (B. Meilleur, pers. comm., 1992, C. Corn pers. comm., 1995).

Reasons for Decline

*Pritchardia affinis* grew in areas that have been cleared for urban development and agriculture. Beccari and Rock (1921) indicated that Hawaiians used the fruits as a food source. Very few individuals occur in natural conditions, and those that do occupy prime areas for development near Kailua-Kona. Development and human disturbance are serious threats. Accompanying human habitation, black roof rats consume fruits and seeds. Feral pigs root and destroy seedlings, preventing regeneration (Beccari and Rock 1921; Hull 1980; C. Corn, pers. comm., 1992, 1995). Fire is a serious threat. Lava flowing from Kilauea destroyed several individuals near Wahaula in 1989 (L. Pratt, pers. comm., 1995). Small number of populations and individuals may compromise the reproductive viability of these individuals and increase the vulnerability of the taxon to random events. Although lethal yellow has not been detected in Hawaii, introduction of this bacteria-like organism that often attacks palms could prove devastating to the few remaining *Pritchardia* plants.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon and have a number of young plants growing at Lawai, Kauai (D. Ragone, pers. comm., 1995). Volcano Rare Plant Facility has germinated seed and, as of 1995, has about 200 individuals about 1-2 in (3-6 cm) high, growing "like weeds" in the greenhouse Patty Moriyasu (pers. comm., 1995). Steve Bergfeld (pers. comm., 1995) has indicated that the Division of Forestry and Wildlife has had no trouble germinating and growing *Pritchardia affinis*, which several nurseries apparently grew to retail before the taxon was listed as endangered (S. Bergfeld, pers. comm., 1995). Hawaii DOFAW provided 20 seedlings to Hawaii State Parks for planting at Kona Coast State Park. Hawaii DOFAW also has approximately 100 seedlings in their nursery (C. Corn, pers. comm., 1996)

Needed Recovery Actions

Protection from development, pigs and rats is necessary. The rare natural habitat of this species should be protected. Propagation and maintenance of *ex situ* genetic stock should continue. Outplanting of propagated plants will likely be necessary in order to augment populations. Efforts to prevent spread of lethal yellow to Hawaii should continue.

**Caryophyllaceae (Pink Family)**

Caryophyllaceae is distributed in warm or temperate regions of the northern hemisphere and comprises 75 genera and about 2,000 species. The family is divided into three subfamilies: Alsinoideae, Silenoideae and Paronychioideae (Wagner *et al.* 1990). In the Hawaiian Islands, only three genera belong to the subfamily Silenoideae (*Dianthus* L., *Petrorhagia* (Ser. *ex* DC.) Link, and *Silene* L.), while the remainder of genera belong to the subfamily Alsinoideae.

Thirteen genera and 44 species represent the family in the Hawaiian Islands. Two genera are endemic (*Alsinidendron* H. Mann with 4 species and *Schiedea* Cham. & Schlecht. with 22 species). Six other endemic species belong to the genus *Silene* (Wagner *et al.* 1990).

***Silene* (catchfly, campion)**

A genus most widely distributed in northern temperate regions, *Silene* L. contains about 500 species. The genus is represented in the Hawaiian Islands by one naturalized and seven native taxa. Apparently, these arose from two separate colonization events (Wagner *et al.* 1990). Of the seven taxa endemic to the Hawaiian Islands, three are presumed to be extinct, three are listed as endangered, and one, *Silene hawaiiensis*, is listed as threatened (59 FR 10305).

***Silene hawaiiensis* (catchfly)** - Recovery Priority #8

Description

*Silene hawaiiensis* Sherff is a sprawling shrub with climbing or clambering stems (Figure 11) (Wagner *et al.* 1990). Stems, 6-16 in (15-40 cm) long, generally are covered with short, sticky hairs and arise from an enlarged root. Leaves are slender, 0.2-0.6 in (6-15 mm) long and 0.02-0.03 in (0.5-0.8 mm) wide, often recurved and stalkless. Flowers are arranged in loose, elongate clusters that are highly sticky. Each flower is subtended by a stalk 0.1-0.2 in (3 - 6 mm) long. The calyx is fused, 5-toothed, purple-tinged, and 0.4-0.6 in (11-14 mm) long. The five petals are green-white above and sometimes maroon or maroon-streaked below. The petal is divided into two parts, a 2-lobed expanded blade, 0.2 in (4.5-5.5 mm) long, and a long, narrow, stalk-like base. A dry fruit, 0.25-0.3 in (6.5-8 mm) long, splits apart to release brown seeds 0.02-0.03 in (0.4-0.7 mm) long. *Silene hawaiiensis* can be distinguished from other species of the genus in Hawaii

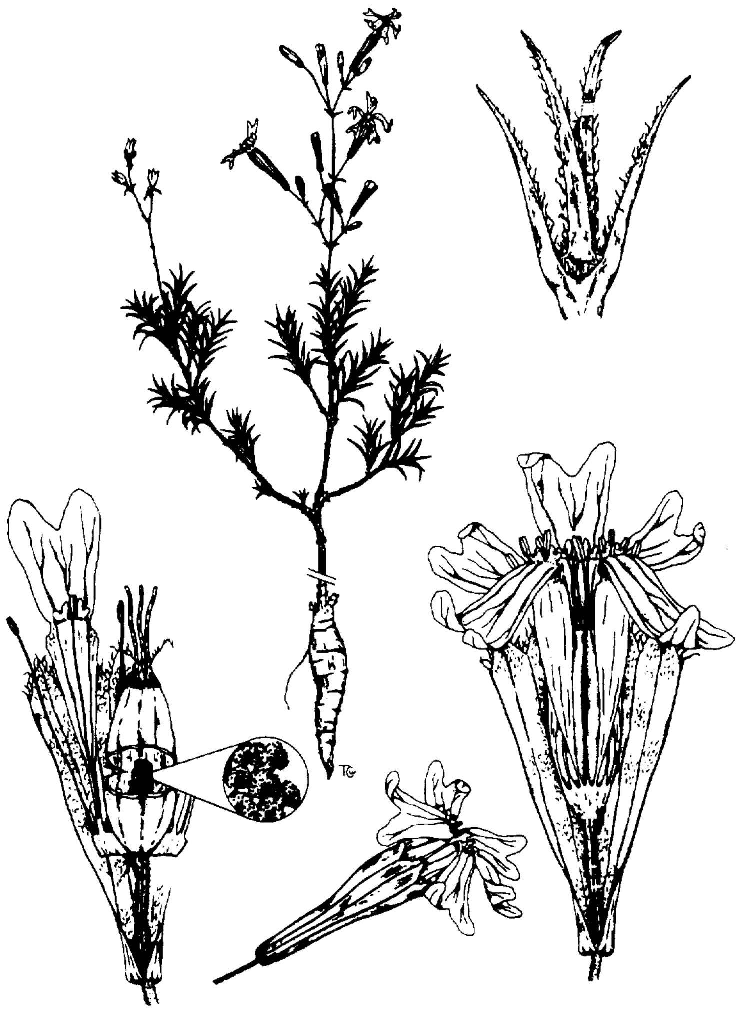

Figure 11: *Silene hawaiienis* (Tracy Wager, CEMML, CSU)

by several characters: sprawling habit, presence of sticky hairs, leaf shape, and color of the petals (green-white with maroon-colored backs) (Wagner *et al.* 1990).

Taxonomy

*Silene hawaiiensis* was first collected on the Big Island during the United States Expedition of 1840-1841. Gray (1854) referred to them as an unknown variety of *S. struthioloides* A. Gray. In 1946, Sherff named this taxon *S. struthioloides* A. Gray var. *gracilis* Sherff, referring to the shape of branches but, in 1949, he raised it to specific rank, *S. hawaiiensis*. The specific epithet refers to the island where it occurs.

Historic Distribution

*Silene hawaiiensis* is known only from the Big Island, on the western slopes of Mauna Kea; the summit of Hualalai; Humuula Saddle; nothern, southern, western, and northwestern slopes of Mauna Loa; and Kilauea Crater (Wagner *et al.* 1990, 59 FR 10305, HHP1991u1-u10, NTBG 1991) (Table 25).

Table 25. Historic (H) and current distribution of *Silene hawaiiensis*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Kau, Kanehaha | Not Available (N/A) | N/A | N/A | N/A | 1911 |
| Hawaii (H) | Hualalai summit | N/A | 8,000 ft (2,440 m) | N/A | Mann<br>Forbes | 19??<br>1911 |
| Hawaii (H) | N. Kona, Puulehua Plain | N/A | N/A | N/A | Rock | 1912 |
| Hawaii (H) | Kilauea, E. of Keanakakoi | N/A | 3,700 ft (1,130 m) | N/A | Neal | 1929 |
| Hawaii (H) | Volcanoes National Park, Kilauea Crater Overlook | Locally common | 4,000 ft (1220 m) | Federal | N/A<br>Crosby and Anderson<br>Pratt | 1929<br><br>1964 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Volcanoes National Park, Mauna Iki Trail | 25 | 3,198 ft (970 m) | Federal | N/A Newell | 1911 1966 |
| Hawaii | N. Kona, Keauhou Ahupuaa, NW slopes of Mauna Loa | N/A | 5,030 ft (1,530 m) | Private | Warshauer, McEldowney | 1978 |
| Hawaii | N. Kona, Keauhou, Ahupuaa | N/A | 5,190 ft (1,600 m) | Private | Jacobi, Higashino | 1980 |
| Hawaii | Saddle Rd. | 10-15 | 6,500 ft (2,000 m) | State | Davis | 1981 |
| Hawaii | Hamakua, Keohe Ahupuaa, W. slope of Mauna Kea | Locally common | N/A | State | Warshauer, McEldowney | 1981 |
| Hawaii | Pohakuloa Training Area | N/A | N/A | Federal | Douglas | 1989 |
| Hawaii | HVNP, Crater Rim Rd., SW rift Zone | 100-200 | 3,700 ft (1,130 m) | Federal | N/A NTBG | 1966 1991 |
| Hawaii | Pohakuloa Training Area | <1,800 | N/A | Federal | CEMML-CSU | 1993 |
| Hawaii | Pohakuloa Training Area | <1,200 | N/A | Federal | CEMML-CSU | 1993 |
| Hawaii | Volcanoes National Park, Crater Rim Drive | 3,751 | 3,600 - 4,000 ft (1,100 - 1,220 m) | Federal | Pratt | 1993-1994 |
| Hawaii | Volcanoes National Park, Mauna Loa Strip Road | 635 | 5,600 - 5,850 ft (1,700 - 1,770 m) | Federal | Pratt | 1994 |
| Hawaii | Volcanoes National Park, Keamoku Lava Flow | 1,162 | 6,000 - 6,100 ft (1,830 - 1,860 m) | Federal | Pratt | 1992-1994 |

Current Distribution

Since 1975, at least 11 populations numbering over 11,000 plants have been identified from the Hamakua district, Humuula Saddle, North Kona, Pohakuloa

Training Area, including a population within the multi-purpose range complex, and Hawaii Volcanoes National Park (Table 25). At the time of listing (June 1994), these populations were thought to be comprised of about 3,000 individuals (59 FR 10305). However, surveys recently conducted in Hawaii Volcanoes National Park show 3 populations of *Silene hawaiiensis* consisting of over 5,500 known plants (L. Pratt, pers. comm., 1995), and surveys in PTA show approximately 3,000 known plants.

Life History

This species was observed in flower during September 1981 (HHP 1991u2) and August 1964 (HHP 1991u5). No other life history information is currently available.

Habitat Description

*Silene hawaiiensis* occurs in montane and subalpine dry shrubland with *Metrosideros polymorpha*, *Sophora chrysophylla*, *Vaccinium reticulatum* Sm. (ohelo), *Styphelia tameiameiae* (Cham. & Schlect.) F.V. Muell. (pukiawe), and *Dodonaea viscosa* Jacq. (aalii). Individuals occur in weathered lava, but are found on variously aged lava flows and cinder substrates as well, at elevations between 3,000-8,500 ft (900-2,575 m) (Wagner *et al.* 1990, Shaw in press).

Reasons for Decline

Feral animals (goats, pigs, and sheep) are detrimental to the taxon's survival. Fragile branches and stems are easily broken or browsed almost to the base of the plant. Individuals on the lower northern slope of Mauna Loa were observed having tender new growth browsed and new leaves stripped away, thus compromising the viability of these individuals. Alien taxa, particularly *Pennisetum setaceum* (fountain grass), are major threats imperiling the survival of *Silene hawaiiensis*. In certain areas where new lava is flowing from Kilauea, plants may be enveloped by molten lava rock and/or consumed by fire. Military training may jeopardize plants on Pohakuloa Training Area. This taxon may be increasingly vulnerable where human habitation is expanding or development is occurring.

Conservation Efforts

In 1992-93, seeds were germinated by staff of the Center for Ecological Management of Military Lands (CEMML) at Colorado State University. Seedlings were grown in the greenhouse. In 1993, seeds were germinated at Pohakuloa Training Area by CEMML staff and about 50 seedlings were outplanted on Puu Kapele. A population of more than 20 individuals survived and produced flowers and fruits. The taxon is growing with *Eragrostis deflexa* Hitchc. in ash on the northwestern slope of the puu, at an elevation of about 5,805 ft (1,640 m).

Needed Recovery Actions

Recent discoveries of several large populations indicate that this plant is not as rare as once thought. Populations should be monitored to ensure that numbers are being maintained. After habitat on which at least five of the larger populations occur is managed to control threats from feral animals, alien taxa, and military training, delisting of this species can be considered.

**Asteraceae (Sunflower Family)**

Asteraceae is most abundant in temperate and subtropical regions, but is fairly cosmopolitan. The family is divided into 13 tribes which contain 1,100 genera and 20,000 species. The Hawaiian Islands' genera are composed of 181 species of which 91 are native. Of the native species, all but one are endemic. Ninety species have been introduced to the Hawaiian Islands (Wagner *et al.* 1990).

***Tetramolopium* (no common name)**

*Tetramolopium* Nees is distributed only on the Hawaiian Islands, Cook Island, and New Guinea. The genus is represented by 36 species and is divided into 3 sections, based on sex expression, ecological preference, and branching patterns: *Alpinum*; *Tetramolopium*; and *Sandwicense* (Lowrey 1990). In Hawaii, the genus is represented by all sections: *Alpinum* (one species, two subspecies, two varieties); *Tetramolopium* (six species, four varieties); and *Sandwicense* (four species, six subspecies, four varieties).

***Tetramolopium arenarium* (no common name)** - Recovery Priority #5

Description

*Tetramolopium arenarium* (A. Gray) Hillebr. is an upright, branched shrub 2.6-4.3 ft (0.8-1.3 m) tall (Figure 12) (Lowrey 1990). Alternate leaves are lance-shaped, 0.6-1.5 in (15-37 mm) long and 0.1-0.4 in (3-9 mm) wide. Hairy and glandular grey-green leaves are yellow or brown when dry. Five to 11 dense flower clusters (heads) are arranged at the tip of each stem. Each flower cluster is comprised of 20-34 lanceolate bracts (involucre), 0.1-0.2 in (2.5-6 mm) high and 0.2-0.4 in (4-9 mm) in diameter, which form a cup under each flower. Bracts are glandular and hairy. The flowers are of two dissimilar types: ray flowers and disk flowers. Ray flowers form a single series of 22 to 45 male flowers. The petal is bilaterally symmetrical and white, with an expanded blade and narrow stalk about 0.5-0.9 in (1.3-2.2 mm) long. Five to nine disk flowers are radially symmetrical and bisexual. Maroon petals are fused, 5-lobed, and 0.1-0.2 in (3.1-4.4 mm) long. Fruits, 0.06-0.12 in (1.5-3 mm) long and 0.02-0.03 in (0.5-0.8 mm) wide, are dry and do not split apart at maturity. Faces of the fruit are 2- to 4-nerved. Hairs at the top of the fruit are 0.1-1.2 in (2.5-6.3 mm) long. This species is separated from other taxa of the genus in the Hawaiian Islands by several characters: upright habit, number of heads per flower cluster (5 to 11), presence and type of glands and hairs, size of male ray flower (1.3 to 2.2 mm), number of bisexual disk flowers (5-9) and their maroon color, and a wide, 2- to 4-nerved fruit with white hairs at the tip (Lowrey 1990).

Three infraspecific taxa are recognized: *Tetramolopium arenarium* subsp. *arenarium* var. *arenarium; T. arenarium* subsp. *arenarium* var. *confertum* Sherff; and *T. arenarium* subsp. *laxum* Lowrey. These taxa are distinguished one from the other by a combination of characters (Table 26).

Figure 12: *Tetramolopium arenarium* (Tracy Wager, CEMML, CSU)

Table 26. Characters differentiating infraspecific taxa of *Tetramolopium arenarium.*

| **Taxon** | **Disk Flowers** | **Peduncle Shape** | **Flower Cluster** | **Leaf Margin** | **Islands** |
|---|---|---|---|---|---|
| Var. *arenarium* | 5-9 | not flexuous | congested | without teeth | Maui Hawaii |
| Var. *confertum* | 4-5 | not flexuous | congested | with teeth | Hawaii |
| Subsp. *laxum* | 6-8 | flexuous | open | with or without | Maui |

Taxonomy

*Tetramolopium* was first collected on the island of Hawaii during the United States Exploring Expedition of 1840 and 1841. The genus was first described by Nees von Esenbeck (1832); however, he failed to designate type specimens. Gray (1861b) relegated *Tetramolopium* to *Vittadinia* A. Rich and named the specimens from the exploring trip *Vittadinia arenaria* A. Gray. Hillebrand (1888) considered the seven Gray species of *Vittadinia* and, because they were so closely related, he reclassified them as *Tetramolopium*, resulting in *T. arenarium*. At that time, he described a new variety, var. *dentatum* Hillebr., which is now synonymous with *T. arenarium* subsp. *laxum*.

Sherff (1934) provided the next comprehensive revision, recognizing 12 species and naming a new variety, *Tetramolopium arenarium* var. *confertum*. Lowrey (1986, 1990) recognized this variety as a variety of subsp. *arenarium*, leaving subsp. *arenarium* without a published name (Laven *et al.* 1991). However, Wagner et al. (1990) recognized three infraspecific taxa: subsp. *arenarium* var. *arenarium*; subsp. *arenarium* var. *confertum*; and subsp. *laxum*. Although listed at the species level, all three taxa are addressed as distinct entities in this plan.

Historic Distribution

*Tetramolopium arenarium* is known from the islands of Maui and Hawaii. Individuals were found on the western slope of Haleakala, Maui, and on the

Kohala mountains, the northwestern slopes of Mauna Kea, Mauna Loa, and Hualalai, Hawaii (Tables 27, 28, 29). The taxon was considered extinct until *Tetramolopium arenarium* subsp. *arenarium* var. *arenarium* was recently rediscovered in Kipuka Kalawamauna, Pohakuloa Training Area, Hawaii (Douglas *et al.* 1989).

Table 27. Historic (H) and current distribution of *Tetramolopium arenarium* subsp. *arenarium* var. *arenarium*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Hawaii (H) | Hualalai | Not Available (N/A) | N/A | N/A | Mann and Brigham | 18?? |
| Hawaii (H) | District of Waimea | N/A | N/A | N/A | U.S.E.E. | 1840 |
| Maui (H) | E. Maui, Kula | N/A | 2500 ft (760 m) | N/A | Hillebrand; in Sherff | 1935? |
| Hawaii | PTA, Kipuka Kalawamauna | <130<br><130<br>2 | 5,069-5,480 ft (1,543-1,670 m) | Federal | Douglas | 1989<br>1991<br>1994 |
| Hawaii | PTA, Kipuka Kalawamauna | 32 | 5,500 ft (1,670 m) | Federal | Shaw and Castillo | 1994<br>1995 |
| Hawaii | PTA, Kipuka Kalawamauna | 350 | 5,400 ft (1,645 m) | Federal | Close and Popolizio | 1994<br>1995 |

Table 28. Historic distribution of *Tetramolopium arenarium* subsp. *arenarium* var. *confertum*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Hawaii | Hohoanaohoe a near Waimea | Not Available (N/A) | N/A | N/A | Hillebrand and Lydgate | 1872 |

Table 29. Historic distribution of *Tetramolopium arenarium* subsp. *laxum*.

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii | Hamakua | Not Available (N/A) | N/A | N/A | Lydgate | N/A |

Current Distribution

Since 1975, three populations of *Tetramolopium arenarium* subsp. *arenarium* var. *arenarium* have been identified. As of 1995, fewer than 400 individuals are known to exist (Table 27). In 1989, approximately 39 reproductive individuals and 79 juveniles of this taxon were distributed over an area of 200 by 660 ft (60 by 200 m) within Kipuka Kalawamauna (NTBG 1990a, Laven *et al.* 1991; HHP 1991v1-v4, 1991w; Shaw in press). This population was virtually extirpated by a fire that swept through Kipuka Kalawamauna in 1994. Only two individuals survived the fire and no seedlings appear to have re-established (Brendan F. Close, Center for Ecological Management of Military Lands, Colorado State University, pers. comm., 1994, 1995). However, in 1994, crews from CEMML discovered 2 populations in the unburned portion of Kipuka Kalawamauna comprising approximately 32 and 350 individuals, respectively (R.B. Shaw, pers. comm., 1994, 1995; Carlo A. Popolizio, Center for Ecological Management of Military Lands, Colorado State University, pers. comm., 1994, 1995; B. Close, pers. comm., 1994, 1995).

Life History

*Tetramolopium arenarium* subsp. *arenarium* var. *arenarium* was observed in flower during January, April, and August 1990 (HHP 1991v4). *T. arenarium* subsp. *arenarium* var. *confertum* was observed in flower during December 1886 (HHP 1991w1). No life history information is currently available for *T. arenarium* subsp. *laxum*.

Habitat Description

The habitat of *Tetramolopium arenarium* on the Big Island is lowland and montane dry shrublands dominated by *Dodonaea viscosa*, at elevations between 2,600 and 5,500 ft (800 and 1700 m) (Lowrey 1990). Associated taxa are

*Styphelia tameiameiae, Dubautia linearis* (Gaud.) D. Keck. (na'ena'e), and *Chamaesyce olowaluana* (Sherff) Croizat & Degener (akoko) (Douglas *et al.* 1989, NTBG 1990a). Maui's populations were restricted to mesic forests (Lowrey 1990).

Reasons for Decline

Feral goats, sheep, and pigs have caused habitat destruction by browsing, trampling, and rooting. All known populations are transected by feral animal trails. Habitat decimation has resulted in opportunities for invasions by alien plant taxa, particularly *Pennisetum setaceum* (fountain grass). The occurrence of fountain grass increases the probability and intensity of fire. The small number of extant individuals and the restricted distribution of this taxon make it extremely vulnerable to random events and/or reduction of reproductive vigor. Unwarranted visits by unauthorized persons may compromise the integrity of these populations.

Conservation Efforts

Seeds were germinated by CEMML staff and viability and germination rates were high (90-100%) as was survivability of seedlings. Approximately 100 individuals were grown in a Colorado State University greenhouse in 1991. Outplanting in Kipuka Kalawamauna was attempted in 1991 by CEMML staff with some success. Unfortunately, the few surviving plants were annihilated by the 1994 fire that swept through the kipuka. Dr. Timothy Lowrey at the University of New Mexico is conducting extensive research on the genetics of the genus and is establishing relationships among the taxa. The National Tropical Botanical Garden has germinated seeds and propagated the taxon (D. Ragone, pers. comm., 1995).

Needed Recovery Actions

Propagation and maintenance of *ex situ* genetic stock should continue. Habitat of existing populations should be protected from feral ungulates and managed for alien plant control. Steps should also be taken to ensure that plants will be protected from fire due to military exercises. Outplanting of propagated plants will likely be necessary to establish two more populations.

**Rutaceae (Rue Family)**

Rutaceae is a family distributed in warm tropical to subtropical or temperate regions worldwide and consists of about 150 genera and 1,600 species. The family is divided into 7 subfamilies and 12 tribes (Stone *et al.* 1990). In Hawaii, Rutaceae is represented by 1 subfamily (Zanthoxyloideae), 1 tribe (Zanthoxyleae), 3 native genera, 1 naturalized genus, and 55 endemic species (Stone *et al.* 1990).

***Zanthoxylum* (a'e, manele, hea'e)**

*Zanthoxylum* L. is a genus of mostly pantropical distribution. The Hawaiian members of the genus belong to section *Blackburnia* (G. Forster) Engl., which includes taxa from Australia, Asia, and other Pacific islands (Stone *et al.* 1990). *Zanthoxylum* in Hawaii is represented by four species and two varieties, all of which are endemic. *Zanthoxylum hawaiiense* is listed as endangered and *Z. dipetalum* var. *tomentosa* is a "species-at-risk"

***Zanthoxylum hawaiiense* (a'e)** - Recovery Priority #2

Description

*Zanthoxylum hawaiiense* Hillebr. is a medium-size tree 10 - 26 ft (3 - 8 m) tall, with a trunk 10 in (25 cm) in diameter (Figure 13) (Stone *et al.* 1990). The bark is pale to dark gray, and the leaves are lemon-scented. Alternate leaves are composed of three small leaves (leaflets), one being terminal and two lateral. The terminal leaflet is subtended by a 2-jointed leaf stalk, 0.6 - 2 in (15 - 52 mm) long, while the lateral stalks are1-jointed, 0.4 - 1.6 in (10 - 40 mm) long. Triangular-oval to lance-shaped, toothed leaflets, 1.3 - 3.9 in (3.4 - 10 cm) long and 0.6 - 2 in (1.5 - 5 cm) wide, are thin or sometimes thick in texture. The surfaces are usually without hairs, or the lower may be finely hairy and glandular. Fifteen to 20 flowers are arranged in open flower clusters, 1.6 - 3.1 in (4 - 8 cm) long, which are subtended by main flower stalks 0.8 - 2 in (20 - 50 mm) long. Each flower is subtended by a flower stalk, 0.08 - 0.2 in (2 - 4 mm). Usually, all flowers on a tree are of one sex, either male or female. Four narrowly triangular, sparsely hairy sepals are 0.04 in (1 mm) long. Four green-white oblong to lance-shaped petals, 0.1 - 0.2 in (3-6 mm) long, sometimes are absent in male flowers. A sickle-shaped, round-tipped fruit, 0.3 - 0.4 in (8 - 10 mm) long, opens on one side to release one round, slightly compressed seed. The seed covering is pitted and sculptured, about 0.27 - 0.31 in (7 - 8 mm) long. *Zanthoxylum hawaiiense* is

Figure 13: *Zanthoxylum hawaiiense* (Tracy Wager, CEMML, CSU)

distinguished from other Hawaiian members of the genus by several characters: three leaflets all of similar size, one joint on lateral leaf stalk, and sickle-shape fruits with a rounded tip (Stone *et al.* 1990, 59 FR 10305).

## Taxonomy

*Zanthoxylum hawaiiense* was described by Hillebrand (1888), based on specimens collected on the island of Hawaii. At that time, he also referred to an unnamed variety collected on Lanai. Engler (1896, 1931) moved the Hawaiian taxa to the genus *Fagara*, resulting in *F. hawaiiensis* (Hillebr.) Engl. and *F. bluettiana* (Rock) Engl. Sherff (1958) described three varieties of *Fagara hawaiiensis*: *F. h.* var. *citriodora* (Rock) Sherff, *F. h.* var. *subacuta* Sherff, and *F. h.* var. *velutinosa* (Rock) Sherff. Several other authors have published names for this taxon including: *Zanthoxylum bluettianum* Rock (Rock, 1913), *Z. hawaiiense* var. *citriodora* Rock (Rock, 1913), *Z. hawaiiense* var. *velutinosum* Rock (Rock, 1913), and *Z. hawaiiense* var. subacutum (Sherff) St. John (St. John 1976b). The most current treatment by Stone *et al.* (1990) considers *Fagara* and all varieties of *Zanthoxylum* well within the range of variation of *Z. hawaiiense*.

## Historic Distribution

*Zanthoxylum hawaiiense* is known from five main islands: Kauai, Molokai, Lanai, Maui, and Hawaii. Populations were located in central Kauai; eastern Molokai; central Lanai; southern and southwestern slopes of Haleakala, Maui; and the Kohala mountains, northern slopes of Hualalai, and northwestern slope of Mauna Loa, Hawaii (Table 30) (Stone *et al.* 1990; HHP- no reference number).

Table 30. Historic (H) and current distribution of *Zanthoxylum hawaiiense*.

| **Island** | **Location** | **Number of Plants** | **Elevation** | **Ownership** | **Source** | **Date** |
|---|---|---|---|---|---|---|
| Kauai (H) | Below Kaholuamano | 1 | Not Available (N/A) | N/A | Rock | 1909 |
| Maui (H) | E. Maui, S. slope of Haleakala | 1 | N/A | N/A | Forbes | 1920 |
| Molokai (H) | Ravine NW of Puu Makaliilii | N/A | 2,850 ft (869 m) | N/A | Degener | 1928 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Hawaii (H) | Slope of Mauna Kea, near Keamoku/ Nohonaohae | N/A | 4,000 ft (1,200 m) | N/A | Rock | 19?? |
| Hawaii (H) | Kohala, edge of Honokane Nui, edge of Honokanenui Gulch | N/A | 4,100 ft (1,250 m) | N/A | Rock | 1910 |
| Hawaii (H) | Kipuka Puaulu | N/A | N/A | N/A | Judd | 1921 |
| Lanai (H) | Kamoku, SW ridge Kaiholena Gulch | N/A | 2,750 ft (840 m) | Private | St. John and Cowan | 1947 |
| Molokai (H) | Waikolu Valley, below Puu Kaeo | 1 | 2,500 ft (7,600 m) | State | St. John *et al.* | 1948 |
| Hawaii (H) | N. Kona, Puu Waawaa | 1 | 3,280 ft (1,000 m) | State | Rock | 1957 |
| Maui (H) | E. Maui | N/A | N/A | State | Degener | 1960 |
| Maui | E. Maui, Kanaio | N/A | 2,400-4,900 ft (730-1,500 m) | State | Medeiros *et al.* | 198? |
| Maui | E. Maui, Lualailua & Laumau Forest | N/A | 2,400-4,900 ft (730 1500 m) | State | Medeiros *et al.* | 198? |
| Maui | E. Maui, Auwahi | N/A | 2,584-4,900 ft (730-1,490 m) | Private | Medeiros *et al.* | 198? |
| Hawaii | PTA | 1 | 4,920-5,250 ft (1,500-1,600 m) | Federal | Fosberg | 1980 |
| Molokai | Makolelau & Kamalo gulches below Puu Kolekole | 2 | 2,650-2,900 ft (810-880 m) | Private | Lau | 1987 |
| Hawaii | PTA, Puu Anahulu Ahupuaa | >20 | 4,850-5,280 ft (1,480-1,610 m) | Federal | Marr and Uchida | 1988 |
| Molokai | Pelekunu Valley, Puu Hoi Ridge | 2 | 1,800-2,020 ft (550-616 m) | Private | HHP | 1989 |

| Island | Location | Number of Plants | Elevation | Ownership | Source | Date |
|---|---|---|---|---|---|---|
| Kauai | Waimea Canyon, Koaie Branch, Kawaiiki Valley | 1 | 2,401 ft (732 m) | State | Perlman and Wood | 1990 |
| Hawaii | PTA | >20 | 5,260 ft (1,603 m) | Federal | N/A | 1990 |
| Hawaii | N. Kona, Puu Waawaa | 13 | N/A | State | CEMML/Giffin | 1995 |
| Hawaii | PTA | 75-100 | N/A | Federal | CEMML/Giffin | 1995 |

## Current Distribution

Since 1975, *Zanthoxylum hawaiiense* has been identified as extant on at least 4 of the 5 islands on which it originally occurred, with at least 11 known populations and over 250 individuals (Table 30) (R.B Shaw, pers. comm., 1995). On Kauai, one extant individual is found in Waimea Valley. On Molokai, at least two populations occur, one in Pelekunu Valley and one near Puu Kolekole. On eastern Maui, three extant populations are located at Auwahi, Lualailua, and Kanaio (HHP-no reference number). On the Big Island, five populations are located at Puu Waawaa and the Pohakuloa Training Area. In addition, Shaw (pers. comm., 1995) and Giffin have found numerous individuals located between Puu Waawaa and Pohakuloa Training Area, and on the western periphery of Pohakuloa Training Area. Shaw (pers. comm., 1995) has indicated that the new populations bring the total number of individuals to over 250.

## Life History

No life history information is currently available for this species.

## Habitat Description

*Zanthoxylum hawaiiense* occurs in lowland dry and mesic forests, and montane dry forest, at elevations between 1,800 and 5,710 ft (550 and 1,740 m) (Gagne and Cuddihy 1990, Stone *et al.* 1990). The taxon grows in forests dominated by *Metrosideros polymorpha, Diospyros sandwicensis*, or *Pleomele auwahiensis* St. John (halapele). Other associated species include *Antidesma platyphyllum* H. Mann (hame) (Kauai), *Streblus pendulinus* (Endl.) F.V. Muell. (a'ia'i) (Maui), *Myrsine lanaiensis* Hillebr. (kolea), *Sophora chrysophylla* (mamane), and *Myoporum sandwicense* A Gray (naio) (Hawaii) (HPCC 1990b; HHP 1991x5; 1991x9; 1991x11; Shaw, in press).

Reasons for Decline

Feral and domestic animals are major threats to this species. Browsing, grazing, and trampling by feral goats (Molokai, Maui, Hawaii), sheep (Hawaii), pigs (Hawaii), and cattle (Maui) have resulted in habitat destruction and have opened new sites to alien plant invasion (Medeiros *et al.* 1988, HPCC 1990b, HHP 1991x10). Introduced weedy species such as *Melia azedarach* (chinaberry), *Lantana camara* (lantana), *Pennisetum clandestinum* (kikuyu grass), and *P. setaceum* (fountain grass) compete with seedlings for light, space, and nutrients, often precluding the establishment of successive generations. Fire is another potential danger to *Z. hawaiiense*, although its response to fire is unknown.

Conservation Efforts

The National Tropical Botanical Garden has propagated the taxon (D. Ragone, pers. comm., 1995). The new individuals observed by Shaw and Giffin near Puu Waawaa and at Pohakuloa Training Area appear healthy and are flowering and fruiting. The individuals found by Judd in 1921 in Hawaii Volcanoes National Park were not present in 1967 and were not seen during surveys in 1992-94 (L. Pratt, pers. comm., 1995). Seeds were germinated by CEMML staff in 1991-93. Individuals grow well in the greenhouse.

Needed Recovery Actions

Propagation and maintenance of *ex situ* genetic stock should continue. Habitat of existing populations should be protected from feral ungulates, and managed for alien plant control. Steps should be taken to ensure that populations remain viable on each of the four islands on which the species presently occurs.

## RECOVERY STRATEGY

Actions outlined in the remainder of this recovery plan are designed to accomplish the recovery objectives described in the following section. The highest priority for recovery of a species is to safeguard its existing gene pool by insuring the survival of existing plants or populations through protection and management (Figure 14). Threats to the taxa may be addressed through fencing

Continue Monitoring

↑

DELIST

↑

Monitor Population Success and Stability

↑

DOWNLIST

↑

Evaluate and Validate Recovery Objectives

↑

Augment Existing Populations
and Create New Populations, as necessary

↑

Conduct Research on Life History

↑

Survey for Additional Populations

↑

Protect and Manage Existing Populations

Figure 14. Schematic of recovery plan for the Big Island Plant Cluster. Time, resources (money, energy, person-power, etc.), and probability of success increase as each step is accomplished.

and/or hunting to control ungulates; control of alien plants; control of rodents and insects; control of diseases; protection from fire; protection from human disturbance; collection, storage, and maintenance of genetic material; and, /monitoring. After known individuals or populations are protected, further surveys or inventories may be necessary to determine if additional plants exist in the wild.

Some taxa may clearly rebound with protection from obvious threats, e.g., excluding feral ungulates via fencing. Monitoring should continue to ensure that higher numbers are maintained. On the other hand, research into the life histories of many Big Island cluster taxa will be necessary in order to achieve recovery. Detailed information concerning the reproductive biology, population ecology, and habitat requirements of these taxa may establish causes of decline as well as requirements for their short and long-term survival. Having established these, a plan can be conceived and instituted to eliminate, reduce, or rectify these causes.

Augmentation of small populations that are not expanding after protection from threats and re-establishment of new populations within the historical range of the taxa may also be needed to achieve recovery goals. Selection and protection of appropriate sites, selection of proper genetic material, and maintenance and monitoring of outplantings are necessary.

Recovery objectives should be evaluated, and either validated or revised. One means of this is a Population Viability Analysis (PVA). If conducting a PVA, acceptable levels of probability and length of survival time must be set based on political, economic, and societal values. For example, the size and number of viable populations necessary to sustain a species is much greater if one desires a 99% probability of survival for 1,000 years versus a 90% probability that a taxon will survive for 500 years.

All taxa should continue to be monitored after downlisting, and for a minimum of 5 years after delisting.

# II. RECOVERY

## RECOVERY OBJECTIVES

Objectives for stabilizing, downlisting, and delisting are provided for the 21 endangered and 1 threatened plant taxa in the Big Island Plant Cluster. The order of tasks listed in the step-down outline and narrative does not necessarily designate the order in which these tasks should be implemented. Priorities for action and recommended time-frames are contained in the Implementation Schedule of this plan.

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

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

The long-lived perennials in this plan are: *Colubrina oppositifolia, Nothrocestrum breviflorum, Ochrosia kilaueaensis, Pritchardia affinis,* and *Zanthoxylum hawaiiense*. The short-lived perennials in this plan are: *Clermontia lindseyana, Clermontia peleana (*spp. *peleana,* spp. *singuliflora), Clermontia pyrularia, Cyanea copelandii* spp. *copelandii, Cyanea hamatiflora* spp. *carlsonii, Cyanea shipmanii, Cyanea stictophylla, Cyrtandra giffardii, Cyrtandra tintinnabula, Delissea undulata, Ischaemum byrone, Isodendrion pyrifolium, Mariscus fauriei, Plantago hawaiensis Portulaca sclerocarpa, Silene hawaiiensis,* and *Tetramolopium arenarium* (spp. *arenarium,* spp. *laxa*). All of the above taxa are listed as endangered except for *Silene hawaiiensis*, which is listed as threatened, and *Delissea undulata*, for which endangered status has been proposed.

Because we have only limited knowledge of the life history of each of these taxa with respect to specific requirements for their short-term and long-term survival, only tentative criteria for stabilizing, downlisting, and delisting are established here. These criteria were formulated based on recommendations by the Hawaii and Pacific Plants Recovery Coordinating Committee, as well as the International Union for the Conservation of Nature and Natural Resources' (IUCN's) draft red list categories (Version 2.2), and the advice and recommendations of various biologists and knowledgeable individuals. Additional information is needed about each of the Big Island taxa so that more meaningful recovery objectives can be quantified.

Interim Criteria

Interim criteria pertain to taxa that are in need of immediate stabilization before the downlisting objectives can be realistically considered. To be considered stable:

(1) Each taxon must be managed to control threats (e.g. fenced) and be represented in an *ex situ* collection.

(2) A minimum total of three populations of each taxon should be documented on the Big Island and, if possible, at least one other island where it now occurs or where it occurred historically.

(3) Each of these populations must be naturally reproducing and increasing in number, with a minimum of 25 mature individuals per population (minimum of 75 mature plants) for long-lived perennials and a minimum of 50 mature individuals per population (minimum of 150 mature plants) for short-lived perennials.

Downlisting Objectives

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

(2) Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials and 300 mature individuals per population for short-lived perennials.

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

Delisting Objectives

(1) A total of 8 to10 populations of each taxon should be documented on the Big Island and at least 1 other island where it now occurs or occurred historically. As with downlisting, there may be cases in which a particular taxon is eligible for delisting even if all 8 to10 of the populations are on only 1 island, provided that all other recovery criteria have been met and the populations in question are widely distributed and secure enough that one might reasonably conclude that the taxon is not likely to become an endangered species within the foreseeable future throughout all or a significant part of its range.

(2) Each of these populations must be naturally reproducing, stable or increasing in number, and secure from threats, with a minimum of 100 mature individuals per population for long-lived perennials and 300 mature individuals per population for short-lived perennials.

(3) Each population should persist at this level for a minimum of 5 consecutive years.

Current status, recovery objectives and needed recovery actions relative to these recovery criteria are summarized for all of the Big Island Cluster taxa in Table 31.

Table 31. Current status, recovery objectives, and needed actions for the Big Island Plant Cluster Taxa.

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Clermontia lindseyana*<br>Current status<br>12 populations<br>400-430 plants | N/A (Not Applicable) | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in existing populations | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in existing populations |
| *Clermontia peleana*<br>Current status<br>4 populations<br>8 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 1-3 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-6 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Clermontia pyrularia*<br>Current status<br>1-2 populations<br>3 wild plants<br>30 outplanted | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Establish 1 population<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 3-5 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 6-8 populations<br>Increase total plants |
| *Colubrina oppositifolia*<br>Current status<br>10 populations<br>300 wild plants<br>64 outplanted | N/A | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in existing populations |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Cyanea copelandii* subsp. *copelandii*<br>Current status<br>1 population ?<br>Unknown number (if any) | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Establish 2 or 3 populations<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-7 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 7-10 populations<br>Increase total plants |
| *Cyanea hamatiflora* subsp. *carlsonii*<br>Current status<br>3 populations<br>14 wild plants<br>51 outplanted | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 2-4 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 5-7 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Cyanea shipmanii*<br>Current status<br>4 populations<br>< 10 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 1-3 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-6 populations<br>Increase total plants |
| *Cyanea stictophylla*<br>Current status<br>3 populations<br>20 wild plants<br>46 outplanted | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 2-4 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 5-7 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
| --- | --- | --- | --- |
| *Cyrtandra giffardii*<br>Current status<br>11 populations<br>> 1,000 plants | N/A | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 0-1 population<br>Increase total plants |
| *Cyrtandra tintinnabula*<br>Current status<br>3 populations<br>18 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 2-4 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 5-7 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
| --- | --- | --- | --- |
| *Delissea undulata*<br>Current status<br>1 population<br>1 wild plant<br>50 outplanted | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Establish 2 populations<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-6 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 7-9 populations<br>Increase total plants |
| *Ischaemum byrone*<br>Current status<br>17 populations<br>> 2,000 plants | N/A | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in1 additional population | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in 4-6 populations |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Isodendrion pyrifolium*<br>Current status<br>1 population<br>50-60 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Establish 2 populations<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-6 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 7-9 populations<br>Increase total plants |
| *Mariscus fauriei*<br>Current status<br>4 populations<br>45-60 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 1-3 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-6 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
| --- | --- | --- | --- |
| *Nothocestrum breviflorum*<br>Current status<br>6 populations<br>Unknown | Objective<br>3 populations<br>25 mature plants each<br>75 total mature plants<br>Needed Increases<br>Increase total plants? | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 0-1 population<br>Increase total plants? | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 2-4 populations<br>Increase total plants |
| *Ochrosia kilaueaensis*<br>Current status<br>Extinct in wild?<br>1 population<br>Unknown number of plants | Objective<br>3 populations<br>25 mature plants each<br>75 total mature plants<br>Needed Increases<br>Establish 2-3 populations<br>Increase total number of plants? | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 4-7 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 7-10 populations<br>Increase total plants |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Plantago hawaiensis*<br>Current status<br>8 populations<br>> 5,000 plants | N/A | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 0-2 populations<br>Increase total plants |
| *Portulaca sclerocarpa*<br>Current status<br>12 populations<br>> 1,000 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in 4-6 populations | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants in 7-9 populations |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Pritchardia affinis*<br>Current status<br>8 populations<br>50-65 plants | Objective<br>3 populations<br>25 mature plants each<br>75 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 0-2 populations<br>Increase total plants |
| *Silene hawaiiensis*<br>Current status<br>11 populations<br>> 11,000 plants | N/A | N/A | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Sustain for 5 years |

| Species | Interim | Downlisting | Delisting |
|---|---|---|---|
| *Tetramolopium arenarium*<br>Current status<br>3 populations<br>< 400 plants | Objective<br>3 populations<br>50 mature plants each<br>150 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 2-4 populations<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Establish 5-7 populations<br>Increase total plants |
| *Zanthoxylum hawaiiense*<br>Current status<br>11 populations<br>>250 plants | Objective<br>3 populations<br>25 mature plants each<br>75 total mature plants<br>Needed Increases<br>Increase total number of plants | Objective<br>5-7 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants | Objective<br>8-10 populations<br>At least 300 mature plants each<br>Sustained for 5 years<br>Needed Increases<br>Increase total plants |

STEPDOWN OUTLINE

1. Protect current populations and manage threats.

  11. Ensure long-term protection of habitat for current populations.

    111. Locate, verify, and delineate all extant wild populations.

    112. Delineate management units for preservation.

    113. Provide long-term protection for each management unit and/or taxon.

      1131. Continue and enhance protection on Federal lands.

      1132. Continue and enhance protection on other public lands.

      1133. Continue and enhance protection on private lands.

  12. Manage threats to existing populations.

    121. Develop management plans for each management unit.

    122. Manage threats.

      1221. Control ungulates.

        12211. Construct and maintain fencing.

        12212. Evaluate alternative means for control of ungulates.

        12213. Consider eradication programs for control of ungulates.

      1222. Control other introduced animals, as necessary.

        12221. Control rodents.

12222. Control gastropods, insects, etc. found to be harmful to listed species.

1223. Control noxious alien plants.

12231. Establish impacts of alien plants and determine species necessary to control.

12232. Determine effective control method(s) and implement alien plant control program.

1224. Control diseases, as necessary.

1225. Provide necessary wildfire protection.

12251. Determine impacts of wildfire on taxa.

12252. Develop and implement fire protection and response plan(s).

1226. Define, document, and mitigate other potential and controllable threats.

12261. Determine impacts of and manage hunting and other recreational activities.

12262. Determine military impacts and manage for species' benefit.

123. Monitor status of wild populations.

124. Revise management plans, as necessary.

13. Maintain genetic stock of each taxon *ex situ*.

2. Conduct essential research.

21. Establish ecosystem history and collect diagnostic data on associated ecosystem components.

22. Define habitat requirements for each taxon.

23. Determine population characteristics for each taxon.

24. Determine the reproductive potential of each taxon.

25. Conduct research necessary for maintenance of genetic stock.

    251. Determine characteristics of pollen and seed formation.

    252. Study pollination ecology.

    253. Study factors affecting germination and seedling establishment.

3. Expand existing wild populations, as necessary.

    31. Identify populations for augmentation.

    32. Propagate material for augmentation.

    33. Prepare sites and augment wild populations.

    34. Maintain, monitor and evaluate outplantings.

4. Create new populations within historical range, as necessary.

    41. Select new population sites and obtain long-term protection for sites.

    42. Control threats to plants at new sites.

    43. Transplant selected material.

    44. Maintain, monitor and evaluate new populations.

5. Evaluate and validate recovery objectives.

    51. Validate the number of individuals and populations necessary for recovery of each taxon.

    52. Refine/revise downlisting and delisting criteria, as necessary.

    53. Evaluate species for downlisting and delisting.

STEPDOWN NARRATIVE

1. Protect current populations and manage threats.

Protection and proper maintenance of extant (wild) populations of the Hawaii Plant Cluster taxa are essential and should be the focus of initial recovery actions for these taxa. Too often propagation, transplanting, and attempts at creating new populations in marginal habitats are offered as an alternative to saving, supporting, and maintaining wild populations and proper habitat (Allen 1994). This temptation should be avoided at all costs. Not only is it essential to protect surviving individuals and the gene pool of each taxon of the Hawaiian Plant Cluster, but suitable and adequate habitat must be protected and maintained as well. In addition, surveys should begin immediately for taxa that have not been observed for several years. If a species cannot be found, they may be considered for delisting due to extinction.

11. Ensure long-term protection of habitat for current populations.

Adequate (large scale) areas should be conserved to encourage and enable expansion of populations within a given location. Often areas selected for protection are not sufficient to contain all the elements of the ecosystem needed to maintain the species of concern.

111. Locate, verify, and delineate all extant wild populations.

All known, potential, and/or suspected locations where each taxon might occur should be intensively surveyed. It is important to document, as is economically feasible, the number of individuals of each taxon and the extent of the populations. Presence or absence of the species from known areas should be documented. Detailed biological (associated species, population structure, phenology, etc.) and ecological (edaphic characteristics, climatic regime, community type, etc.) data should be collected at each location where new individuals are found. Also, detailed site information (directions, map, geographic location (using global position systems for accuracy if possible), etc.) should be taken at each location.

112. Delineate and prioritize management units for preservation.

The responsible agencies and landowners should evaluate management units for their potential to adequately protect the species of concern. Size, accessibility, amount of disturbance, potential for protection, ability to protect, land ownership, cooperative efforts with State and other Federal agencies, cost, etc. should all be considered in the site selection process. Ideally, all sites where these taxa occur should be protected. Realistically, economics will most likely limit the number of sites that can be protected. Sites should be prioritized, taking the following factors into consideration: degree of endangerment, number of endangered species in the area, and probability for successful protection and management. Additionally, sites that contain some of the last remaining examples or remnants of plant communities in near pristine condition should be considered high priority for preservation.

Following is a list of those areas depicted in figure 15, which delineates areas on the island of Hawaii where large numbers of listed species occur and/or where large areas of relatively undisturbed habitat still exists, and that are owned by State or Federal agencies with mandates to manage for biological resources (L. Pratt, pers. comm., 1995). This list is based on limited and preliminary data. It should be modified as new information is accumulated concerning threats, distribution, and ecological requirements of the taxa, and in accordance with management units designated by responsible agencies and landowners.

**1. Kohala Mountain Bogs.**

Although no taxa from this recovery plan occur in this area, it should be included in any attempt to break the Big Island into management units. The Kohala Mountains are unique because a high percentage of native, fairly undisturbed vegetation still exists there, and because boggy areas still occur at higher elevations. These bogs are important as habitat and potential reintroduction sites for many species of birds, for comparative purposes to the bogs and swamps on other islands (e.g., Alakai Swamp on Kauai), and as the youngest example of bog development within the islands.

**2. Laupahoehoe Natural Area Reserve/Hakalau National Wildlife Refuge.**

These two areas represent a unique ecological area on the northern flank of Mauna Kea and are worthy designation as a management unit. The following taxa from the Hawaii Plant Cluster are found in these areas: *Clermontia lindseyana, Clermontia pyrularia, Cyanea shipmanii,* and *Cyrtandra tintinnabula.* Care should be taken to ensure that *Clermontia pyrularia* (likely the only extant population of this species), which occurs just outside the Refuge boundaries, is included within this management unit.

**3. Puu Makaala Natural Area Reserve.**

The following taxa from the Hawaii Plant Cluster occur in the area: *Cyanea copelandii, Cyrtandra giffardii, Clermontia lindseyana,* and *Cyanea shipmanii.*

**4. Hawaii Volcanoes National Park (HVNP).**

The size, protection, and climatic diversity found at the Park provides an opportunity for a significant number of rare species to occur in the area. The following species from the Hawaii Plant Cluster are reported from HVNP or in close proximity to the boundary: *Portulaca sclerocarpa, Silene hawaiiensis, Clermontia lindseyana, Clermontia peleana,*

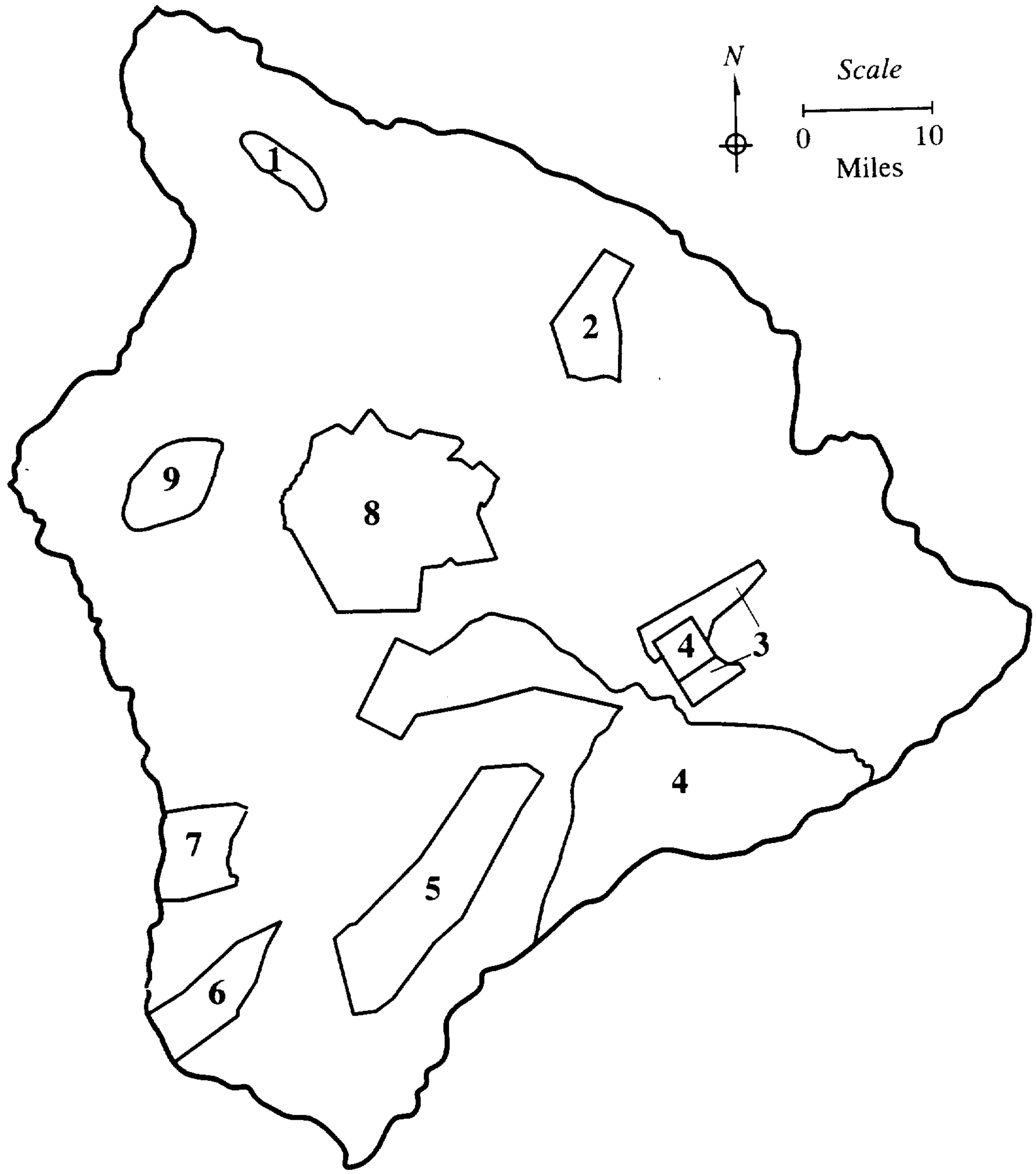


Figure 15: Location of potential areas on the island of Hawaii for consideration as management units for the Hawaii Plant Cluster recovery plan: 1) Kohala Mountain bogs (ecologically important area but no taxa reported); 2) Laupahoehoe Natural Reserve Area/Hakalau National Wildlife Refuge; 3) Puu Makaala Natural Area Reserve; 4) Hawaii Volcanoes National Park; 5) Kau Forest Reserve; 6) Manuka Natural Area Reserve; 7) Kipahoehoe Natural Area/South Kona Forest Reserve; 8) Pohakuloa Training Area; and 9) Puu Waa Waa.

*Cyanea copelandii, Cyrtandra giffardii, Ischaemum byrone,* and *Nothocestrum breviflorum.*

**5. Kau Forest Reserve.**

The following taxa from the Hawaii Plant Cluster supposedly occur on the Kau Forest Reserve: *Mariscus fauriei, Plantago hawaiensis, Cyanea stictophylla,* and *Clermontia peleana.*

**6. Manuka Natural Area Reserve.**

The following taxa from the Hawaii Plant Cluster occur along the southwestern coast of Hawaii and potentially occur in this area: *Clermontia lindseyana, Cyanea stictophylla, Mariscus fauriei, Nothocestrum breviflorum,* and *Pritchardia affinis.*

**7. Kipahoehoe Natural Area Reserve/South Kona Forest Reserve.**

The following taxa from the Hawaii Plant Cluster occur along the southwestern coast of Hawaii and potentially occur in this area: *Clermontia lindseyana, Cyanea stictophylla, Mariscus fauriei, Nothocestrum breviflorum,* and *Pritchardia affinis.*

**8. Pohakuloa Training Area (PTA).**

Four taxa within the Hawaii Plant Cluster occur at PTA: *Portulaca sclerocarpa, Silene hawaiiensis, Tetramolopium arenarium* and *Zanthoxylum hawaiiense.* Approximately 12 additional endangered, threatened, or category candidate species occur at PTA.

**9. Puu WaaWaa Wildlife Sanctuary/Hualalai.**

The Puu WaaWaa area and slopes of Hualalai are rich botanical areas and represent one of the most significant management areas. The following taxa occur in the area and are on the Hawaii Plant Cluster list: *Nothocestrum breviflorum, Ochrosia kilaueaensis, Plantago hawaiensis, Zanthoxylum hawaiiense, Colubrina oppositifolia, Mariscus fauriei, Cyanea hamatiflora, Cyanea stictophylla,* and *Delissea undulata.*

113. Provide long-term protection for management units and/or taxa.

Maximum protection of the taxa included in this recovery plan will be assured by obtaining cooperation from Federal and State agencies, and private landowners to carry out planned conservation efforts that will enhance the habitat of the Hawaii Plant Cluster plants and other important or unique taxa. Long-term cooperative management plans should be arranged for adequate habitat for each management unit or taxon (if they do not fall into a management unit).

1131. Continue and enhance protection on Federal lands.

Protection and management of listed taxa occurring on Federal lands are mandated in the Endangered Species Act. Cooperation between the Service and other Federal agencies, including the National Park Service and the Department of Defense, with regard to conservation planning and listed species management, should be continued and enhanced.

1132. Continue and enhance protection on public lands.

Hawaii State law (Chapter 195D of the Hawaii Revised Statutes) provides protection against taking of endangered plants throughout Hawaii. Protection and management of taxa occurring on all public lands should be continued and enhanced. Cooperation among Federal, State and county agencies in conservation planning and listed species management should be sought. Sufficient habitat and species' populations should be protected and managed on all lands controlled and administered by DLNR, specifically Natural Area Reserves. Sufficient habitat and species' populations should also be protected and managed on all other public lands where they occur including, but not limited to, Hawaiian Home Lands and county lands.

1133. Continue and enhance protection on private lands.

Cooperation with private landowners to protect and manage listed taxa should be sought, and Hawaii State law should be strictly enforced in order to protect these taxa.

12. Manage threats to existing populations.

Management of species' habitat to control and/or eliminate immediate threats to extant wild populations is of paramount importance to the survivability of taxa in the Hawaii Plant Cluster plan.

121. Develop management plans for each management unit.

Management plans should be developed for each protected area in cooperation with landowners on whose lands the plants occur and whose lands lie adjacent to the management units. Designation of management teams or working groups consisting of landowners and knowledgeable individuals with substantial hands-on experience and expertise with the species and areas in question may serve to facilitate this process.

Management plans should be tailored to fit the unique needs of the management unit, and may include some or all of the tasks below as well as others that become necessary as more is learned about the areas and species. Among the immediate actions that must be included in the majority of plans are: protection from grazing and trampling by feral ungulates; reduction of competition from alien plants; and protection from fire. Other actions that may be specific to certain taxa or management units are: protection from other introduced species, such as insects or rodents; and protection from disease. Management plans should be revised periodically (see Task # 124).

122. Manage threats.

After management plans are developed, implementation of these plans should proceed. Management to control threats should not be limited to management units, however, as most species also occur outside of these units. Threat management outside the designated management units is important for taxa that occur on other islands, and is vital for *Isodendrion pyrifolium*, which is known from only one population that does not occur in any of the proposed units. Indeed, a special effort should be made to ensure that *I. pyrifolium* is protected and managed, and that populations of the Big Island cluster taxa that occur on other islands remain extant, in order to maintain genetic distinctiveness.

1221. Control ungulates.

The impact of ungulates (cattle, sheep, goats, pigs) on native Hawaiian plant communities is well documented (Stone 1985), as is their role in extinction of certain plant species. Protection of native plant communities, including listed taxa, from ungulates is of utmost importance.

Total eradication of feral animals would be an impossible task due to the enormous numbers of individuals in the wild and strong public support for recreational hunting of these animals. Eradication from specific areas for the protection of individual taxa, management units, or undisturbed native Hawaiian vegetation is more feasible.

12211. Construct and maintain fencing.

Fencing is usually the most effective, although costly, method of protecting native plants from feral animals within Hawaii. Obviously, the fencing strategy for each species and/or management unit will vary depending upon the specific fencing objectives, land ownership patterns, and terrain of the area. However, several general strategies common to all areas can be made.

First priority should be given to protection of the listed plant species. This may require fencing of relatively small areas to protect the known individuals. An attempt should be made to include as much undisturbed potential habitat as possible to allow for expansion of the population(s) or for possible augmentation of the species at a later time. A perimeter of a minimum of 164 feet (50 meters) from the nearest individual should be used as a general guideline.

Ideally, management units including numerous listed species and large tracts of undisturbed native vegetation should be identified and fenced to exclude feral animals. These areas also could act as potential reintroduction or species' population augmentation sites for future outplantings.

Fences should follow roads, trails, powerlines, or other anthropogenic features as much as possible. This will eliminate or decrease the amount of vegetation clearing necessary to construct the fence. Thus, costs will be lowered, disturbance of native vegetation will be reduced, and maintenance will be less labor-intensive.

Fences should be constructed in such a manner as to exclude as many feral animal species as possible. For example, fences should be a minimum of 8 feet (2.5 meters) high to prevent sheep and goats from jumping into exclosures. Also, strands of barbed-wire should be buried or placed at ground level to prevent hogs from rooting under the fence. Concrete corner posts and metal posts should be used to prevent rotting in wetter areas and to lower maintenance costs.

Eradication of feral ungulates within the exclosures will be necessary following completion of the fenced exclosures. Animals can be removed by various techniques. Some of the more successful methods are baiting and trapping, snaring, poisoning, and public or controlled hunting. A combination of removal techniques will probably be necessary to ensure complete eradication of the ungulates from the exclosures. Care should be taken to guarantee that the method of eradication and/or the act of removing the animals does not inadvertently harm the plants that are being protected.

Periodic inspection and maintenance of fences are necessary to provide for continued exclusion of feral animals from the fenced areas.

Possible negative impacts of fencing on the listed plant species and management areas must be evaluated. For example, fencing and eliminating feral animals could increase pest plant biomass that was previously being consumed by grazing and browsing. An increase in plant biomass might serve to increase competition to native species, and/or present an increased wildland fire hazard.

Finally, as with the fences themselves, a monitoring program is necessary to evaluate the protected areas for ungulate damage. Periodic checking for signs of animal damage will ensure that the feral ungulates do not reenter the exclosures. Obviously, if feral animal damage is discovered, the animals must be eliminated and their method of entry into the exclosure found and corrected.

12212. Evaluate alternative means for control of ungulates.

Where fencing is not feasible, other means for control of feral ungulates may be considered. Alternative means include staff-controlled or liberal public hunting on public lands. It should be made clear, however, that listed taxa should be in no way compromised by such activities.

12213. Consider eradication program for control of feral ungulates.

The possible development, support, and funding of a large scale (island-wide) introduced animal control program should be evaluated. Complete eradication from large areas and islands may be the only method for removing this threat and protecting the listed species while slowing or halting degradation of native plant communities. The feasibility, however, of greatly reducing or eradicating complete animals populations is questionable due to fiscal constraints as well as public support of hunting.

1222. Control other animals, as necessary.

While feral ungulates are by far the most detrimental animals to the plants within the Hawaii Plant Cluster, they certainly are not the only ones that could have a negative impact on the plants. Rodents, insects, gastropods, and other organisms may present direct or indirect threats to the species.

12221. Control rodents.

Rodents, particularly rats, have been observed to negatively impact *Zanthoxylum hawaiiense*. Deposits of fruit husks of *Z. hawaiiense* have been found and thought to be the result of rats collecting and consuming the seeds (J. Giffin, pers. comm., 1995). Rats should be controlled in populations of *Z. hawaiiense* and any other listed plant species they impact. Control should be concentrated during seed production and fruit fall to facilitate reproduction of the listed taxa.

12222. Control gastropods, insects, etc. found to be harmful to listed species.

Investigations into the potential impact of other animals on the vigor and survival of listed plant species should be undertaken. If gastropods, insects, etc., are shown to be a threat to any of the species within the Hawaii Plant Cluster, necessary control measures should be used to eliminate the threat.

1223. Control noxious alien plants.

Competition with alien plants for light, water, nutrients, space, and other essential elements for growth and survival is one of the major reasons for the decline of many native taxa and a continued threat to their existence. Control of alien plant species that pose a threat to Hawaii Cluster taxa is of major importance and should be given a high priority. Construction of exclosures and removal of feral animals might actually increase the negative impacts of alien plant species. Indeed, release of alien species from grazing and browsing pressures could be more harmful to the listed plants than the animal impacts. It should be noted that all plant control methods have the potential to disturb native plant communities. Protective measures should be taken to eliminate the negative effects of plant control (direct destruction of habitat, other nonnative species introduction, road and trail development, etc.).

12231. Establish impacts of alien plants and determine species necessary to control.

Not all alien species pose a direct or indirect threat to listed plant species. Each management unit and/or species must be evaluated for the influence of alien species. For example, banana poka and fireweed are a major threat in the wetter areas (HVNP, Puu Makaala Forest Reserve, etc.), while fountain grass is a threat in drier areas (PTA, Puu WaaWaa). Alien species to be controlled must be prioritized on the basis of which ones present the most immediate and dangerous threats as well as which ones can be effectively controlled.

12232. Determine effective control method(s) and implement alien plant control program.

Many methods for control of plants are available. Mechanical methods (such as pulling by hand, grubbing by machine, etc.) are highly effective and species-specific; however, they are labor intensive and frequently cost-prohibitive. Chemical control with herbicides is often cost-effective, but many of the compounds are not specific enough for use in the vicinity of rare taxa. General herbicides can be made more effective and specific when applied by hand; however, the cost will grow because of increased labor. Biological control can be extremely effective, but runs great risks, especially in fragile island ecosystems, that biological agents will become pests themselves. Each species and management unit will probably require the application of any number of control methods. Regardless of the method(s) selected, each should be rigorously tested and evaluated prior to use.

After the species to be controlled and appropriate methods of control have been identified, an intensive control program should be implemented. Obviously, areas and species most threatened by alien plants should be treated first. Fenced exclosures and other areas selected for protection of the listed species should be given priority.

Plant control programs are long-term and require intensive monitoring to properly evaluate control efforts. Monitoring will not only accurately identify the most effective and useful techniques to employ in controlling undesirable species, but will also indicate when additional treatments are necessary to prevent reinfestation.

Monitoring of plant control programs also may be useful in evaluating the unintentional impacts of any recovery techniques on native plant communities. Any damage to the communities, such as the possible introduction or spread of other "weedy" species, can be documented during the monitoring programs and rectified.

1224. Control diseases, as necessary.

If disease is found to present a threat to any taxon, then necessary control methods should be used to eliminate the threat.

1225. Provide necessary wildfire protection.

Wildfire presents a grave threat to the survival of many listed Hawaiian plant species. Fire protection can take various forms. Reduction in fuel loads, as often found with alien grass invasion (i.e., fountain grass), is an obvious form of fire prevention and protection. Fuel reduction also is one of the prevention methods over which humans have some control. Another form would be reduction in ignition sources. While little can be done concerning lightning strikes or lava flows, other methods of eliminating or decreasing ignition sources can be undertaken, e.g., restricting smoking, camping or cooking fires, and cars with catalytic converters from grassy areas. Fuel and fire breaks can be constructed and maintained around listed species populations and/or management units to prevent the spread of wildfires.

12251. Determine impacts of wildfire on taxa.

Not all impacts of wildfires on plants are negative. Fire may have little impact on plants and occasionally positive benefits can be achieved from burning. The influence of fire on the life cycles of each of listed species should be evaluated and documented.

12252. Develop and implement fire protection and response plan(s).

Fire protection and response plans should be developed for each listed species habitat or for each of the larger management units. The drier parts of the island are more prone to wildfires and should be addressed first. The wetter areas, however, should not be ignored. During periods of drought these areas will become susceptible to wildfires. Plans should be developed for each management unit with the input of the local fire department, the landowner(s), responsible agencies, and, if necessary, recognized experts in wildland fire prevention and wildland firefighting as appropriate. These plans should clearly specify the location of the rare plant taxa and should be distributed to all of the above parties.

Fire protection and response plans should be implemented. As with other land management operations, the effectiveness of the fire protection plan must be monitored and evaluated on a long-term basis. Consideration must be given to the results of other recovery management programs. For example, reduction in feral animals numbers may result in increased forage production because of lack of grazing. The greater herbaceous plant growth may in turn increase the probability of wildfire because of larger fuel loads.

1226. Define, document, and mitigate other potential and controllable threats.

Additional threats to the survival of the listed species within the Hawaii Plant Cluster may exist. Identifying and addressing these threats is necessary for the protection and enhancement of the species.

12261. Determine impacts of and manage for hunting and other recreational activities.

Recreational activities can potentially have both a positive and negative impact on the listed taxa. These impacts should be determined and appropriate actions taken for the protection and enhancement of the listed species.

Hunting of feral animals can benefit the listed species by eliminating damage by grazing and browsing animals. However, hunters may physically damage plants or increase the risk of wildfire from automobiles, camp and cooking fires, and smoking. If hunting is desirable and allowed in areas where listed species occur, public awareness programs to increase the benefits and eliminate the disadvantages of hunting should be implemented.

Hiking, camping, bird watching, etc., are recreational activities that might negatively impact listed species populations or habitat. Among the greatest threats are increased risk of wildfires, introduction and movement of alien species, trampling, and destruction of fences. If recreational activities are to be allowed in listed species habitat, public awareness techniques should be employed to alert users of potential conflicts.

12262. Determine military impacts and manage for species' benefit.

As with recreational uses, military training can have both a positive and negative impact on listed species. Obvious negative impacts included trampling, increased risk of wildfire, introduction and movement of alien species, dust, etc. Positive impacts include protection of large areas from development and reduction of damage by feral animals. Military impacts should be evaluated at the PTA and adjusted to benefit the listed species while allowing for the continuation of the military mission.

123. Monitor status of wild populations.

Populations of all taxa in the Hawaii Plant Cluster Recovery Plan should be monitored to ensure that current information is available regarding the status of each taxon and the effectiveness of management techniques. Data should include quantities and location of all extant plants as well as any other relevant observations regarding habitat or situation. Information such as changes in numbers of plants by size class, changes in vigor of individual plants, and changes or disturbances to the habitat should be noted as appropriate and recorded.

124. Revise management plans, as necessary.

Management plans should be evaluated periodically to determine if the recovery goals and objectives are being met, evaluate the overall stability and ecological health of each of the listed species, make recommendations on how to improve the recovery efforts, and ensure implementation of recommendations. Management plans should be revised to reflect new threats and life history information, and the need to protect and manage newly discovered populations.

13. Maintain genetic stock of each taxon *ex situ*.

Cultivated populations of Hawaii cluster taxa should be maintained in order to establish pools of genetic resources to safeguard against loss of the material due to catastrophic events. Material for cultivation should represent as wide a range of genetic diversity as is economically feasible. Cultivated plants should be used for all needs (research, experimentation, seed source, etc.) rather than disturbing naturally occurring populations. It should be noted, however, that cultivation of these plants is not a substitute for their preservation or protection in the wild (Allen 1994). Collection methods and quantities of materials should be designed to have minimal impact on wild populations. All collected materials should be labelled accurately as to exact origin, collection date, etc.

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

2. Conduct essential research.

Defining the habitat requirements and population characteristics of each taxon within the Hawaii Plant Cluster is important in maintenance or augmentation of existing populations as well as establishing new populations. The information will indicate the parameters of the environment that are essential for establishment, growth, and reproduction for each taxon, and the optimum population structure for each species. This information should be evaluated within the context of associated ecosystem components.

21. Establish ecosystem history and collect diagnostic data on associated ecosystem components.

Establishing the history of habitats where listed species occur will assist in determining each taxon's response to perturbation. For example, a species occurring in an area that was burned 5 years before might indicate the plant is resistant to fire, may establish easily with reduced competition, or might require fire to germinate.

Floral characteristics of the native ecosystems such as species composition, cover, structure, etc., and invertebrate, bird and other faunal populations within each management area should be documented. This will assist in better understanding the relationship among organisms and identifying areas within and outside of the management area where Hawaii cluster taxa might survive without constant species-specific management.

22. Define habitat requirements for each species.

It is important to identify as well as possible the environmental parameters essential for establishment, growth and reproduction of each taxon.

Determination of soil parameters where listed species occur is important in selection of sites for population augmentation or creation of new populations. Important soil parameters include, but are not limited to, textural class, pH, organic matter, and macro- and micronutrient content.

Measurement of macro- and microclimatic characteristics where the listed species currently occur will yield valuable information about the optimum climatic requirements for the taxa within the Hawaii Plant Cluster. Precipitation, temperature, solar radiation, relative humidity, wind speed, etc., should be collected in representative habitats for each species. The relationship between microclimatic features and plant success should be investigated.

23. Determine population characteristics for each species.

Information about population dynamics of each taxon in the Hawaii Plant Cluster is essential to determining viable population structure. Demographic data for each taxon would be used to conduct population viability analyses.

Populations of all the taxa within the Hawaii Plant Cluster should be inventoried and monitored to evaluate the species' current status and serve as a baseline for determining the success of the recovery effort. Permanent field plots should be used. Individuals of the listed species should be mapped, tagged, or otherwise delineated so they can be monitored through time.

The age-class distribution of each perennial species should be determined when establishing permanent field plots and creating a baseline data set. For example, when each individual is mapped, tagged, or otherwise delineated, its size, status (seedling, juvenile, adult, reproductive adult, dead, etc.), and condition should be noted. Longevity of individuals is an important variable in determining population structure and dynamics for each species. Long-term monitoring is one of the best methods for determining this variable.

Recruitment rates along with turnover rates are essential to describing the dynamics of population structure. For example, if an organism is long-lived (large tree), recruitment can be very low. Conversely, if an organism is short-lived (herbaceous perennial), recruitment must be higher to maintain a constant population density.

Based on the demographic data collected from inventorying and monitoring programs, it is possible to model and predict the demographic "behavior" of the listed species (Menges 1986). The behavior of each of the individual populations can be predicted, as well as the average behavior for a particular taxon.

25. Determine the reproductive potential of each species.

Investigations into the reproductive biology of the listed taxa are necessary to understanding the potential for reintroduction and reestablishment of that taxon, as well as determining whether certain reproductive attributes may result in rarity (Douglas & Shaw 1992).

251. Determine characteristics of pollen and seed formation.

Microsporogenesis and megasporogenesis (pollen and seed formation) should be examined for each taxon. Chromosome number, morphology, and behavior should be documented (Smith 1974). Occurrence of apomixis (female-only produced offspring) should be evaluated. Crossing experiments should be conducted to check for self-compatibility or obligatory outcrossing (Fritz-Sheridan 1988).

252. Study pollination ecology.

Pollen biology and pollination ecology should be determined for each taxon within the Hawaii plant cluster. Pollen vectors should be collected and identified, and their abundance estimated to determine if they are a limiting factor in reproduction. Actions should be taken to ensure that pollinators are not restricted and remain available for pollen transmittal. Pollen viability and pollen morphology should be evaluated to ensure that they are not interfering with reproduction (Radford et al. 1974).

253. Study factors affecting germination and seedling establishment.

Information concerning the seed biology of the listed species in the Hawaii plant cluster is vital if sustaining populations are to be maintained and/or created. Seed viability (Larsen 1965), germination rates (Brown & May 1988), potential dormancy, and other factors affecting germination (hormones, scarification, leaching, seed ripening, temperature) must be determined (Barton 1965, Kanzler & Van Staden 1984).

Data concerning seedling establishment requirements is vital to creating and/or augmenting populations. Without knowledge of temperature, photoperiod, water, and edaphic limits for seedling establishment the ability to establish taxa is restricted (Oechel 1988).

26. Conduct research necessary for maintenance of genetic stock.

Populations of each listed taxon should be maintained in cultivation to safeguard against loss of genetic material due to catastrophic event, and to provide propagules for reintroduction, experimentation, and preservation. For many Hawaii plant cluster taxa, cultivation methods and seed storage requirements are unknown or untested.

The purpose of long-term storage of seed at the National Seed Storage Laboratory is to preserve the genetic diversity in the gene pool. Preservation of the gene pool is extremely important in endangered species management, and the samples submitted for storage should represent the diversity within the species. Prior to storage, the viability and germination percentages, existence of innate dormancy periods, and necessary treatments for breaking dormancy should be determined for each taxon (see task #253). A subsample of each type of seed placed into storage should be grown out periodically (approximately every 5 years) to determine the effects of long-term storage on viability, germination, and genetic diversity. Seeds should be recollected as needed (Tracy Halward, Colorado State University, pers. comm., 1995).

Asexual reproduction sometimes can be as important as sexual reproduction in the spread of plants (Hartmann & Kester 1975). The potential for propagation of the listed taxa by vegetative means should be investigated.

3. Expand existing wild populations, as necessary.

Individual numbers of the Hawaii plant cluster taxa should naturally increase following protection of wild populations and removal of some or all threats from their habitat. However, in some cases, augmentation of the wild populations will be necessary. If naturally occurring populations fall short of the required number of individuals, the populations should be increased with outplantings from nursery stock. Taxon-specific or management unit plans should carefully specify the location, augmentation methods, timing, and monitoring schemes that they propose. The public should be notified of the plans to augment populations, and public assistance and review of the process should be encouraged. Extreme caution should be taken to prevent the introduction of harmful organisms (alien plant species, soil microorganisms, diseases, etc.) into the habitats of the listed taxa.

31. Identify populations for augmentation.

Known populations for each taxon should be ranked based on a set of "criteria for successful transplanting" developed during the planning process. Number of individuals to transplant, age and size classes of individuals, etc., should be estimated using transitional matrices (Aplet et al. 1994, Menges 1986) developed from information collected under task #2 (demographic and reproductive parameters).

32. Propagate material for augmentation.

Under tasks #13 and 25, techniques for propagating nursery stock should have been determined for each taxon. Material from the populations to be augmented should be used to generate the nursery stock used in the outplantings. Using genetic stock from the existing population should help in reducing genetic contamination of the wild populations; however, maintaining inherent genetic diversity within the populations should be emphasized. The number, age, and size of individuals to be used may be determined using transitional matrices.

33. Prepare sites and augment wild populations.

Each selected site must be prepared to meet the requirements for seedling and plant establishment determined for each taxon. In some cases, this might mean completely clearing an area near the original populations. In other cases, that won't be necessary as new transplant stock will be placed under "nurse" plants. Care should be taken to ensure that each site continues to be protected from threats.

The new plants should be placed into the wild populations in the appropriate manner. As stated previously, care should be taken to guarantee that no alien plants or harmful soil microorganisms are introduced into the wild populations. The use of supplemental water and nutrients (fertilizer) to assist the establishment of the transplants should be evaluated on a site-by-site and species-by-species basis.

34. Maintain, monitor and evaluate outplantings.

Success of the outplantings should be monitored in a similar fashion to the scheme used for the existing populations. Also, the techniques used for outplanting should be evaluated and modified as necessary to increase success. Protection and maintenance of the outplanting sites should be the same as for the existing populations (i.e., feral animal control, alien plant control, etc.). Unsuccessful transplants should be replaced to maintain the minimum number of individuals recommended for a viable population.

4. Create new populations within historical range, as necessary.

To meet the downlisting and delisting criteria established by the recovery plan, it will be necessary to create new populations of some of the taxa. These new populations should be within the estimated historical range of taxa. By creating the populations within each taxon's historical range, the probability of successful establishment should increase because the taxon was once adapted to the local ecological parameters. The overall objective of this task is to create new viable populations, which will be protected and maintained in a similar fashion to the known existing wild populations.

41. Select new population sites and obtain long-term protection.

If new populations are determined to be necessary, a detailed planning process is required. Some parameters to consider would be: identification of sites; appropriate approval for creation of new populations; genetic material to be used for transplant stock; protection of sites; methods of establishment; and monitoring of populations.

Sites for new populations should be within the known historical range of the species. Matching of ecological information (soils, climate, associated species, etc.) from existing populations should assist in selecting the potential locations for new populations. Choice of sites should have considerable public input to avoid any potential land use conflicts. Selection of sites should not be limited to areas in close proximity to existing populations, but should include other islands (within historical range) and similar habitats on the island of Hawaii.

Care should be taken in selection of genetic material to be used in creating the new populations. If no genetic material from the new site can be documented, transplant trials might be necessary. A wide range of plants from all or many existing populations should be tested to determine which material is best adapted to the site and has the best chance of survival.

Obtaining cooperation from Federal and State agencies and private landowners is necessary to carry out planned conservation efforts that will enhance the habitat of the Hawaii Plant Cluster taxa. Long-term cooperative management plans should be arranged for each site.

42. Control threats to plants at new sites.

Threats should be identified and controlled in a similar fashion to the existing plant populations. Areas should be fenced, feral animals controlled within the exclosures, and alien plants controlled or eliminated. Care should be taken not to excessively disturb the selected sites nor to introduce new alien plant species or pathogens into the area.

43. Transplant selected material.

Once the sites have been identified and protected, selected plant materials should be transplanted. The techniques tried and modified in augmenting existing populations in task #3 should help in establishing these new populations. Decisions on whether to artificially supply additional water or nutrients to aid in establishment should be made on a site-by-site and species-by-species basis.

44. Maintain, monitor and evaluate new populations.

The success of the new populations should be closely monitored. Unsuccessful populations should be carefully studied as documentation of the causes for establishment failures are important for the success of future outplantings. Any failed attempts to create new populations should be evaluated, and either reattempted at the original site or more appropriate sites selected.

5. Evaluate and validate recovery objectives.

Progress and feasibility of recovery efforts should be periodically evaluated. As new information is generated by implementation of the recovery plan and by independent and/or related scientific research, alteration of specific objectives and recovery criteria may be necessary.

51. Validate the number of individuals and populations necessary for recovery of each taxon.

The population and reproductive biology information generated in task #2 can be incorporated to determine minimum viable population size and number necessary to ensure the survival of listed taxa at some level of confidence for a specified number of years (Soule 1986, 1987). The desired level of probability for survival and existence time are two critical societal issues which must be established before size estimates can be made (Shaffer 1987). Political, economic, and societal values will dictate which levels are acceptable and realistic (Douglas & Shaw 1992).

Monitoring of the overall condition and demographic characteristics of existing and created populations should be used to check the original minimum viable population estimates. As new data become available, more accurate estimates can be made concerning the numbers needed within each population as well as the number of populations.

Loss of adaptability, inbreeding, fragmentation, and demographic variation can all cause decreased growth, increased fragmentation, and lower effective population size which, if unchecked, can lead to extinction (Gilpin 1987). Maintenance and/or establishment of genetically diverse, outbreeding, interconnected, and properly structured populations can counteract these extinction forces.

52. Evaluate species for downlisting and delisting.

As recovery objectives are implemented and specific tasks accomplished, the number of individuals of each taxon should begin to increase. Populations should increase in size, vigor, and stability. Monitoring of the original wild populations and created populations should indicate which species are successfully recovering and which are not. Bases for downlisting and delisting established in this recovery plan may be refined during implementation of the recovery plan. When the determined number of minimum viable populations have been established for the required length of time the taxon may be downlisted or delisted according to these criteria.

53. Refine/revise downlisting and delisting criteria, as necessary.

Based on scientific information gathered during recovery efforts, recovery criteria for each of the Hawaii cluster taxa should be revised to reflect new information. Until such time as additional sound information is available, the criteria presented in this recovery plan should be used as the basis for downlisting and delisting.

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# III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs (including costs for salaries) for the Big Island plant cluster recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, agencies responsible for committing funds, and estimated costs. The agencies responsible for committing funds are not, necessarily, the entities that will actually carry out the tasks. When more than one agency is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the Implementation Schedule, when accomplished, should protect habitat for the taxa, stabilize existing populations, and increase 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 according to the following guidelines:

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 population/habitat quality, or some other significant negative impact short of extinction.

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

Key to Acronyms Used in the Implementation Schedule

DLNR - Department of Land and Natural Resources
DOD - Department of Defense
PIE - U.S. Fish and Wildlife Service, Pacific Islands Ecoregion
LE - U.S. Fish and Wildlife Service, Law Enforcement
NBS - National Biological Service
NPS - National Park Service
BOT - Various Botanical Gardens (e.g., National Tropical Botanical Garden, Lyon Arboretum, Waimea Botanical Garden, etc.)
HDOA - Hawaii Department of Agriculture
PL - Private Landowners

Key to Other Codes Used in the Implementation Schedule

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

## RECOVERY PLAN IMPLEMENTATION SCHEDULE
## THE BIG ISLAND PLANT CLUSTER

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 111 | Locate, verify and delineate all extant wild populations | 5 | DLNR* | 300.0 | 15 | 15 | 15 | 15 | 15 |
| | | | | NBS | 300.0 | 15 | 15 | 15 | 15 | 15 |
| | | | | PIE | 42.0 | 3 | 3 | 3 | 3 | 3 |
| | | | | DOD | 42.0 | 3 | 3 | 3 | 3 | 3 |
| | | | | NPS | 42.0 | 3 | 3 | 3 | 3 | 3 |
| 1 | 112 | Delineate management units for preservation | 1 | PIE* | 1.0 | | 1 | | | |
| | | | | DLNR | 1.0 | | 1 | | | |
| 1 | 1131 | Continue and enhance protection on Federal lands | O | DOD | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | NPS | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | PIE | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | LE | 20.0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1132 | Continue and enhance protection on other public lands | O | DLNR* | 100.0 | 5 | 5 | 5 | 5 | 5 |
| 1 | 1133 | Continue and enhance protection on private lands | O | DLNR* | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | PL | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | PIE | 20.0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 121 | Develop management plans for each management unit | 2 | DLNR* | 30.0 | | 15 | 15 | | |
| | | | | PIE | 30.0 | | 15 | 15 | | |
| | | | | DOD | 5.0 | | 2.5 | 2.5 | | |
| | | | | NPS | 5.0 | | 2.5 | 2.5 | | |
| | | | | PL | 5.0 | | 2.5 | 2.5 | | |

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
| 1 | 12211 | Construct and maintain fencing | O | DLNR* | 1,000.0 | 50 | 50 | 50 | 50 | 50 |
| | | | | PIE | 1,000.0 | 50 | 50 | 50 | 50 | 50 |
| | | | | DOD | 400.0 | 20 | 20 | 20 | 20 | 20 |
| | | | | NPS | 400.0 | 20 | 20 | 20 | 20 | 20 |
| | | | | PL | 400.0 | 20 | 20 | 20 | 20 | 20 |
| 1 | 12212 | Evaluate alternative means for control of ungulates | 5 | DLNR* | 65.0 | | 5 | 5 | 5 | 5 |
| | | | | PIE | 65.0 | | 5 | 5 | 5 | 5 |
| | | | | DOD | 26.0 | | 2 | 2 | 2 | 2 |
| | | | | NPS | 26.0 | | 2 | 2 | 2 | 2 |
| | | | | PL | 26.0 | | 2 | 2 | 2 | 2 |
| 1 | 12213 | Consider eradication programs for control of ungulates | 3 | DLNR* | 3.0 | | 1 | 1 | 1 | |
| | | | | PIE | 3.0 | | 1 | 1 | 1 | |
| 1 | 12221 | Control rodents | TBD | DLNR* | 0.0 | TBD | | | | |
| | | | | DOD | 0.0 | TBD | | | | |
| | | | | NPS | 0.0 | TBD | | | | |
| | | | | PL | 0.0 | TBD | | | | |
| | | | | PIE | 0.0 | TBD | | | | |
| 1 | 12222 | Control gastropods, insects, etc. found to be harmful to listed species | TBD | DLNR* | 0.0 | TBD | | | | |
| | | | | DOD | 0.0 | TBD | | | | |
| | | | | NPS | 0.0 | TBD | | | | |
| | | | | PL | 0.0 | TBD | | | | |
| | | | | PIE | 0.0 | TBD | | | | |
| 1 | 12231 | Establish impacts of alien plants and determine species necessary to control | 5 | DLNR* | 65.0 | | 5 | 5 | 5 | 5 |
| | | | | NBS | 65.0 | | 5 | 5 | 5 | 5 |
| | | | | PIE | 65.0 | | 5 | 5 | 5 | 5 |
| | | | | DOD | 26.0 | | 2 | 2 | 2 | 2 |
| | | | | NPS | 26.0 | | 2 | 2 | 2 | 2 |
| | | | | HDOA | 26.0 | | 2 | 2 | 2 | 2 |

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12232 | Determine effective control method(s) and implement alien plant control program | O | DLNR* | 950.0 | | 50 | 50 | 50 | 50 |
| | | | | PIE | 380.0 | | 20 | 20 | 20 | 20 |
| | | | | DOD | 190.0 | | 10 | 10 | 10 | 10 |
| | | | | NPS | 190.0 | | 10 | 10 | 10 | 10 |
| | | | | HDOA | 190.0 | | 10 | 10 | 10 | 10 |
| | | | | PL | 190.0 | | 10 | 10 | 10 | 10 |
| 1 | 1224 | Control diseases, as necessary | TBD | DLNR* | 0.0 | TBD | | | | |
| | | | | HDOA | 0.0 | TBD | | | | |
| | | | | PIE | 0.0 | TBD | | | | |
| 1 | 12251 | Determine impacts of wildfire on taxa | 5 | NBS* | 190.0 | | 10 | 10 | 10 | 10 |
| | | | | PIE | 95.0 | | 5 | 5 | 5 | 5 |
| | | | | DLNR | 95.0 | | 5 | 5 | 5 | 5 |
| 1 | 12252 | Develop and implement fire protection and response plan(s) | C | DLNR* | 159.0 | | 20 | 20 | 7 | 7 |
| | | | | DOD | 27.0 | | 5 | 5 | 1 | 1 |
| | | | | NPS | 27.0 | | 5 | 5 | 1 | 1 |
| | | | | PL | 27.0 | | 5 | 5 | 1 | 1 |
| | | | | PIE | 27.0 | | 5 | 5 | 1 | 1 |
| 1 | 12261 | Determine impacts of and manage hunting and other recreational activities | C | DLNR* | 95.0 | | 5 | 5 | 5 | 5 |
| | | | | PIE | 19.0 | | 1 | 1 | 1 | 1 |
| 1 | 12262 | Determine military impacts and manage for species' benefit | C | DOD* | 95.0 | | 5 | 5 | 5 | 5 |
| 1 | 123 | Monitor status of wild populations | C | DLNR* | 200.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | NBS | 200.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | DOD | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | NPS | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PL | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PIE | 40.0 | 2 | 2 | 2 | 2 | 2 |

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 124 | Revise management plans, as necessary | TBD | DLNR | 0.0 | TBD | | | | |
| | | | | DOD | 0.0 | TBD | | | | |
| | | | | NPS | 0.0 | TBD | | | | |
| | | | | PL | 0.0 | TBD | | | | |
| | | | | PIE* | 0.0 | TBD | | | | |
| 1 | 13 | Maintain genetic stock of each taxon *ex situ* | C | DLNR | 200.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | BOT | 400.0 | 20 | 20 | 20 | 20 | 20 |
| | | | | PIE | 400.0 | 20 | 20 | 20 | 20 | 20 |
| NEED 1 (Preserve and protect existing populations) | | | | | 6,100.0 | 279 | 539 | 537 | 470 | 468 |
| 2 | 21 | Establish ecosystem history and collect diagnostic data on associated ecosystem components | 5 | NBS* | 100.0 | | | | | |
| | | | | PIE | 50.0 | | | | | |
| | | | | DLNR | 50.0 | | | | | |
| 2 | 22 | Define habitat requirements for each taxon | 5 | NBS* | 100.0 | | | | | |
| | | | | PIE | 50.0 | | | | | |
| | | | | DLNR | 50.0 | | | | | |
| 2 | 23 | Determine population characteristics for each taxon | 5 | NBS* | 100.0 | | | | | |
| | | | | PIE | 50.0 | | | | | |
| | | | | DLNR | 50.0 | | | | | |
| 2 | 24 | Determine the reproductive potential of each taxon | 5 | NBS* | 100.0 | | | | | |
| | | | | PIE | 50.0 | | | | | |
| | | | | DLNR | 50.0 | | | | | |
| 2 | 251 | Study pollen and seed formation | 5 | BOT* | 15.0 | | | | | |
| | | | | NBS | 15.0 | | | | | |
| | | | | PIE | 15.0 | | | | | |
| | | | | DLNR | 15.0 | | | | | |
| 2 | 252 | Study pollination ecology | 5 | BOT | 20.0 | | | | | |
| | | | | NBS* | 20.0 | | | | | |
| | | | | PIE | 20.0 | | | | | |
| | | | | DLNR | 20.0 | | | | | |

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 253 | Study germination and seedling establishment | 5 | BOT* | 15.0 | | | | | |
| | | | | NBS | 15.0 | | | | | |
| | | | | PIE | 15.0 | | | | | |
| | | | | DLNR | 15.0 | | | | | |
| NEED 2 (Research) | | | | | 1,000.0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 31 | Identify populations for augmentation | 5 | DLNR* | 5.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | DOD | 2.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | | | NPS | 2.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | | | PL | 2.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | | | | PIE | 2.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 2 | 32 | Propagate material for augmentation | 10 | BOT* | 100.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | HDOA | 100.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | PIE | 100.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | DLNR | 100.0 | 10 | 10 | 10 | 10 | 10 |
| 2 | 33 | Prepare sites and augment wild populations | 10 | DLNR* | 100.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | DOD | 35.0 | 5 | 5 | 5 | 5 | 5 |
| | | | | NPS | 35.0 | 5 | 5 | 5 | 5 | 5 |
| | | | | PL | 35.0 | 5 | 5 | 5 | 5 | 5 |
| | | | | PIE | 35.0 | 5 | 5 | 5 | 5 | 5 |
| 2 | 34 | Maintain, monitor and evaluate outplantings | O | DLNR* | 200.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | DOD | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | NPS | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PL | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PIE | 40.0 | 2 | 2 | 2 | 2 | 2 |
| NEED 3 (Augment existing populations) | | | | | 1,015.0 | 91 | 91 | 91 | 91 | 91 |
| 3 | 41 | Select new population sites, and obtain approval and long-term protection for site | 10 | DLNR* | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | DOD | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | NPS | 20.0 | 1 | 1 | 1 | 1 | 1 |
| | | | | PIE | 20.0 | 1 | 1 | 1 | 1 | 1 |

| Priority # | Task # | Task Description | Task Duration (yrs) | Responsible Party | Total Cost | Cost Estimates ($1,000's) FY 1996 | FY 1997 | FY 1998 | FY 1999 | FY 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 42 | Control threats to plants at new sites | C | DLNR | 475.0 | 50 | 50 | 50 | 50 | 50 |
| | | | | DOD | 80.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | NPS | 80.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | PIE | 80.0 | 10 | 10 | 10 | 10 | 10 |
| 3 | 43 | Transplant selected material | 10 | DLNR | 200.0 | 30 | 30 | 30 | 30 | 30 |
| | | | | DOD | 35.0 | 5 | 5 | 5 | 5 | 5 |
| | | | | NPS | 35.0 | 5 | 5 | 5 | 5 | 5 |
| | | | | PIE | 35.0 | 5 | 5 | 5 | 5 | 5 |
| 1 | 44 | Maintain, monitor and evaluate new populations | C | DLNR | 200.0 | 10 | 10 | 10 | 10 | 10 |
| | | | | DOD | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | NPS | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PL | 40.0 | 2 | 2 | 2 | 2 | 2 |
| | | | | PIE | 40.0 | 2 | 2 | 2 | 2 | 2 |
| NEED 4 (Re-establish populations) | | | | | 1,440.0 | 146 | 146 | 146 | 146 | 146 |
| 3 | 51 | Validate the number of individuals and populations necessary for recovery of each taxon | 3 | NBS* | 60.0 | | | | | |
| | | | | DLNR | 15.0 | | | | | |
| | | | | PIE | 15.0 | | | | | |
| 3 | 52 | Refine/revise downlisting and delisting criteria, as necessary | 2 | PIE | 5.0 | | | | | |
| 3 | 53 | Evaluate species for downlisting and delisting | O | PIE | 0.0 | TBD | | | | |
| NEED 5 (Revise Recovery Plan) | | | | | 95.0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL COST | | | | | 9,102.0 | 516 | 776 | 774 | 707 | 705 |

# APPENDIX A - ALIEN PLANTS

*Pennisetum clandestinum* (kikuyu grass)

*Pennisetum clandestinum* Chiov. (Poaceae), is an aggressive, mat-forming perennial that was introduced into Hawaii from East Africa as a primary rangeland grass of upland pasture because of its resistance to trampling and grazing (Hosaka 1958, Medeiros *et al.* 1986, Smith 1989, Wagner *et al.* 1990). First collected in 1838 (Wagner *et al.* 1990), *Pennisetum clandestinum* has become an increasingly serious problem by threatening native vegetation in dry, mesic and disturbed wet habitats up to 10,000 ft (3,050 m) (Wagner *et al.* 1990). Its clambering, mat-forming habit and allelopathic capabilities preclude most native seedings from germination and establishment (Medeiros *et al.* 1986, Smith 1989, Wagner *et al.* 1990). Kikuyu grass rapidly spreads vegetatively, but it fails to flower or set seed unless closely cropped (Sanchez and Davis, 1969). Medeiros *et al.* (1986), Smith (1989), and O'Connor (1990) described this vigorous taxon as a noxious weed. Gardner and Kageler (1983) reported control of kikuyu grass by 0.5% solution of glyphosate with little detrimental effect on native plant taxa.

*Pennisetum setaceum* (fountain grass)

*Pennisetum setaceum* (Forssk.) Chiov (Poaceae) is a fire-stimulated, tufted perennial (O'Connor 1990). A native of tropical Africa (Wagner *et al.* 1990), *Pennisetum setaceum* has become established along roads and in pastures, spreading rapidly over lava flows and open areas since its introduction in Hawaii as an ornamental in the 1900s (Smith 1989). Major infestations occur on the Kona side from sea level to well above 8,990 ft (2,740 m) on Mauna Kea, where it invades lava flows previously dominated by native plants (Cuddihy and Stone 1990, Jacobi and Warshauer 1992). Dense stands of fountain grass increase the potential of fire to sweep through areas occupied by native plants, particularly threatening endangered plant populations in dry shrublands and forests (Cuddihy and Stone 1990). An aggressive colonist, *Pennisetum setaceum* is capable of rapid re-establishment after fire, thus retarding native plant regeneration. Fountain grass poses a particular threat to dry forest of the Big Island (HPCC 1990a, 1991h).

*Andropogon virginicus* (broomsedge or yellow bluestem)

*Andropogon virginicus* L. (Poaceae) is a perennial bunchgrass native to northeastern America. It was first collected in Hawaii in 1924 (Smith 1985, O'Connor 1990, Wagner *et al.* 1990). Unrecorded in Hawaii Volcanoes National Park until after 1947, today broomsedge is a dominant ground cover herb (L. Pratt, pers. comm., 1995). *Andropogon virginicus* sometimes forms dense continuous stands at elevations between 160-4,000 ft (50-1200 m) above sea level (Smith 1985), occupying boggy, mesic, and dry habitats. An infamous fire carrier, *Andropogon virginicus* is fire-stimulated (Hughes *et al.* 1991). Seeds appear to be easily distributed by wind, clothing, vehicles, and feral animals (Smith 1989). *Andropogon virginicus* may release allelopathic substances, which dramatically decrease native plant re-establishment (Rice 1972). Mueller-Dombois *et al.* (1981) indicated that, because *Andropogon virginicus* is dormant during the rainy season in Hawaii, erosion has increased in some areas.

*Digitaria ciliaris* (Henry's crabgrass, kukaepuaa)

*Digitaria ciliaris* (Retz.) Koeler (Poaceae) is a decumbent, mat-forming annual. A native of China, Indochina, Samoa, and the Philippines, *Digitaria ciliaris* was introduced in 1909 (O'Connor 1990). Presently, it grows in lawns and pastures at elevations below 3,020 ft (920 m) (O'Connor 1990).

*Oplismenus hirtellus* (basketgrass, honohono kukui, honohono maoli)

*Oplismenus hirtellus* (L.) P. Beauv. (Poaceae) is a common grass throughout most of the tropics and was introduced to the Hawaiian Islands in 1819 (O'Connor 1990). Scandent (climbing), perennial, and rooting at the nodes, *Oplismenus hirtellus* occurs in various habitats, including lightly to densely shaded, mesic to wet valleys and forests (O'Connor 1990).

*Setaria palmaefolia* (palmgrass)

*Setaria palmaefolia* (Koen.) Stapf (Poaceae) is a native to tropical Asia that was first collected on Hawaii in 1903 (O'Connor 1990). A large-leafed, perennial herb, it reaches about 6.5 ft (2 m) in height at maturity, shading out native vegetation. Palmgrass is resistant to fire and recovers quickly after being burned. Feral animals provide new areas for establishment by disturbing native vegetation (Cuddihy and Stone 1990). *Setaria palmaefolia* is naturalized in mesic valleys and wet forests between elevations of 980 and 6,500 ft (300 to 2,000 m) (O'Connor 1990). Major infestations occur on the trade wind side of Hawaii (Smith 1985).

*Rubus rosaefolius* (thimbleberry, Mauritius raspberry, olaa, akala, akalakala)

*Rubus rosaefolius* Sm. (Rosaceae) is native to Asia and may have been introduced from Samoa to Hawaii by D.H Hitchcock in 1880 (Degener 1936, Wagner *et al.* 1990). Dispersion of this prickly taxon may be increased by feral animals and birds (Smith 1985). *Rubus rosaefolius* has become a common weed in disturbed mesic to wet forests on eastern Hawaii at elevations between 200-5,675 ft (60-1,730 m) (Wagner *et al.* 1990).

*Passiflora mollissima* (banana poka)

*Passiflora mollissima* (Kunth) L.H. Bailey (Passifloraceae) is an aggressive light-loving liana introduced from the South American Andes, where it is grown for its edible fruits (Escobar 1980, Wagner *et al.* 1990). Introduced in Hawaii for its beautiful flower and as camouflage for outhouses early in the 1900s, the vine rapidly spread, smothering the forest canopy and precluding light from reaching the forest floor (Degener *et al.* 1973; Jack Jeffrey, Hakalau Forest National Wildlife Refuge, pers. comm., 1995). *Passiflora mollissima* seeds are readily dispersed naturally or by humans, birds (long distance dispersal), or feral pigs (short distance dispersal) (Warshauer *et al.* 1983, La Rosa 1992). Fallen fruits encourage rooting and trampling by pigs (J. Jeffrey, pers. comm., 1995). Lacking natural biological control agents in Hawaii, major infestations of banana poka occur at Hualalai, Laupahoehoe, and Hawaii Volcanoes National Park (Warshauer *et al.* 1983). The taxon has been noted in relative abundance in the saddle between Mauna Kea and Mauna Loa.

In the early 1990s, an attempt was made by the Department of Land and Natural Resources (DLNR) to mechanically control *Passiflora mollissima*; however, these efforts were quickly ceased (F.R. Warshauer, National Biological Service, pers. comm., 1995). Markin (1989) reported that Federal and state agencies have been screening organisms indigenous to South America to find biological control agents for *Passiflora mollissima*. Two moths were released in Kula, Maui, to control banana poka. In Hawaii, this noxious vine represents a serious pest in mesic forests at elevations between 2,790-7,300 ft (850-2,225 m), because it competes with native plant species for light, space, water and nutrients (Stone and Loope 1987). Efforts must be continued to control this invasive taxon.

*Melia azedarach* (China berry, pride of India, inia, ilinia)

*Melia azedarach* L. (Meliaceae) is a small, deciduous tree that rapidly grows to about 65 ft (20 m) (Wagner *et al.* 1990). A native of southwestern Asia, *Melia azedarach* was introduced to Hawaii as early as 1839 (Degener 1932). A brew produced from the large yellow fruits was used in Maui to treat leprosy sores (Wagner *et al.* 1990). The taxon is thought to be distributed in Hawaii primarily because of its ornamental value (Smith 1985). Feral pigs appear to relish the fruits; the seeds may be distributed through their feces (Stone 1985). The major infestations occur at elevations from sea level to 2300 ft (700 m) in disturbed areas, particularly in gulches and pastures in Kona (Hawaii), Waimea Canyon (Kauai), and Nuu (Maui) (Smith 1985).

*Leucaena leucocephala* (koa haole, ekoa, lilikoa)

*Leucaena leucocephala* (Lam.) Dewit. (Fabaceae) is a small, thornless shrub or tree which grows to about 30 ft (9 m) tall (Wagner *et al.* 1990). A nitrogen fixer, the taxon forms dense colonies that ultimately exclude other vegetation (Smith 1985). *Leucaena leucocephala* is native to the neotropics and was introduced to Hawaii for fodder (Smith 1985). In Hawaii, *Leucaena leucocephala* is found in dry to mesic areas at elevations from sea level to 2,275 ft (700 m) (Wagner *et al.* 1990). Approximately 50 years ago lowland sites were seeded with the fruits (Smith 1985). Consequently dense stands occur in coastal habitats of the island. The plant is rich in the amino acid mimosine; illness may result when domestic animals' intake is great (Wagner *et al.* 1990). When left ungrazed, *Leucaena leucocephala* spreads throughout the area. Fire is retarded in mature stands because of reduced fire loads. When it does burn, sprouts develop readily at the base (Smith 1985). Seeds are dispersed on occasion by humans, rodents, and granivorous birds (Smith 1985). A psyllid (insect in the jumping plantlice family, Order Homoptera) introduced in 1980, *Heteropsylla* cf. *incisa*, may be used as a biological control agent (Nakahara and Lai 1984). However, this may be met with considerable opposition because of the use of *Leucaena leucocephala* in agriculture and as a fuel source.

*Schinus terebinthifolius* (Christmas berry, wilelaiki, naniohilo)

*Schinus terebinthifolius* Raddi (Anacardiaceae) is a shrub or small tree that grows to about 23 ft (7 m) tall and forms dense stands (Wagner *et al.* 1990). Native to Brazil, the taxon was cultivated in Hawaii where its bright red berries and green foliage are used by Hawaiians for Christmas wreaths and decorations (Wagner *et al.* 1990). Fruits are dispersed by frugivorous birds and humans (Smith 1985). An aggressive invader, *Schinus terebinthifolius* shades out native taxa and prevents their re-establishment with its allelopathic capabilities (Gogue *et al.* 1974). Although killed by intense fires, *Schinus terebinthifolius* regenerates readily where a large seed bank is available (Smith 1985). Now a serious naturalized weed, *Schinus terebinthifolius* forms dense colonies in mesic disturbed areas and is considered by Smith (1985) to be one of Hawaii's top ten most infamous weedy pests. Biological control agents have been explored, but none has proven effective.

*Lantana camara* (lantana, lakana, laau kalakala, lanakana, mikinolia hihiu, mikinolia hohono, mikinolia kuku)

*Lantana camara* L. (Verbenaceae) is an aggressive, thorny shrub that forms impenetrable thickets (Wagner *et al.* 1990). It was introduced to Hawaii as an ornamental in the mid-1800s from the West Indies and became naturalized before 1871 (Hillebrand 1888, Wagner *et al.* 1990). The taxon appears to survive fire and regenerates rapidly from basal shoots (Smith 1985). Allelopathic capabilities of roots and shoots prevent re-establishment of native taxa (Smith 1985). Dispersed by frugivorous birds and humans, this weedy species has invaded mesic forests and dry shrublands from sea level to 3,500 ft (1,070 m) (Wagner *et al.* 1990). Twenty biological control insects introduced after

1902 have reduced this aggressive pest, but have not halted the species' spread (Davis *et al.* 1992).

*Polygonum punctatum* (watersmart)

*Polygonum punctatum* Elliot (Polygonaceae) is a perennial herb that often roots at the node (Wagner *et al.* 1990). Introduced from North and South America and the West Indies, the taxon is established in Hawaii along streams, wet areas, and disturbed forest from sea level to 2,950 ft (900 m) (Wagner *et al.* 1990).

*Ardisia elliptica* (shoebutton ardisia)

*Ardisia elliptica* Thumb. (Myrsinaceae) is an evergreen shrub that grows to about 13 ft (4 m) tall (Wagner *et al.* 1990). A native to Sri Lanka, *Ardisia elliptica* was probably introduced to Hawaii by Hillebrand (Degener 1939). Red to black drupes are favored by frugivorous birds. Fruits are dispersed and grow into dense monotypic stands that preclude the establishment of native seedlings (Smith 1985). The stands occur in disturbed mesic to wet forests from sea level to 1,800 ft (550 m) on Kauai, Oahu, Maui, and Hawaii (Wagner *et al.* 1990). There is no indication of fire resistance nor is there any evidence of a biological control agent available (Davis *et al.* 1992).

*Casuarina* spp. (ironwood)

Two species of ironwood introduced from Australia occur on the Big Island: *Casuarina equisetifolia* L. and *C. glauca* Siebold *ex* Spreng. (Casuarinaceae) (Wagner *et al.* 1990). They both grow to heights of 130 ft (40 m) and form monotypic stands (Wagner *et al.* 1990). Little vegetation grows under the trees, suggesting allelopathic response or nutrient depletion (Neal 1965). When burned, both taxa rejuvenate from basal shoots (Wagner *et al.* 1990). Cultivated in Hawaii to serve as windbreaks, the species were naturalized by wind dispersal of seeds. *Casuarina glauca* is Hawaii's most aggressive taxon because it forms exceptionally dense stands (Wagner *et al.* 1990). Because of their use for windbreaks, erosion control, and nitrogen fixation, little has been explored as biological control agents for these taxa (Davis *et al.* 1992).

*Heterotheca grandiflora* (telegraph weed)

*Heterotheca grandiflora* Nutt. (Asteraceae) is an aromatic, annual weed introduced to Hawaii from North America and was first collected on Molokai in 1915 (Wagner *et al.* 1990). A common weed to all islands except Niihau and Lanai, it occurs in dry, disturbed areas from sea level to 7,445 ft (2,270 m), particularly in the saddle between Mauna Kea and Mauna Loa. Little is known about the impact of *Heterotheca grandiflora*. However, native seedling establishment may be inhibited where *H. grandiflora* is abundant.

*Cannabis sativa* (marijuana)

*Cannabis sativa* L. (Cannabaceae) probably is native to central Asia. It is illicitly cultivated in isolated areas on public and private lands on the Big Island and elsewhere. Unfortunately, marijuana is a big cash crop. This illegal agricultural practice encourages clearing of native forests. After the cultivated areas are abandoned, alien taxa invade the disturbed sites (Medeiros *et al.* 1988, Wagner *et al.* 1990).

# APPENDIX B - DOMESTIC AND FERAL ANIMALS

*Sus scrofa* (pigs)

Pigs were introduced by the Polynesians in the fourth and fifth centuries (Stone 1985, Cuddihy and Stone 1990). These animals roamed wild, were fed occasionally by the Polynesians, and probably had little impact on the environment. In 1778, Captain Cook left a pair of English-bred pigs in Hawaii (Medeiros *et al.* 1986, Wagner *et al.* 1990). Native to Europe and North Africa, the animals became feral, populating mesic and dry forests of upper elevations. Their abundance and distribution may have been increased by a kapu (taboo) in the 1700s.

Today, large areas of native forest are disturbed by pigs. Pigs are omnivores that feed opportunistically and abide in diverse habitats. They select vegetation that is most palatable, often choosing rare plant taxa (Smith 1985, Stone 1985). Rooting the ground searching for earthworms, an important source of protein, pigs disturb and decimate the vegetation. Removal of the native flora allows opportunistic plant taxa to occupy disturbed sites and replace native stands (Cuddihy and Stone 1990). Often, plant seeds are dispersed in the pigs hooves, hair, and digestive tracts, their feces acting as fertilizer for the newly established introduced taxa (Smith 1985, Stone 1985, Medeiros *et al.* 1986, Tomich 1986, Cuddihy and Stone 1990, Wagner *et al.* 1990).

*Bos taurus* (cattle)

A native to northern Africa and southwestern Asia, cattle were introduced to Hawaii in 1773 (Stone 1985). In 1794, King Kamehameha I allowed expansive feral herds to grow by a decree that prohibited cattle hunting (Smith 1985, Cuddihy and Stone 1990). In 1848, land was made available to individuals, and large and small ranching enterprises began (Smith 1985, Stone 1985, Cuddihy and Stone 1990). So much land was cleared that rainfall amounts decreased and rainfall distribution patterns changed (Wenkam 1969). The introductions of non-native forest taxa followed in attempts to conserve watersheds (Smith 1985). Large ranches of many thousands of acres were established on Maui and Hawaii. Lands acquired for these ranches were privately owned, removed from Forest Reserves or conservation districts, or leased by the State (Smith 1985, Cuddihy and Stone 1990).

On the Big Island, large ranching operations are of major economic importance (Loope and Scowcroft 1985). Most cattle grazing occurs on privately managed land. Cattle, like other grazers and browsers, consume and trample native vegetation, erode soil, and degrade the environment.

The effects of livestock degradation persist in most natural habitats. Alien seeds transported by cattle are dispersed in degraded grassland and forests, and these introduced taxa remain long after the animals are removed. Hunting of feral cattle is no longer allowed in Hawaii (Hawaii DLNR1985).

*Capra hircus* (goats)

Goats were introduced to the Hawaiian Islands in 1792 from the Middle East and India (Stone 1985, Cuddihy and Stone 1990). Feral populations of goats have occurred for 100-175 years and currently persist on five of the islands (Kauai, Oahu, Molokai, Maui, and the Big Island).

High reproductive capabilities have allowed goat populations to inhabit various habitats, ranging from low to mid elevation dry forests, mountain parklands, subalpine woodlands, and alpine grasslands. Browsing and trampling of these areas increase soil erosion, decrease native plant taxa, and promote invasion of alien plants (Stone *et al.* 1985).

Goats are able to forage in rugged terrain where even the most isolated native taxa are vulnerable (Tomich 1986, Culliney 1988, Cuddihy and Stone 1990). Goats were drastically reduced on Mauna Kea in 1981, following a lawsuit against the Department of Land and Natural Resources aimed at establishing critical habitat for the endangered honeycreeper *Loxioides bailleui* (palila) (Juvik and Juvik 1984).

Goats are a managed game animal in Hawaii, and hunting is permitted at certain times dependent on the area (Hawaii DLNR 1985), although it seems to have little impact on numbers.

*Ovis aries* (sheep)

Five rams and two ewes were introduced to the Big Island from California by Captain Vancouver in 1791, and later stock was brought from Australia, Germany and the Mediterranean for sheep production (Tomich 1986, Cuddihy and Stone 1990). Sheep were established on leeward Mauna Kea in 1876 (Cuddihy and Stone 1990).

Able to acquire the majority of their water needs from vegetation consumption, sheep inhabited dry forests in remote regions of Mauna Kea and Mauna Loa, including the saddle between the two volcanos. Sheep graze, browse, and trample native vegetation, decimating large areas of native forest and shrubland. Opportunistic taxa invade disturbed sites, the seed carried in sheep wool coats. Today after centuries of degradation, the lands that Douglas described as "highly picturesque and sublime" are very different. Top soil is eroded, moisture regimes and micro-environments are altered, and native plant and animal taxa are sacrificed.

Lacking natural predators, sheep populations expanded to about 40,000 animals by 1930 (Bryan 1937, Scowcroft and Giffin 1983). Large areas were devastated by both sheep and goats as seedling establishment of *Sophora chrysophylla* (Salisb.) Seem. (mamane, mamani) was greatly decreased, ultimately reducing the tree line elevation on Mauna Kea and impacting the palila, an endangered honeycreeper (Warner 1960, Juvik and Juvik 1984). A Federal court ordered complete removal of feral sheep and goats from Mauna Kea in 1979 and 1981 because they were causing degradation of palila critical habitat. These animals were considered removed in July 1981 (Cuddihy and Stone 1990).

Throughout the past 40 years, attempts to protect the vegetation of Mauna Kea and the saddle from sheep have been sporadically effectual. Hunting in the late 1940's and early 1950's reduced the herds from 40,000 to about 200 animals (Juvik and Juvik 1984). In 1970, the sheep population grew to about 1,500 animals, as public interest in protecting sheep (mouflon and mouflon hybrids) as game animals allowed the herds to recover (Stone 1985, Cuddihy and Stone 1990). Numbers of feral sheep must be regulated to protect the remaining native taxa. Natural re-establishment of native vegetation may be possible if animal numbers are carefully monitored and seedling establishment is plausible.

*Ovis musimon* (mouflon)

Mouflon sheep, established on Lanai and Hawaii, have similar effects on native vegetation as feral sheep, but usually travel in smaller groups. On the Big Island, they were released on Mauna Kea, where they inhabit mamane (*Sophora chrysophylla*) forests, in 1962, and subsequently introduced in the Kau District, where they inhabit montane and subalpine ohia (*Metrosideros polymorpha*) forests. A Federal court ordered removal of mouflon from Mauna Kea in 1986 and 1988 (Cuddihy and Stone 1990).

*Axis axis* (axis deer)

Axis deer, native to Sri Lanka and India, were first introduced on the island of Molokai in 1868 as a game animal (Tomich 1986). Their reproduction was so successful that hunting was permitted within 30 years of introduction. By the turn of the century, 3,000 animals were eliminated. Tomich (1986) reported that, at the time, management strategies indicated that the deer would not access native forest while numbers could be controlled by hunting. Therefore, the animals were introduced to Oahu, Lanai, and Maui as well. Hunting of axis deer is allowed only on Molokai and Lanai during 2 months of the year (Tomich 1986). The animals have invaded and destroyed native forests, repeating the scenario of alien plant invasion and reducing the propagation and establishment of native vegetation.

*Rattus rattus, R. exulans, R. norvegicus,* and *Mus musculus* (rats and mice)

Where humans inhabit an area so do rats and mice. Of the four rodent species introduced to the Hawaiian Islands, the arboreal roof or black rat has the greatest impact on native vegetation and animals (Stone and Loope 1987). Roof rats, Polynesian rats, Norway rats, and house mice occupy fields, dry and mesic forests, and human habitations. Extended periods of fruit production provide a continuous food source for growing rodent populations (Stone 1985, Cuddihy and Stone 1990). Because rats and mice utilize fruits from native taxa, especially those fleshy and palatable, they may reduce reproductive rates of rare populations both near human habitation and in remote areas on most of the islands. Black rats damage fruits and flowers, and strip bark from stems of selected taxa, damaging the individuals (Scowcroft and Sakai 1984).

## APPENDIX C - RECOVERY PRIORITY SYSTEM

The Recovery Priority System uses the criteria of (1) degree of threat, (2) recovery potential and (3) taxonomy (level of genetic distinctiveness). By applying these criteria, all listed species are assigned a species priority number of 1 through 18. A fourth factor, conflict, is a supplementary element in determining what actions are to be implemented for recovery of a species. In addition, the fourth factor gives priority, within each category, in preparation of recovery plans to those species that are, or may be in conflict with construction or development projects. Thus, the species retains its numerical rank and acquires the letter designation of "C," indicating conflict (1C-18C) (48 Federal Register 43098.

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

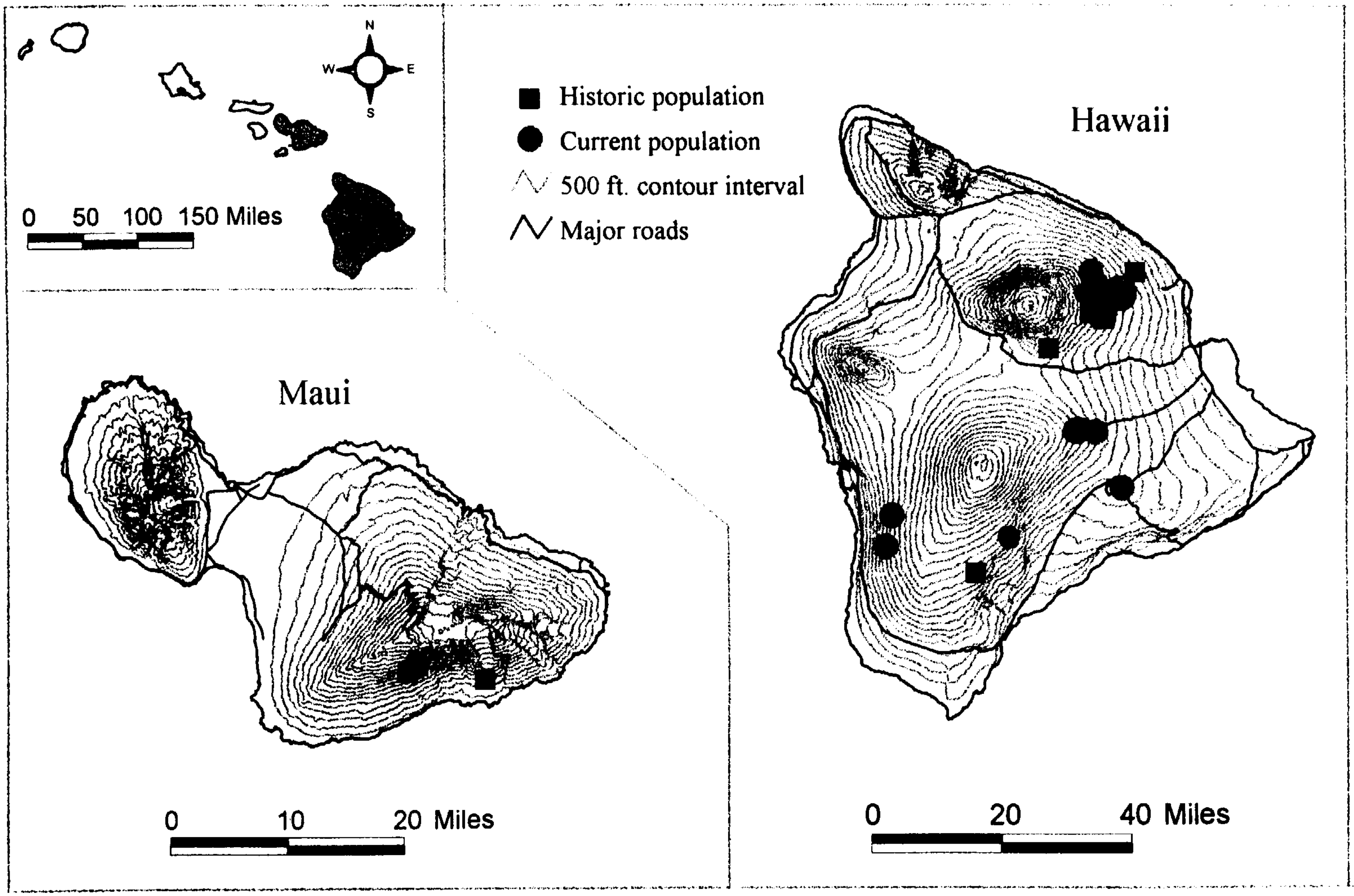


Figure 1. Distribution of *Clermontia lindseyana*.

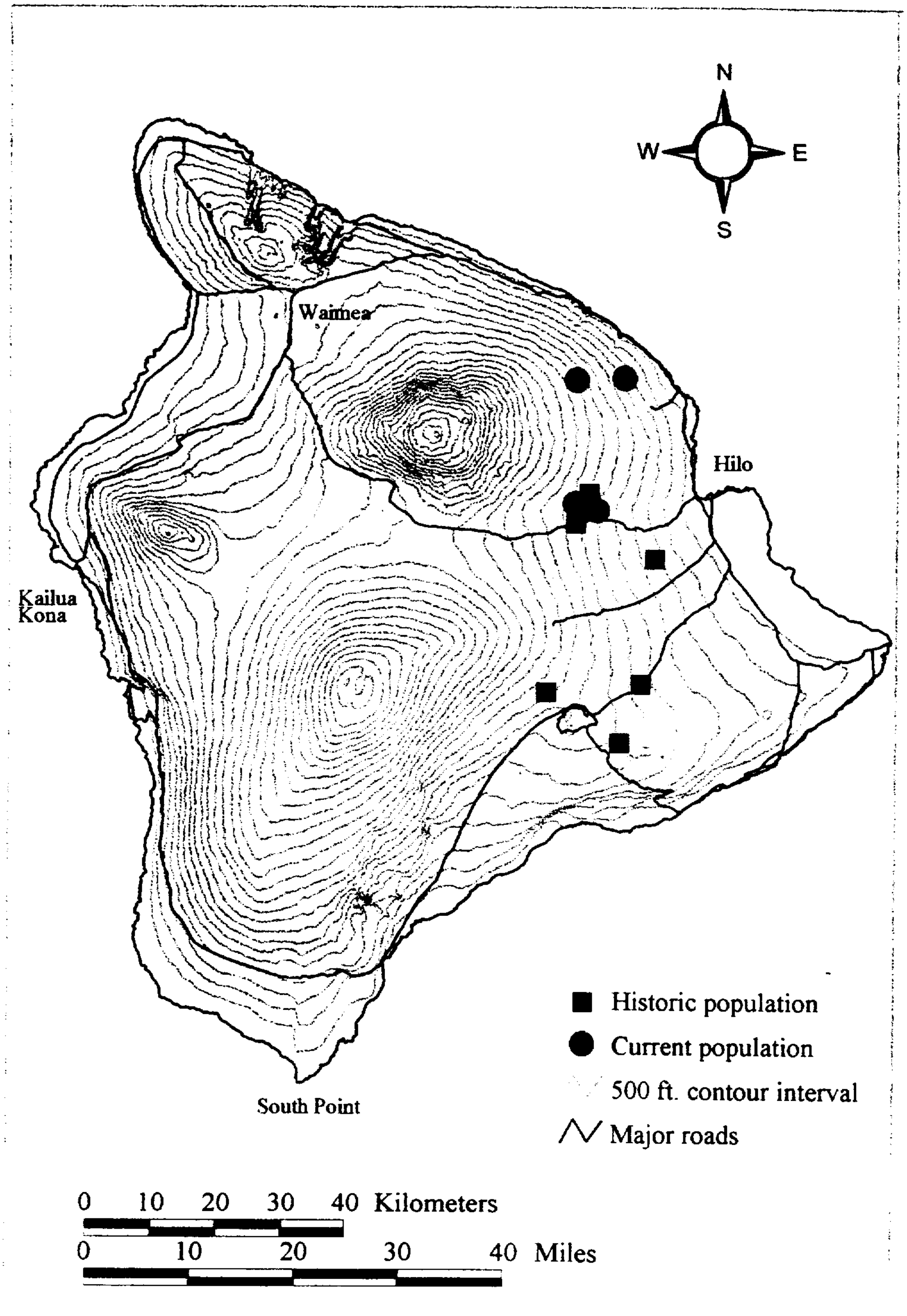


Figure 2. Distribution of *Clermontia peleana* subsp. *peleana*.

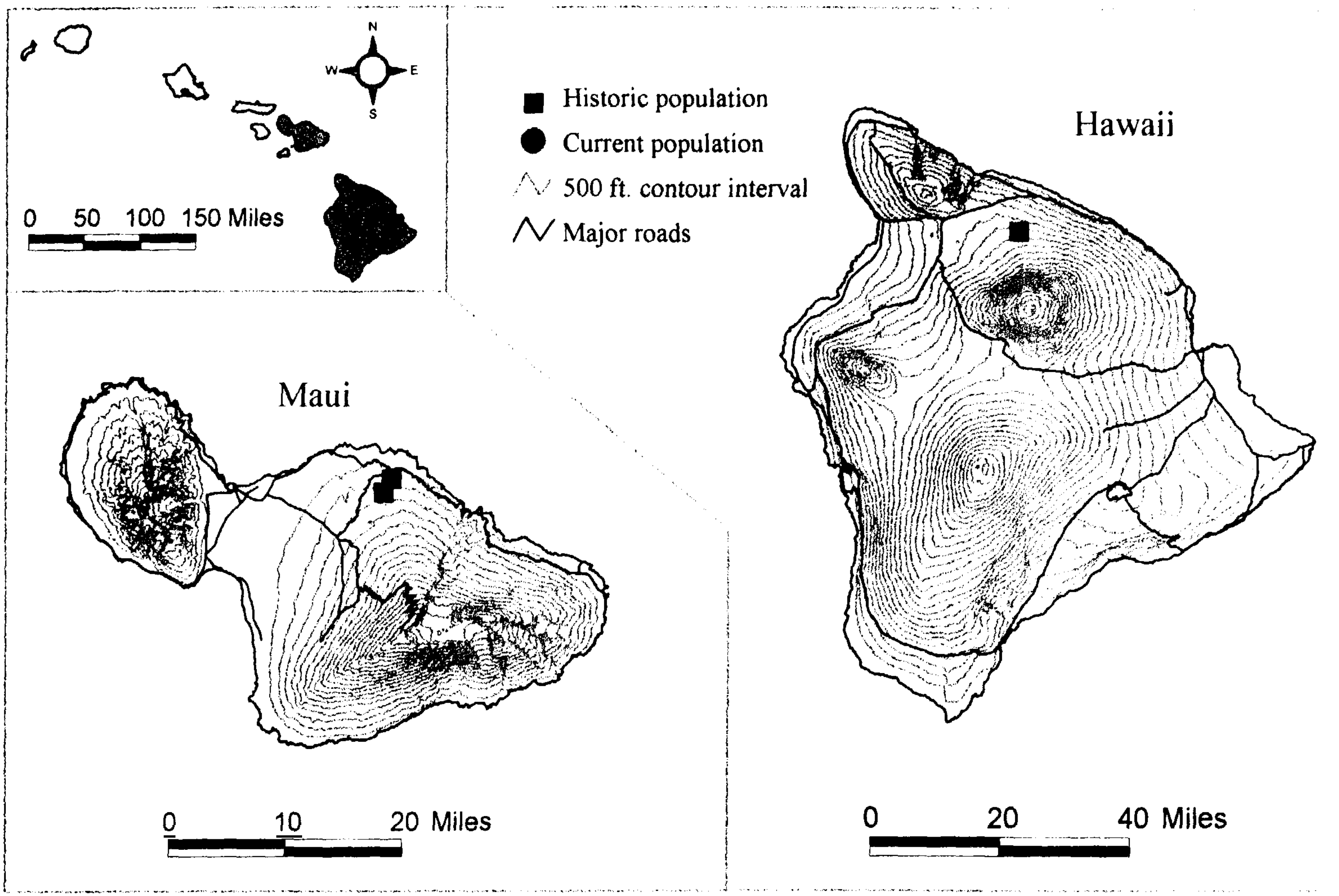


Figure 3. Distribution of *Clermontia pyrularia* subsp. *singuliflora*.

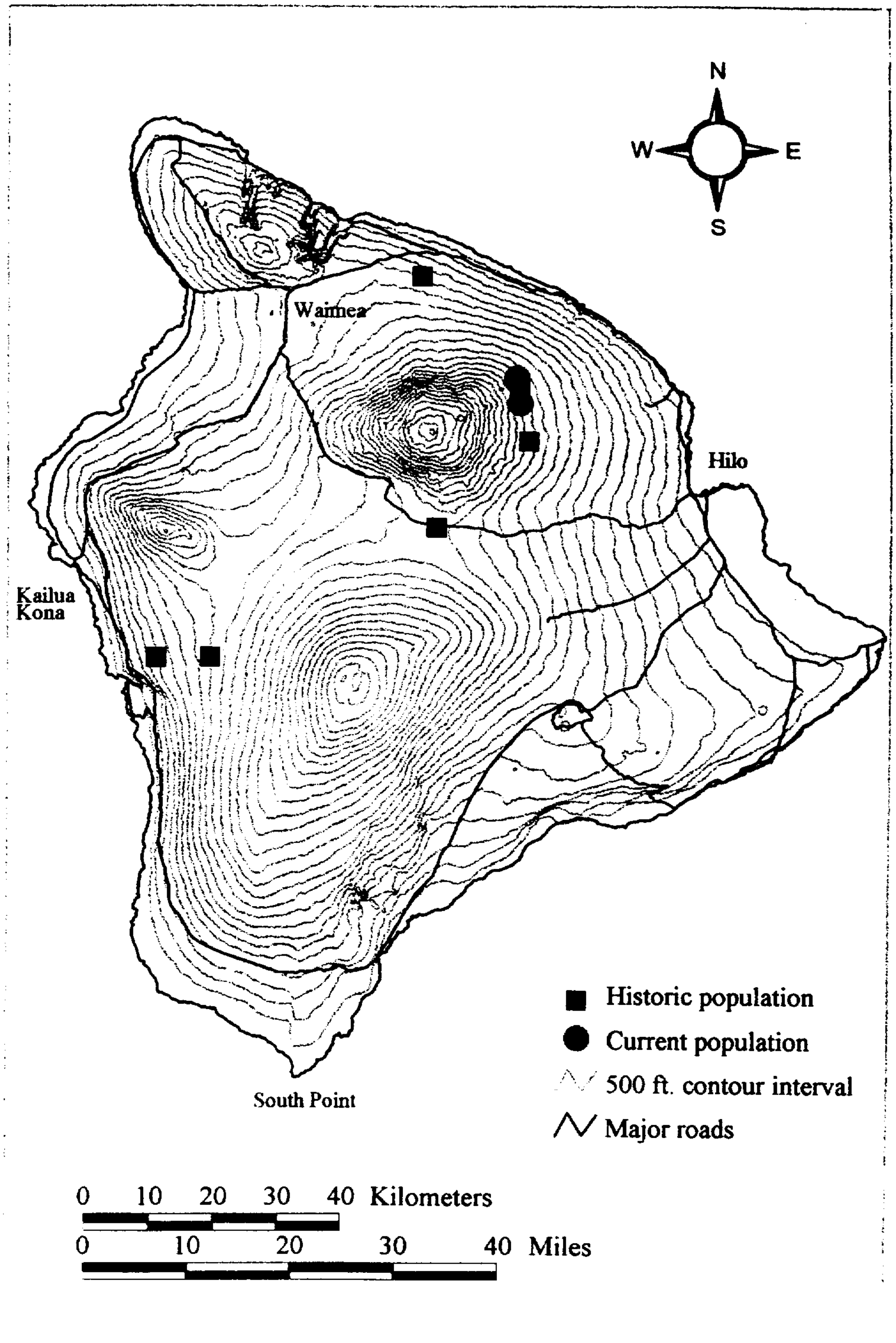


Figure 4. Distribution of *Clermontia pyrularia*.

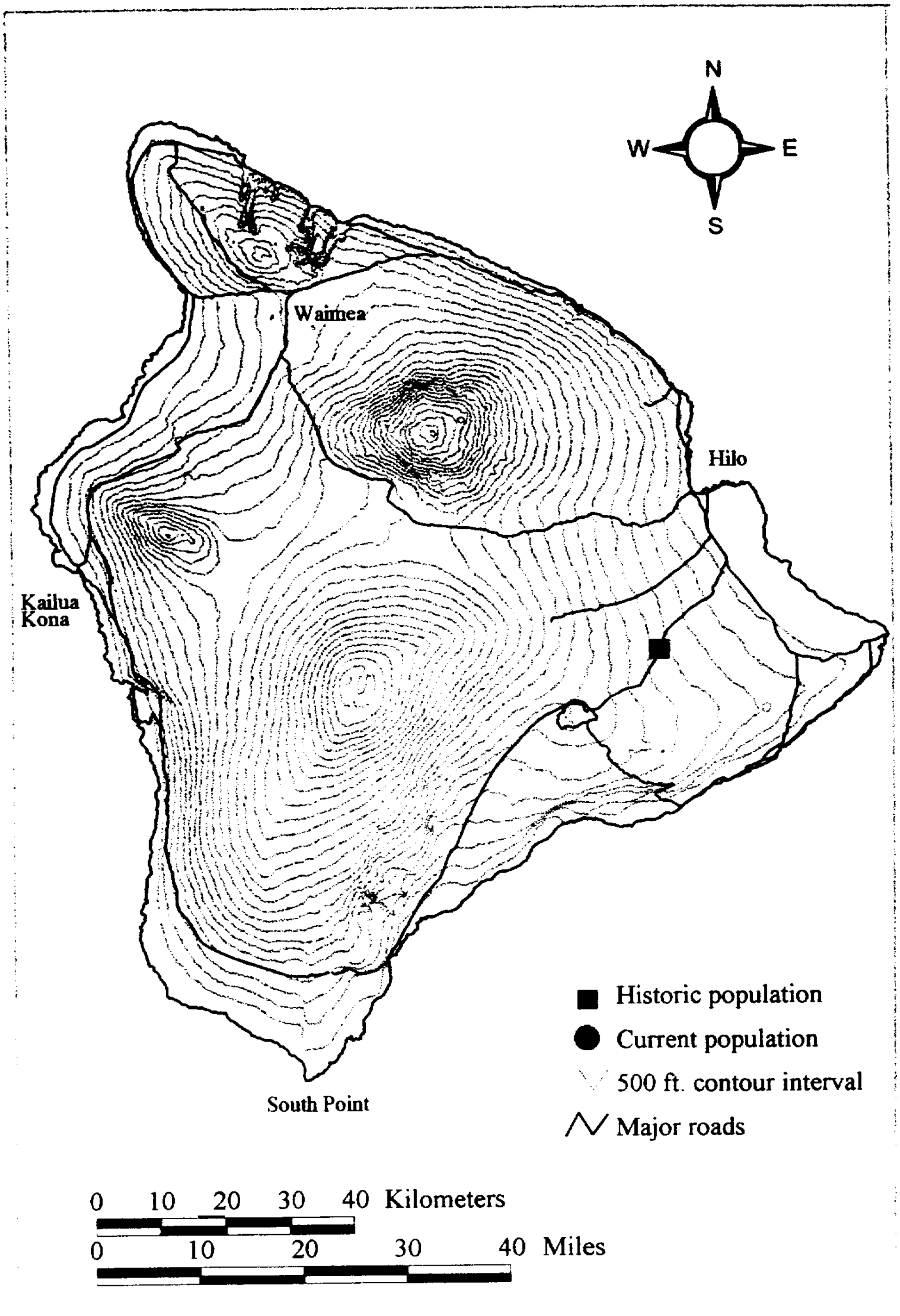


Figure 5. Distribution of *Cyanea copelandii* subsp. *copelandii*.

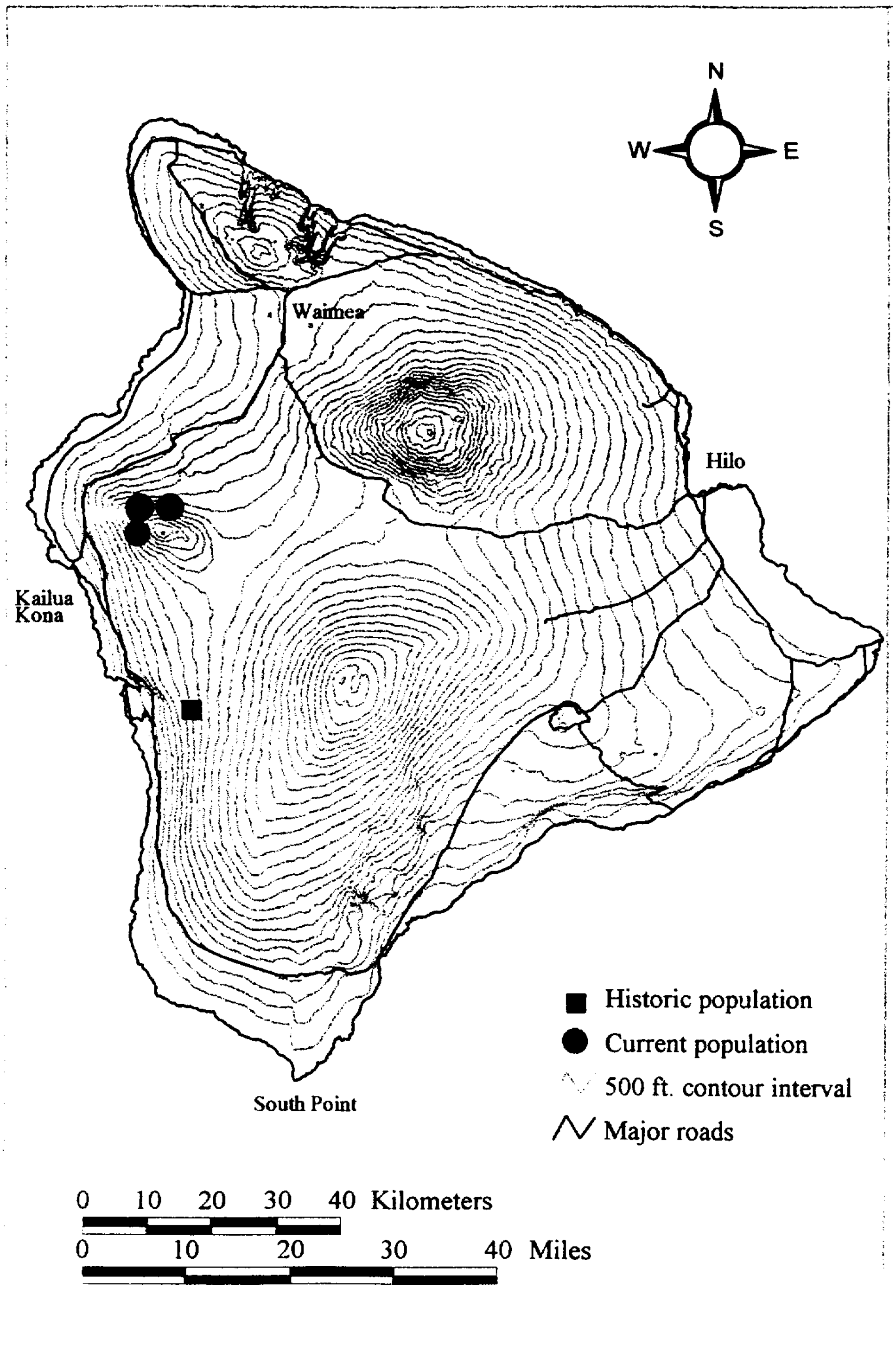


Figure 6. Distribution of *Cyanea hamatiflora* subsp. *carlsonii*.

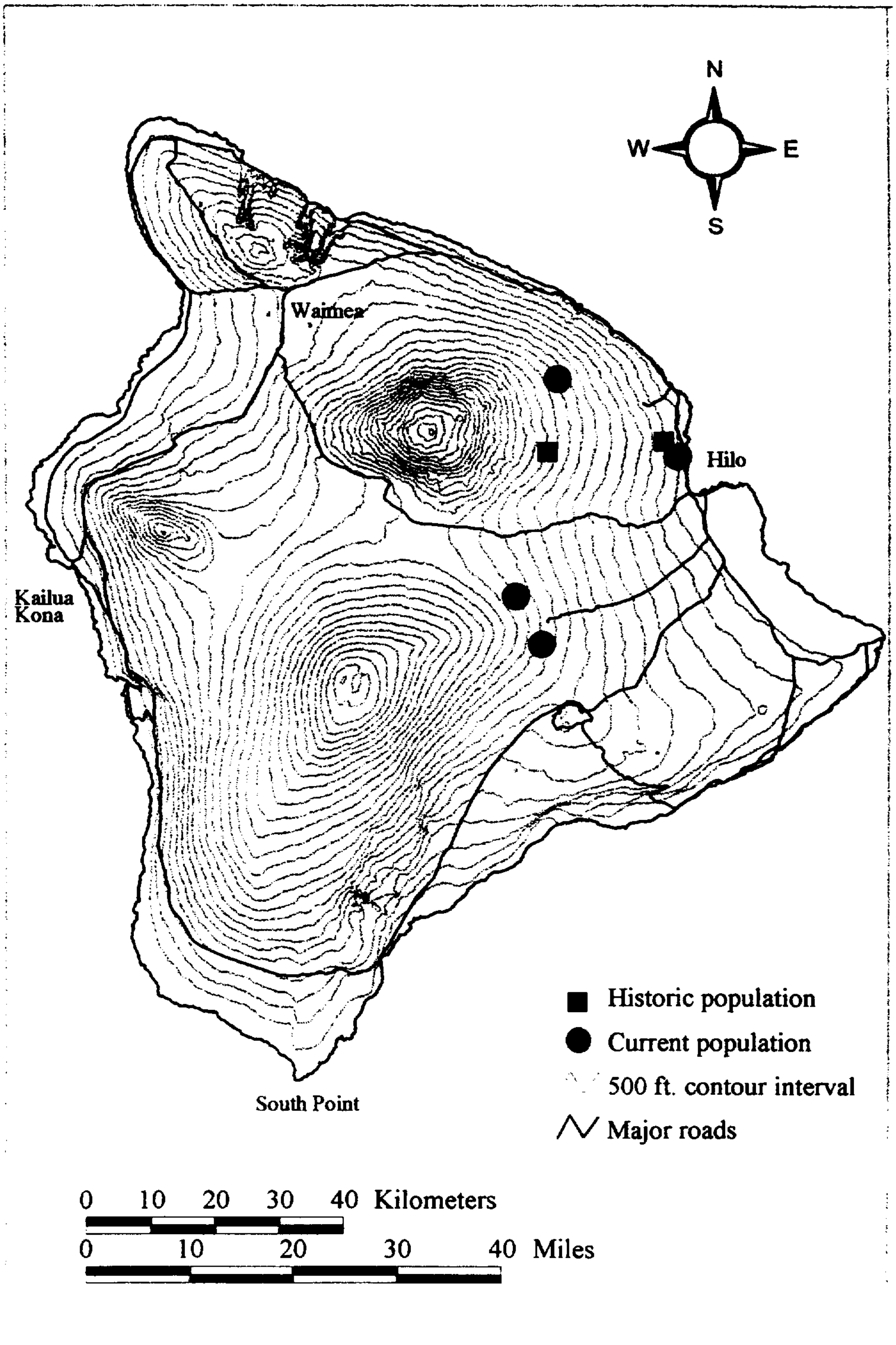


Figure 7. Distribution of *Cyanea shipmanii*.

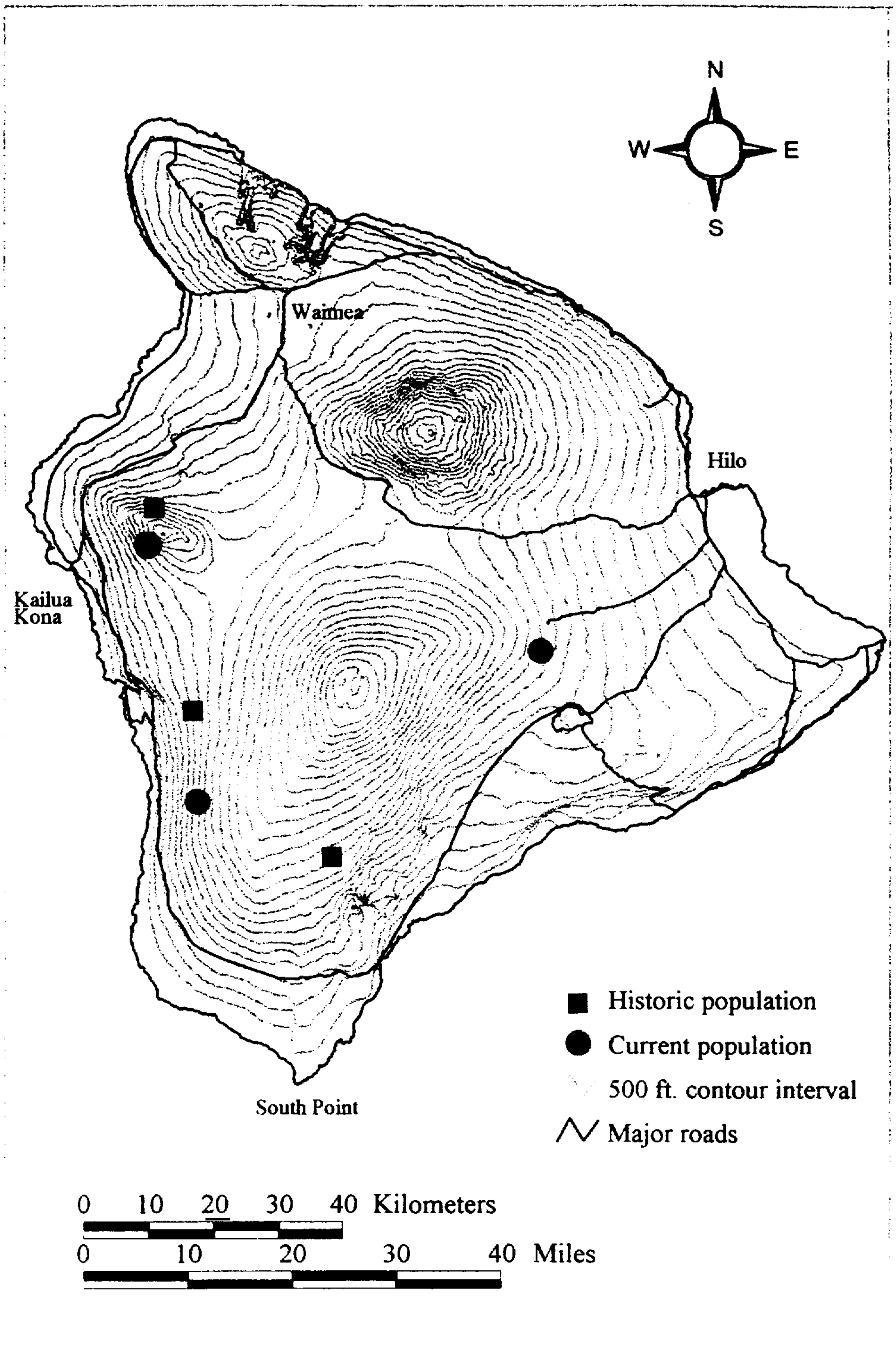


Figure 8. Distribution of *Cyanea stictophylla*.

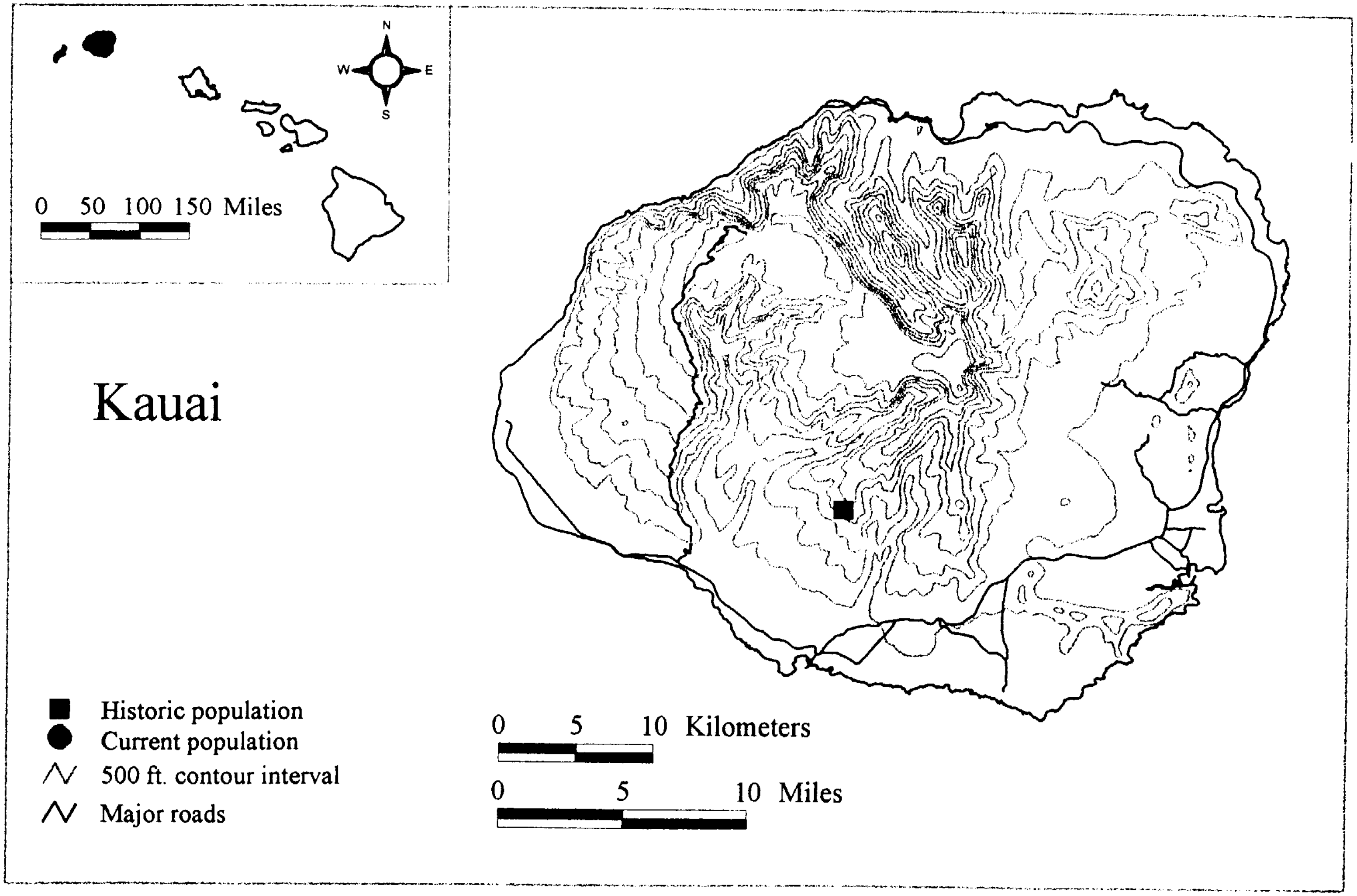


Figure 9. Distribution of *Delissea undulata* subsp. *kauaiensis*.

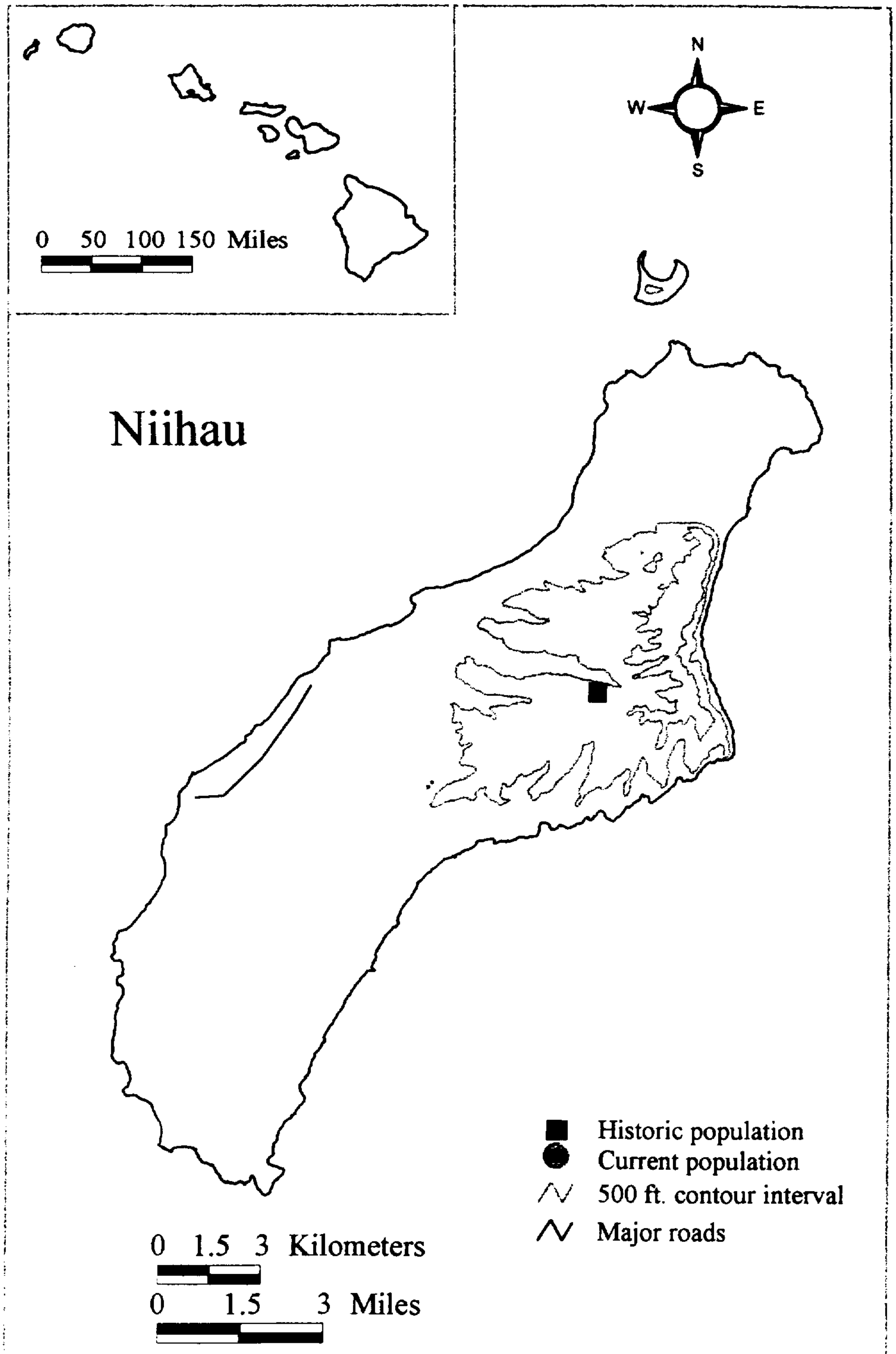


Figure 10. Distribution of *Delissea undulata* subsp. *niihauensis*.

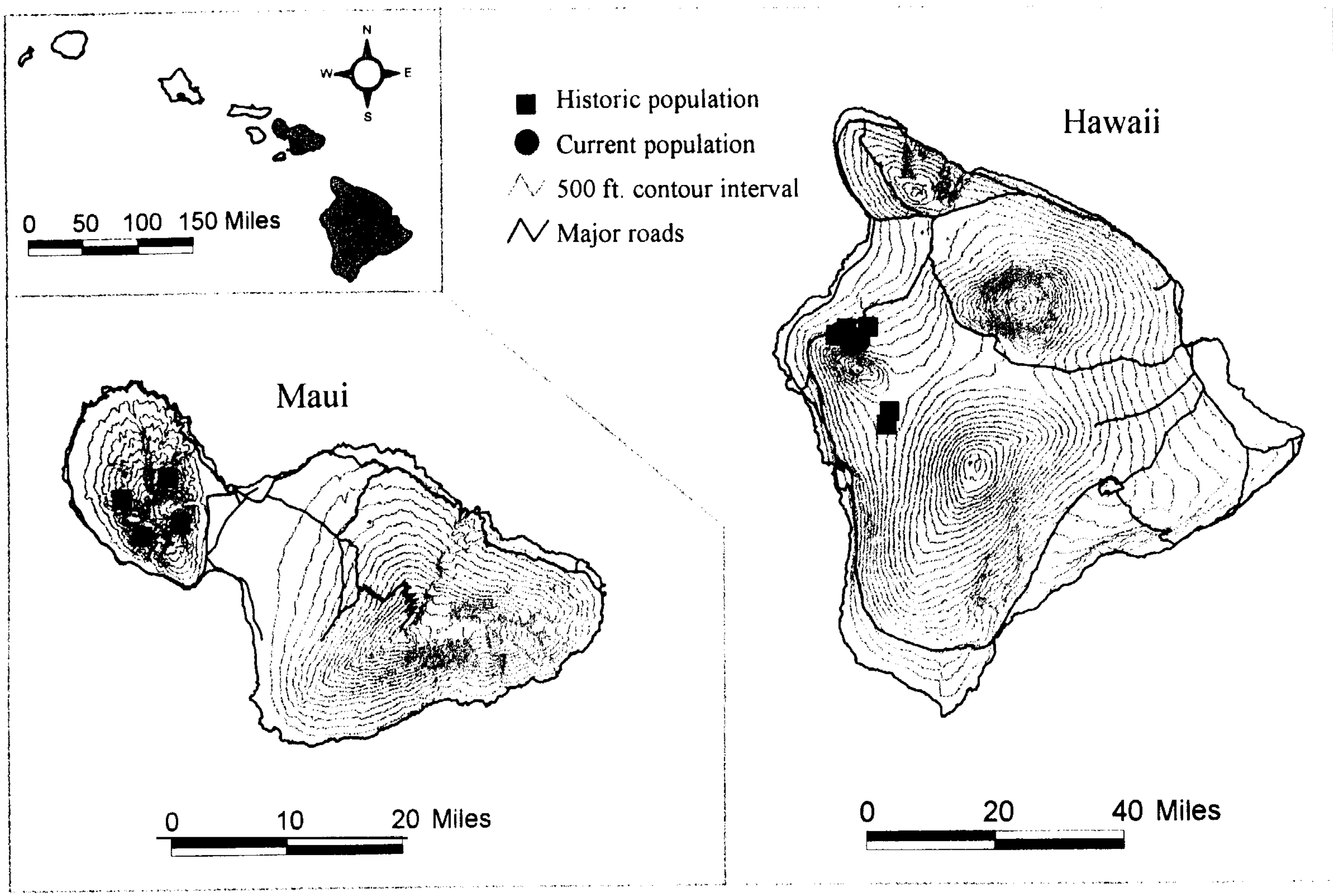


Figure 11. Distribution of *Delissea undulata* subsp. *undulata*.

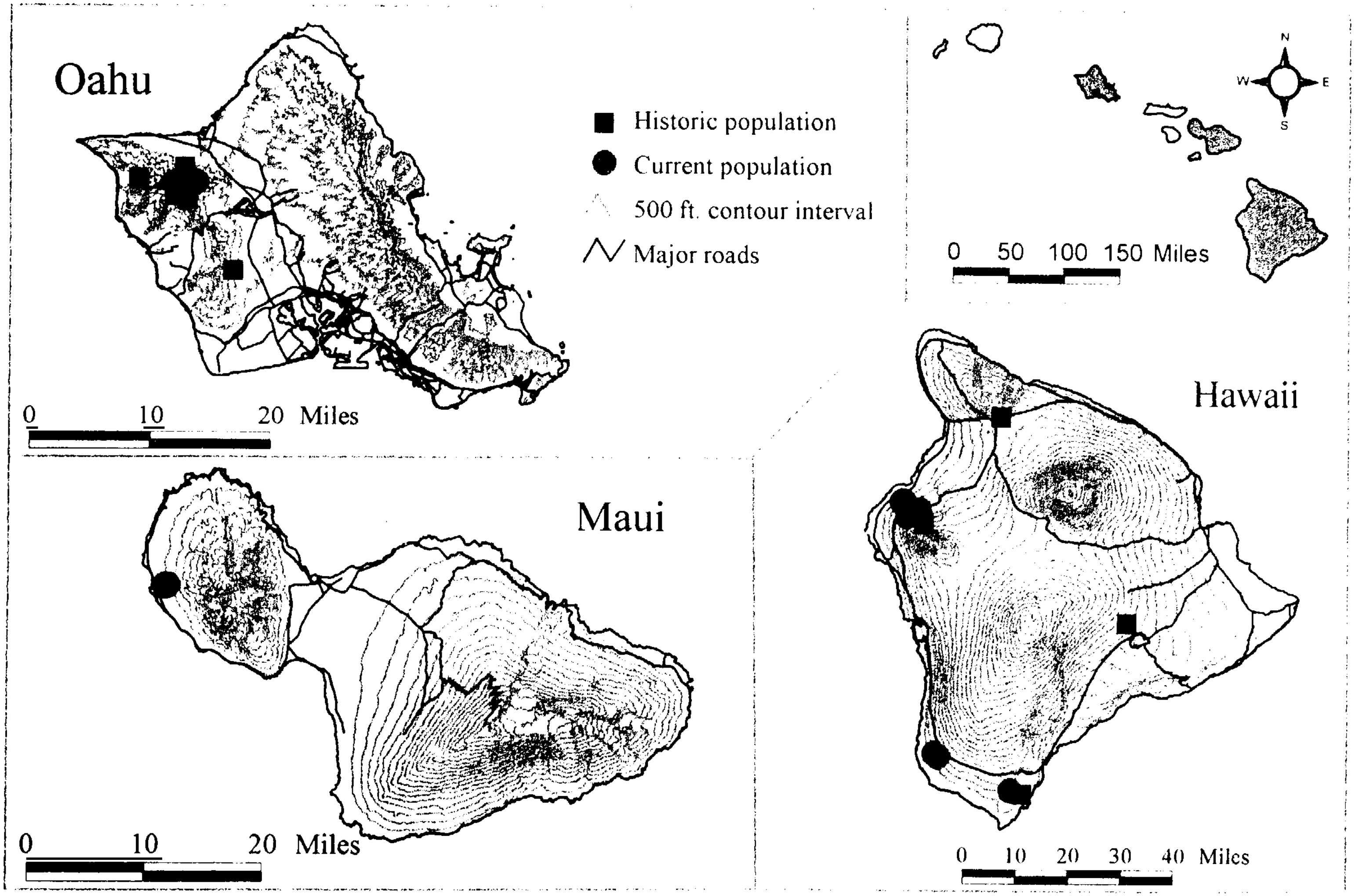


Figure 12. Distribution of *Colubrina oppositifolia*.

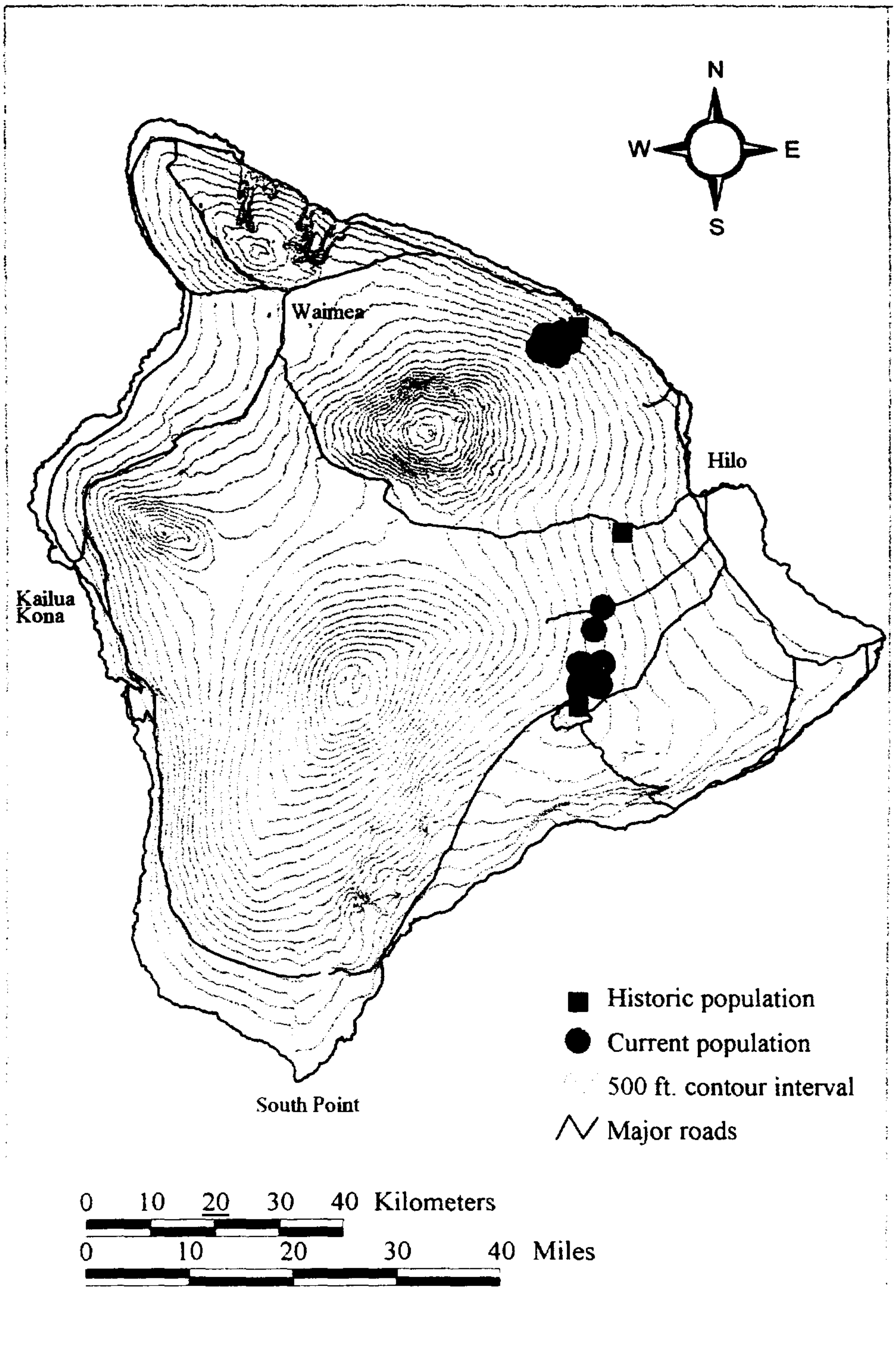


Figure 13. Distribution of *Cyrtandra giffardii*.

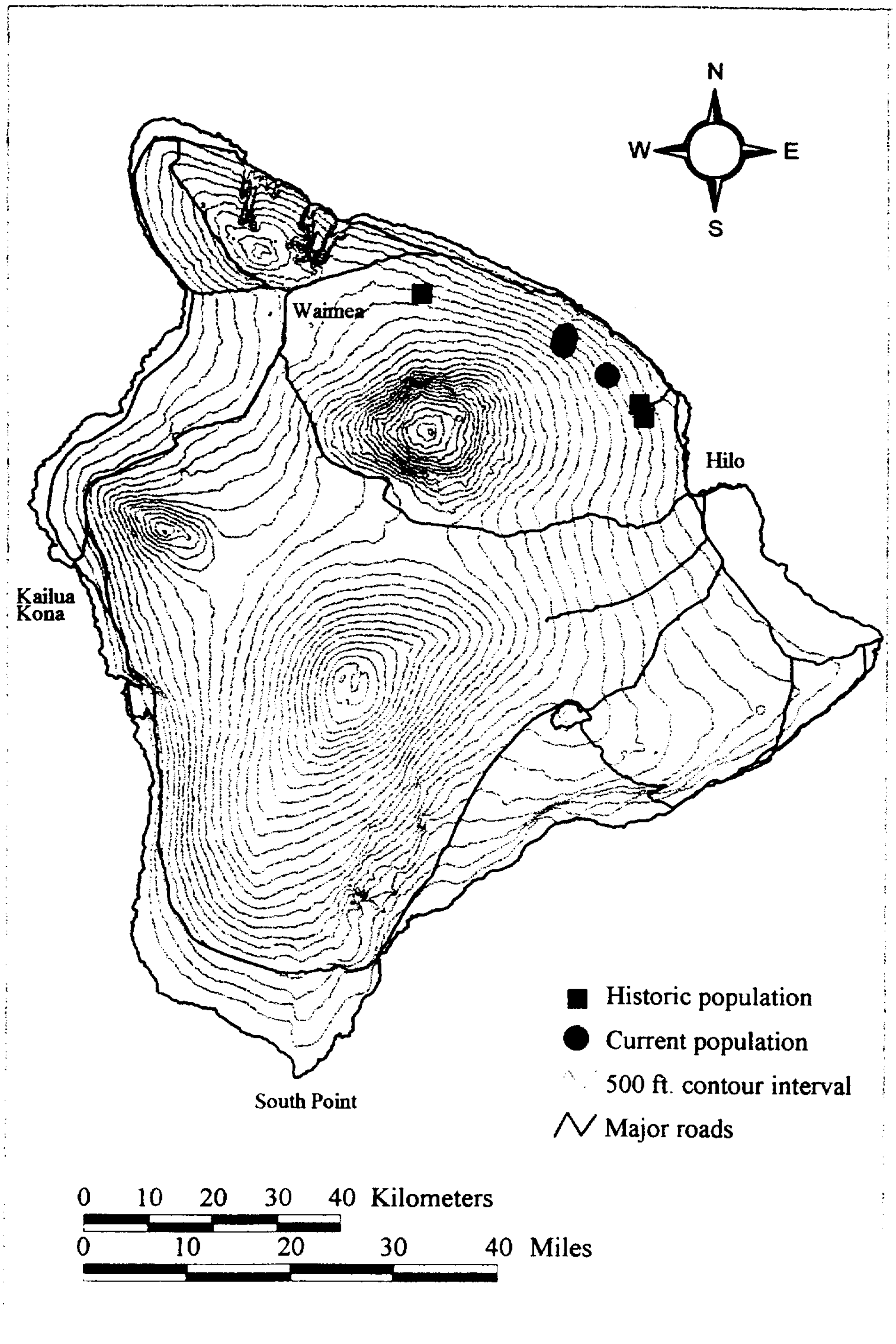


Figure 14. Distribution of *Cyrtandra tintinnabula*.

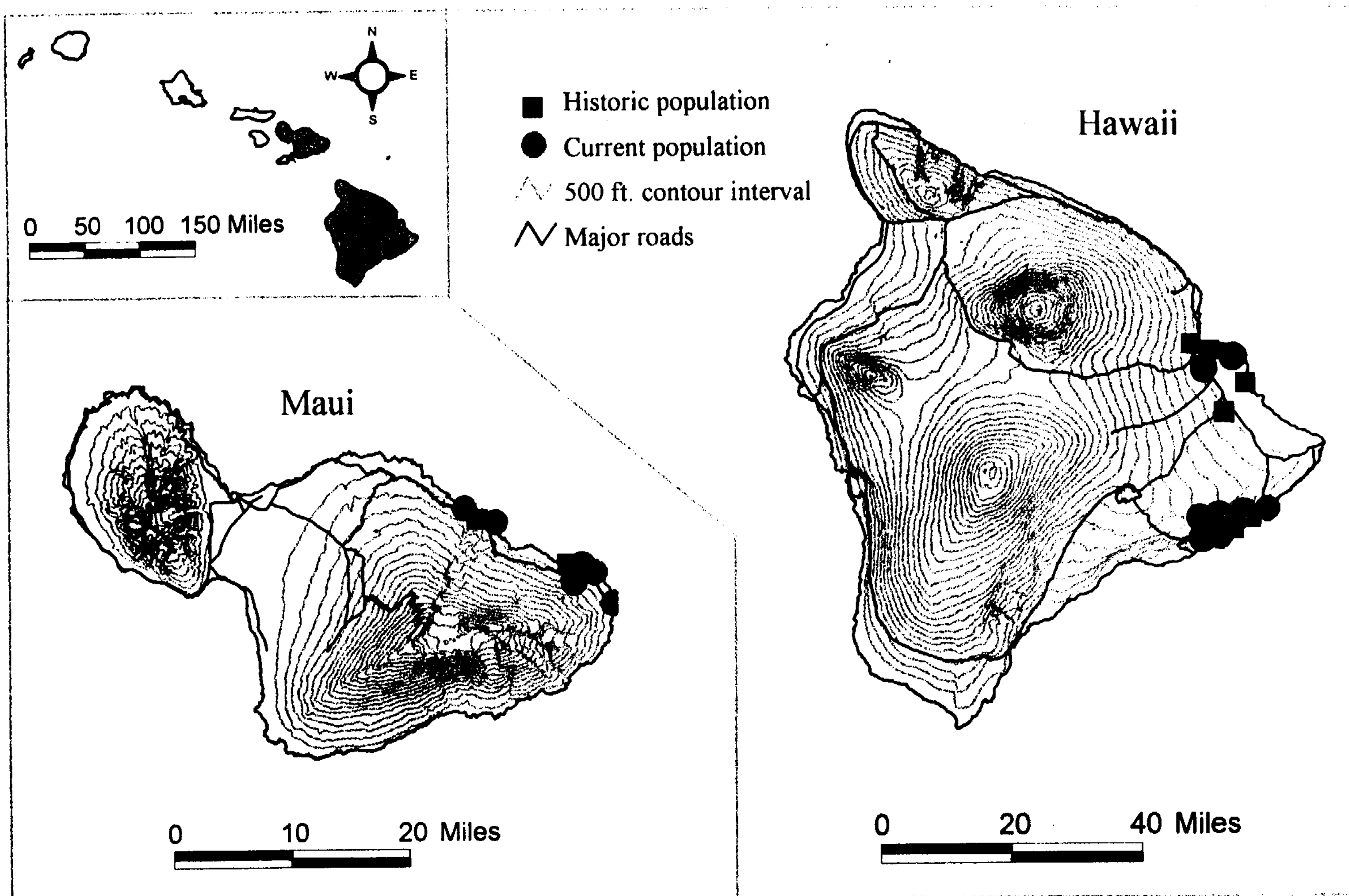


Figure 15a. Distribution of *Ischaemum byrone* (Maui and Hawaii).

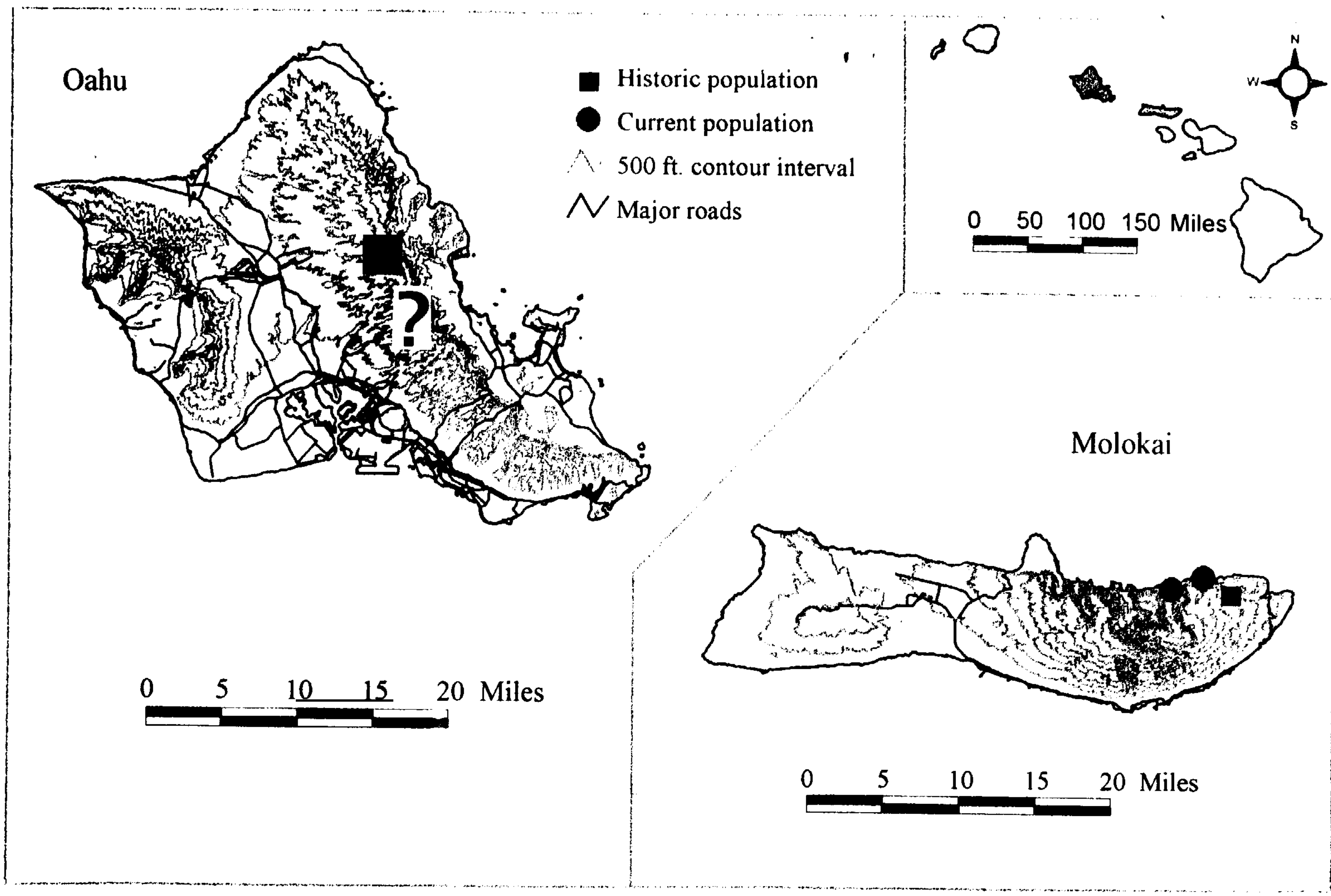


Figure 15b. Distribution of *Ischaemum byrone* (Oahu and Molokai).

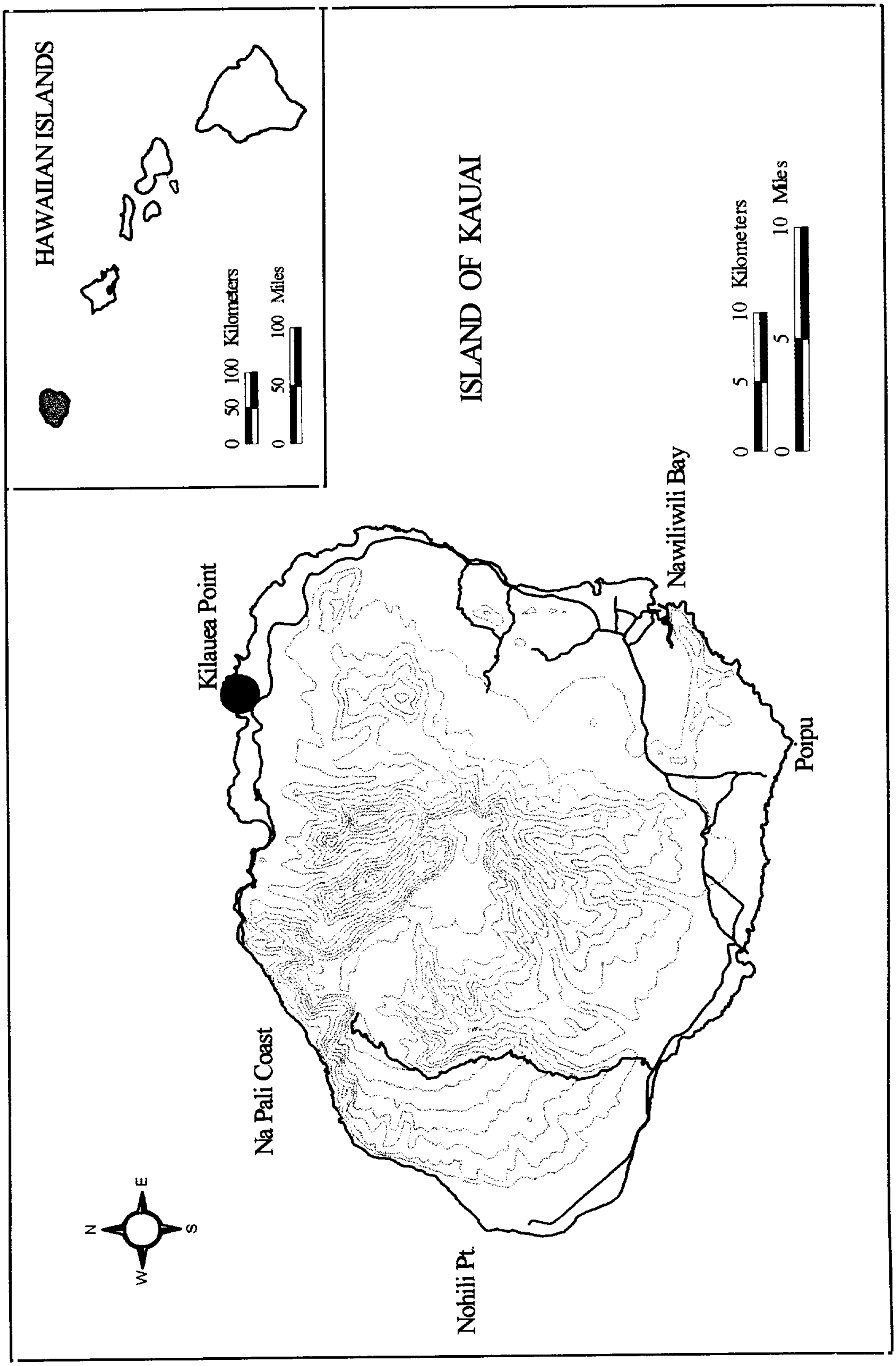


Figure 15c. Distribution of *Ischaemum byrone* (Kauai).

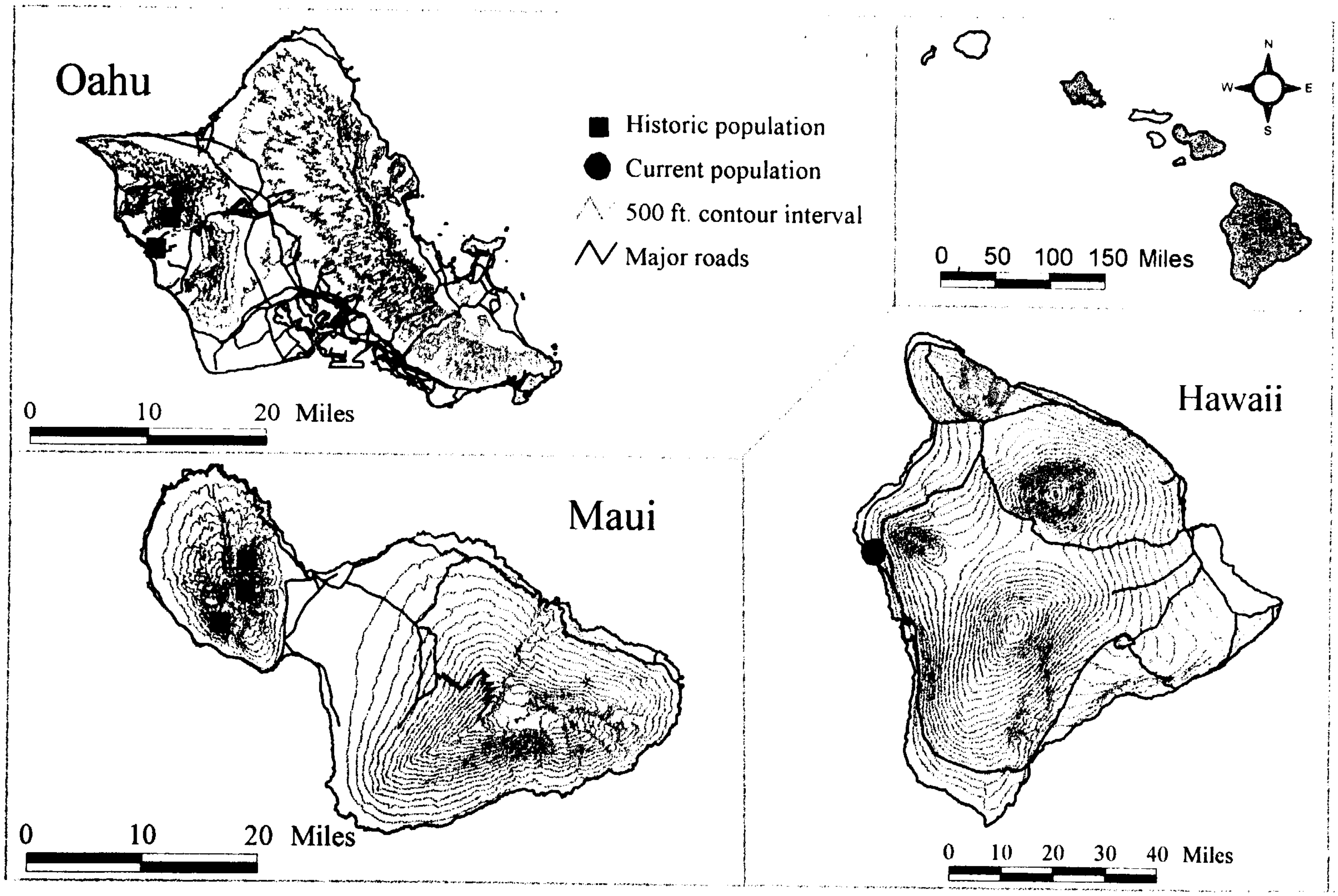


Figure 16. Distribution of *Isodendrion pyrifolium*.

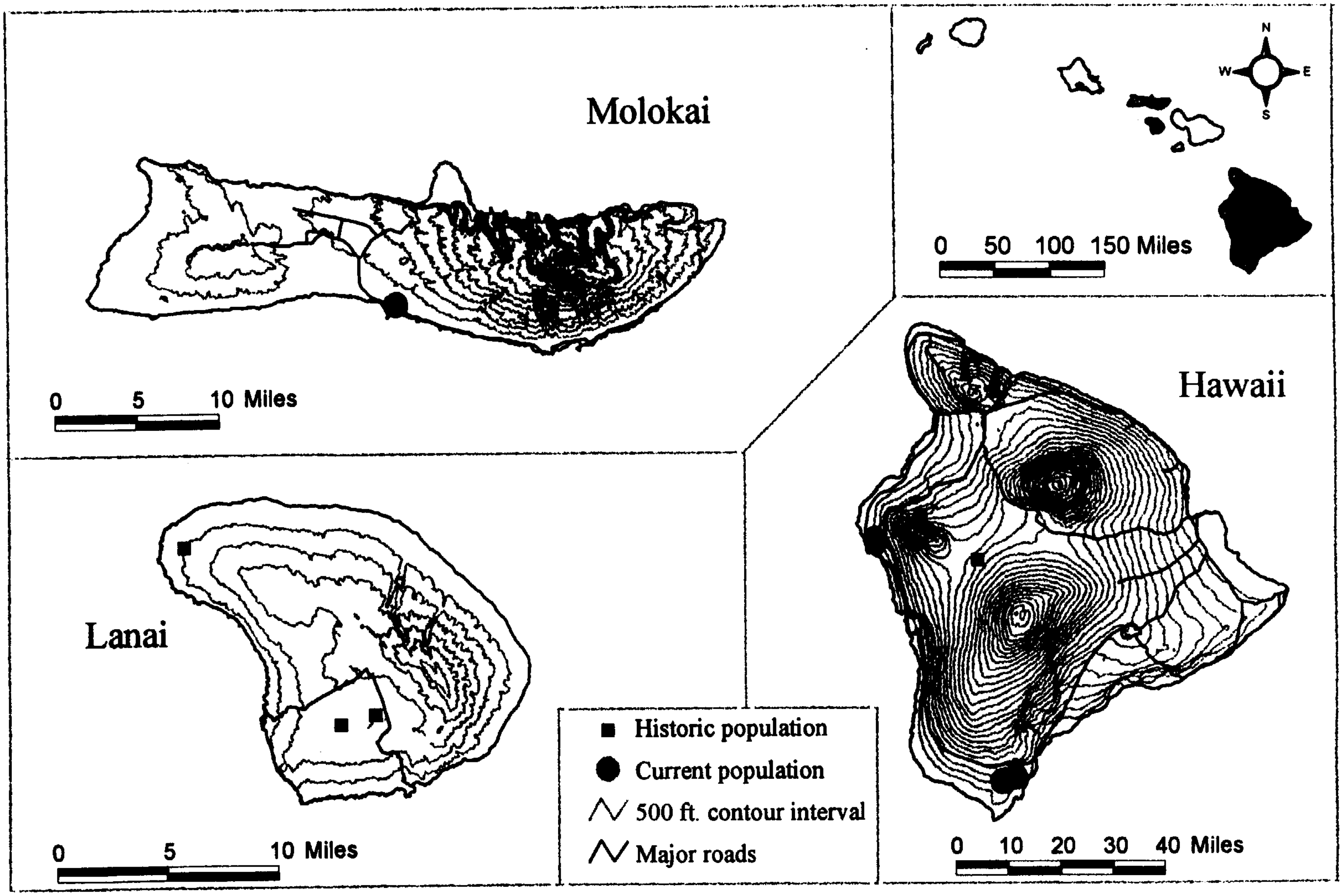


Figure 17. Distribution of *Mariscus fauriei*.

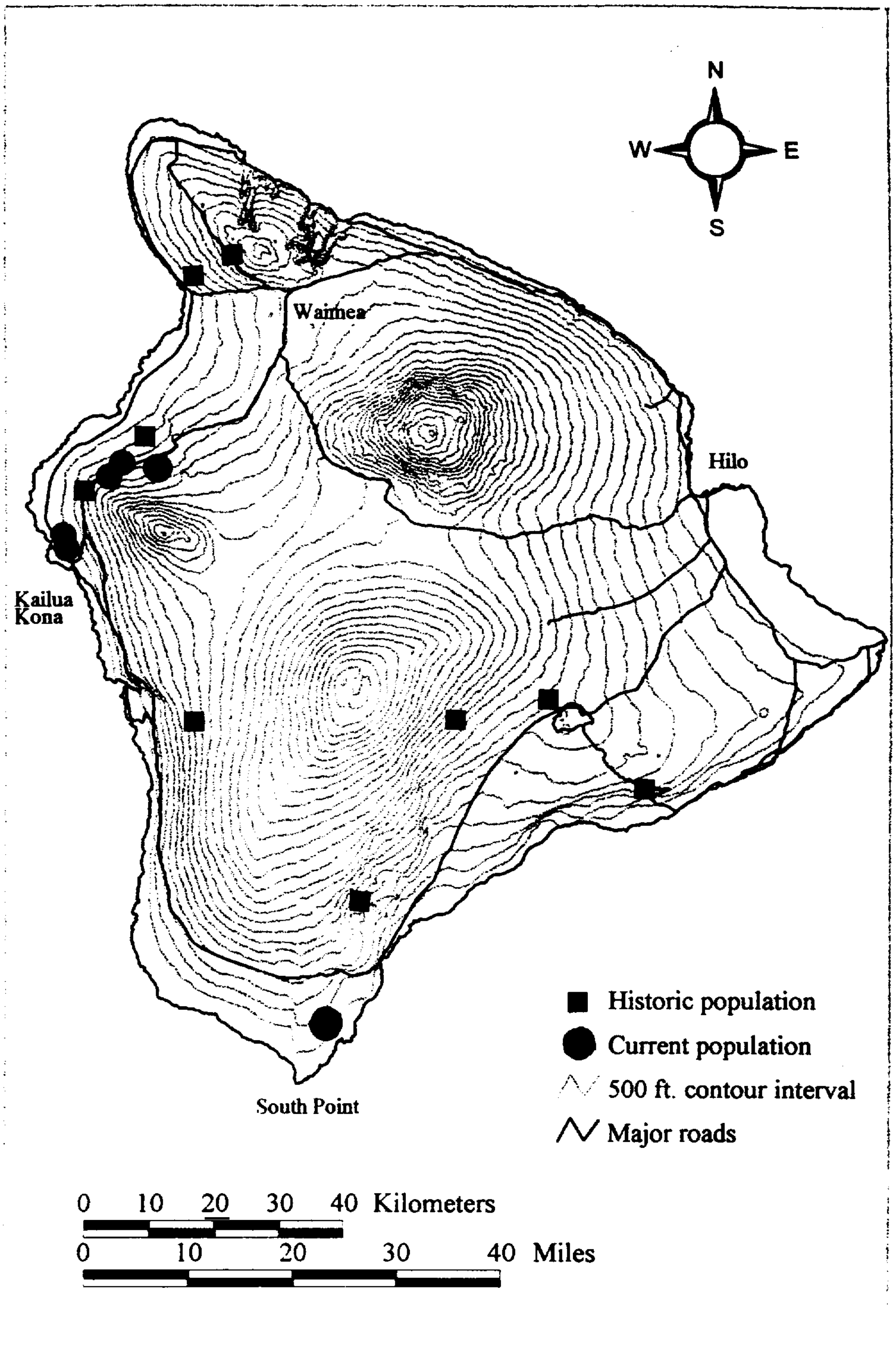


Figure 18. Distribution of *Nothocestrum breviflorum*.

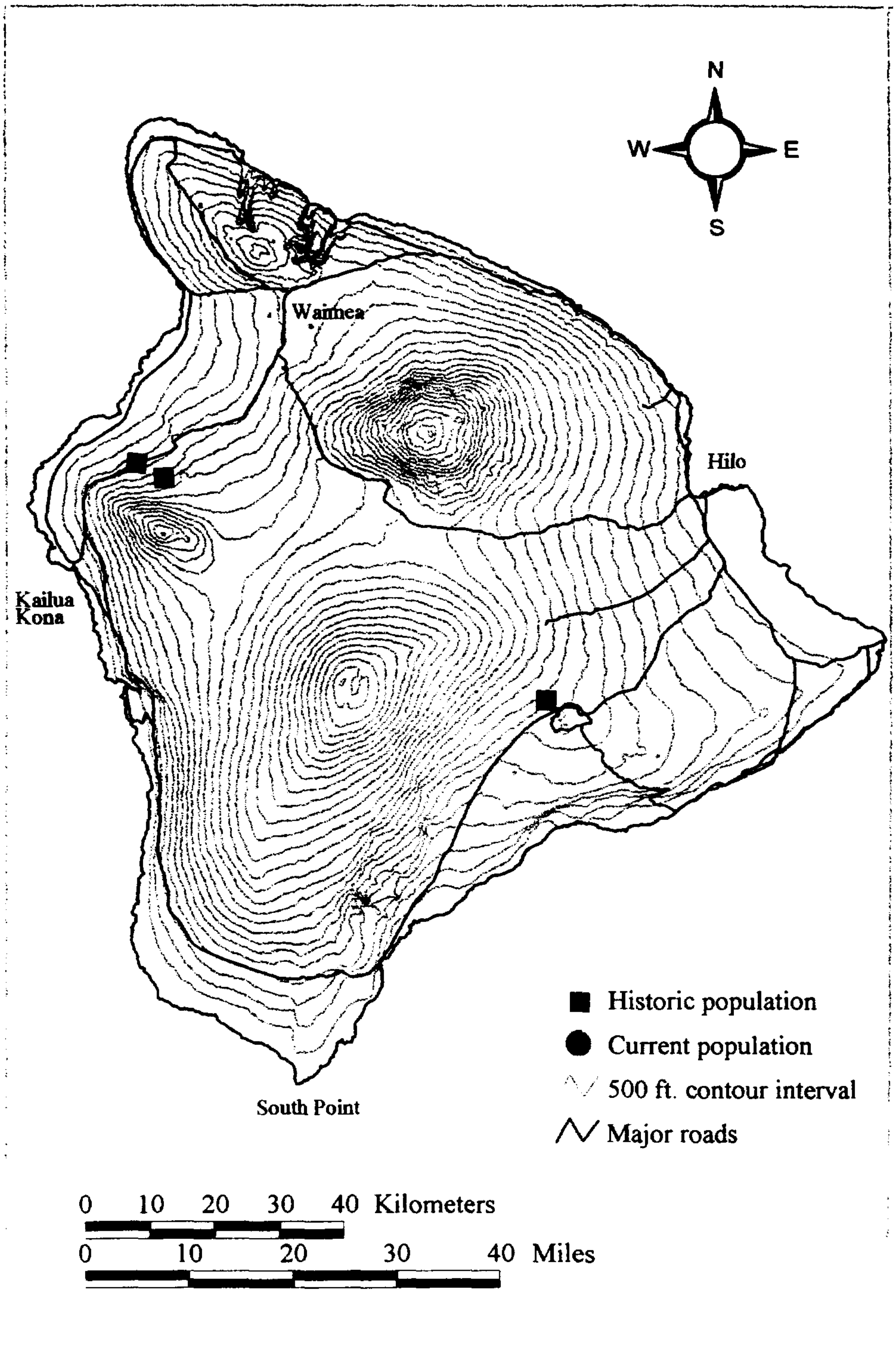


Figure 19. Distribution of *Ochrosia kilaueaensis*.

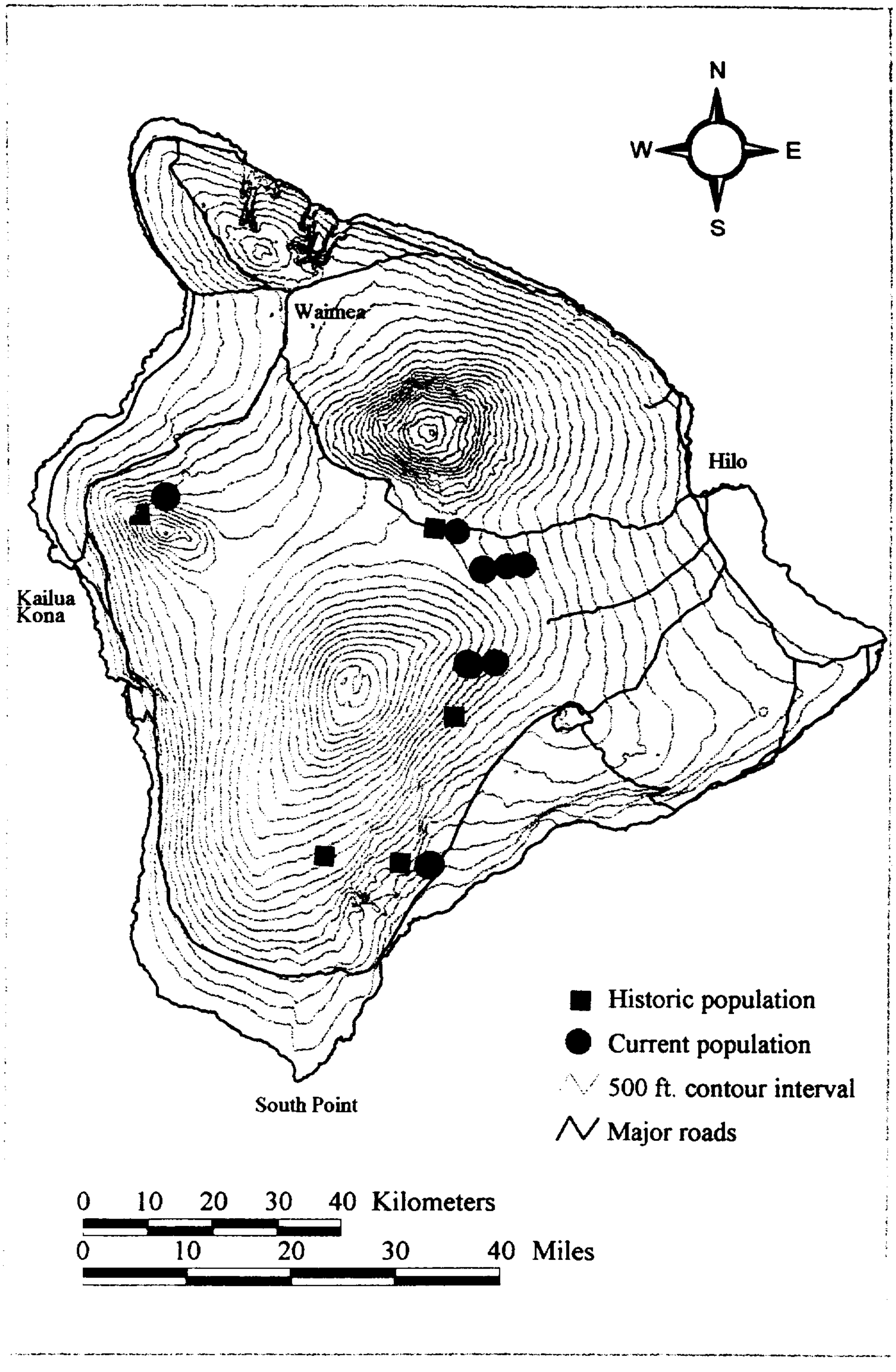


Figure 20. Distribution of *Plantago hawaiensis*.

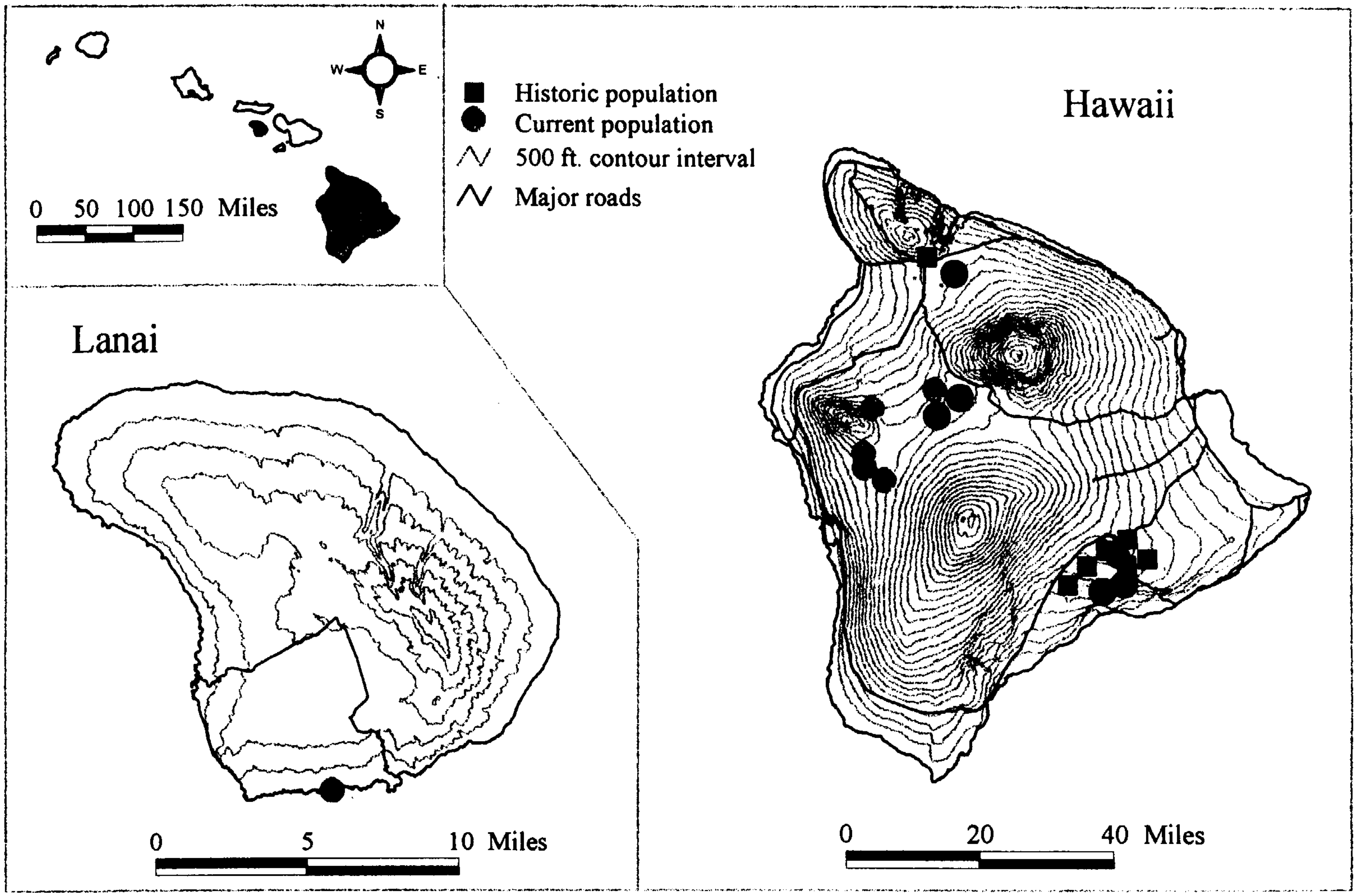


Figure 21. Distribution of *Portulaca sclerocarpa*.

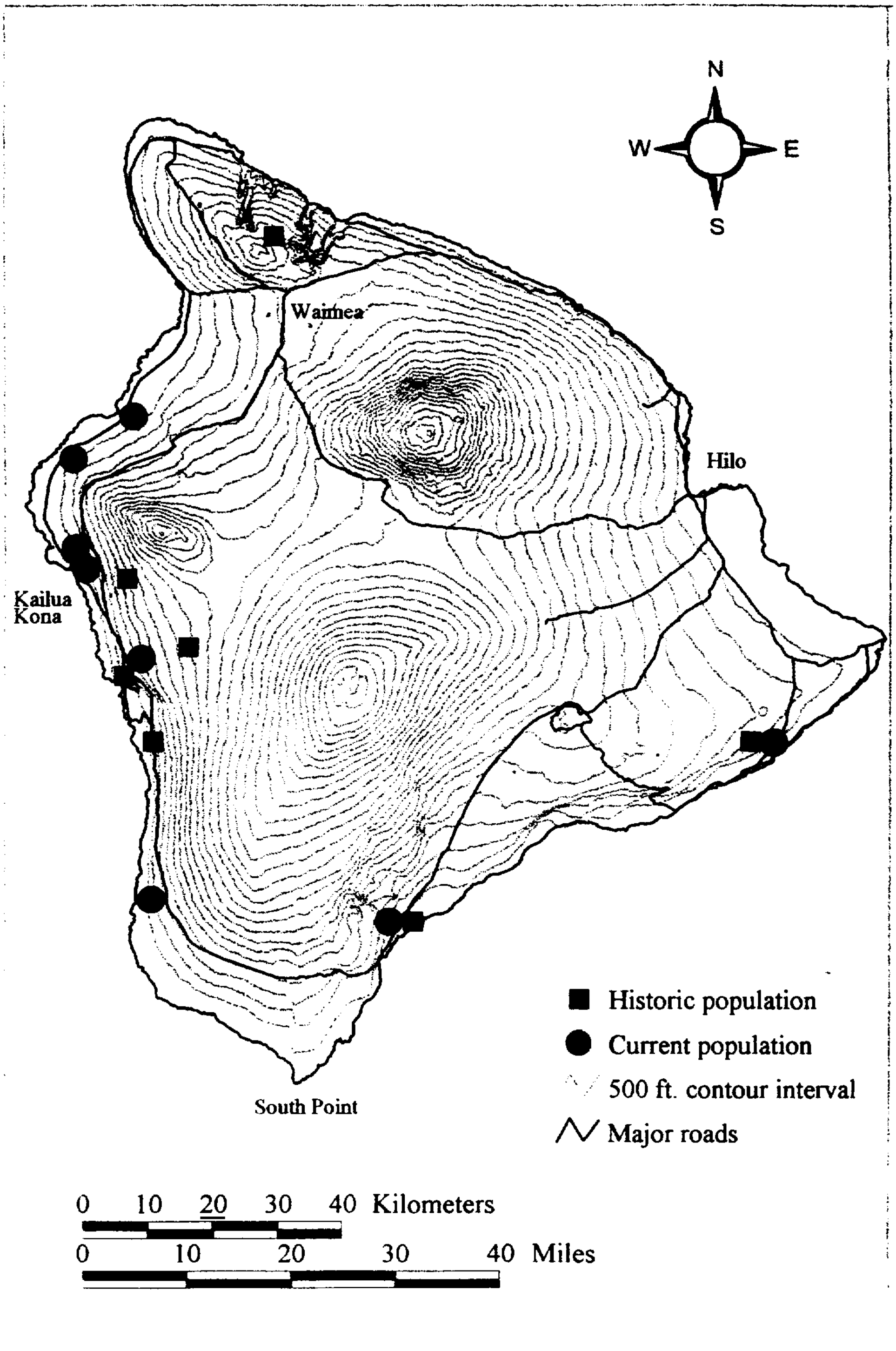


Figure 22. Distribution of *Pritchardia affinis*.

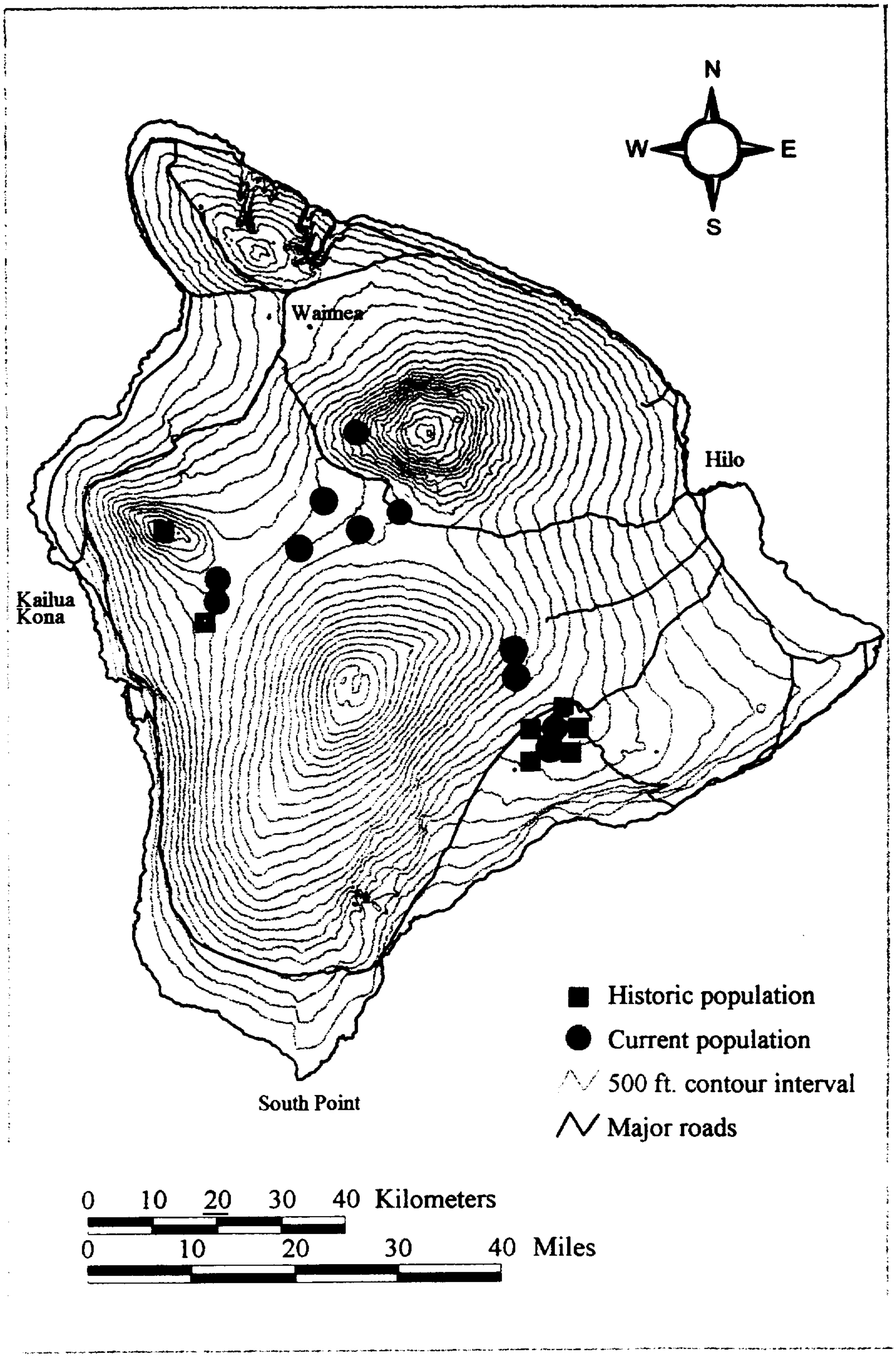


Figure 23. Distribution of *Silene hawaiiensis*.

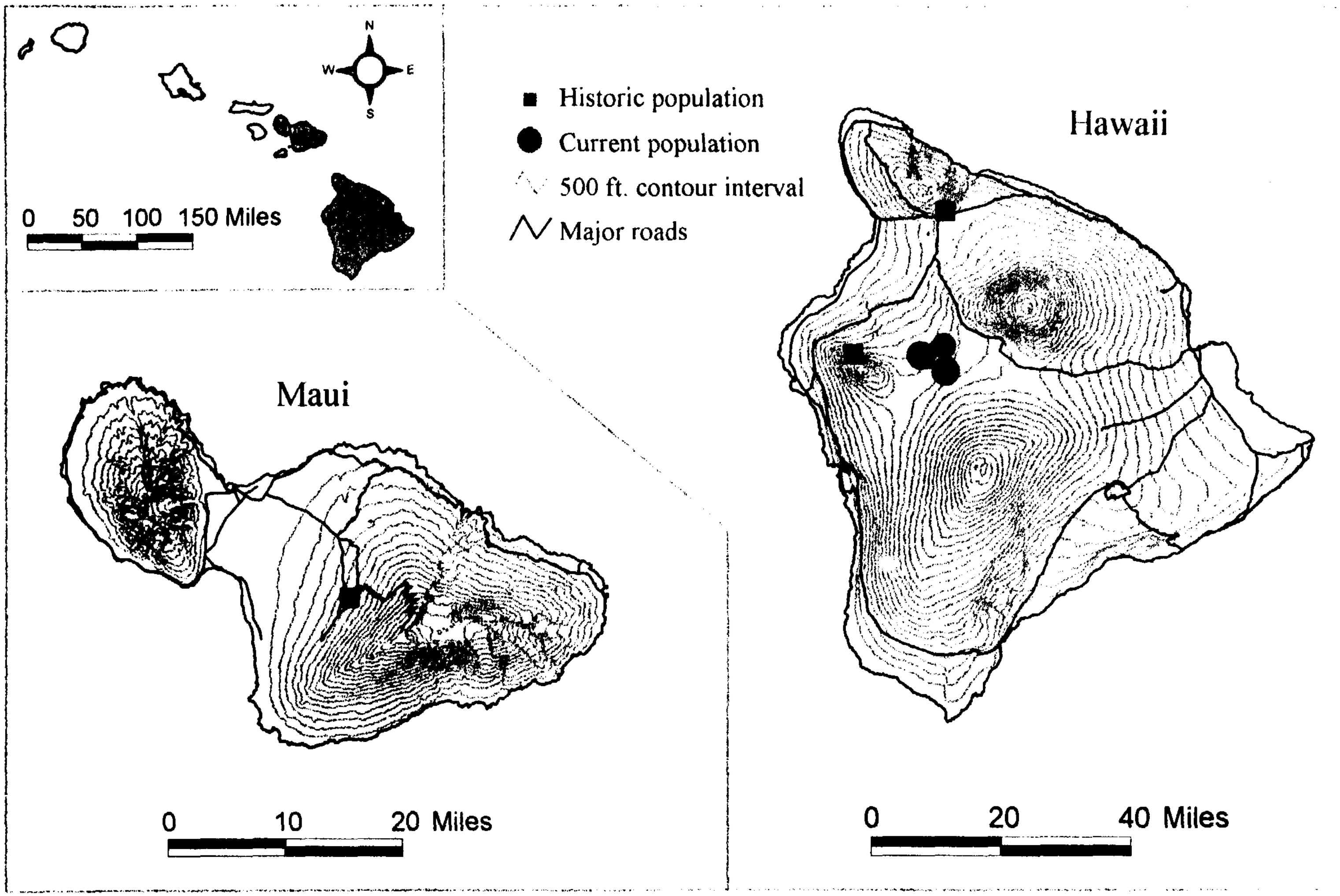


Figure 24. Distribution of *Tetramolopium arenarium* subsp. *arenarium* var. *arenarium*.

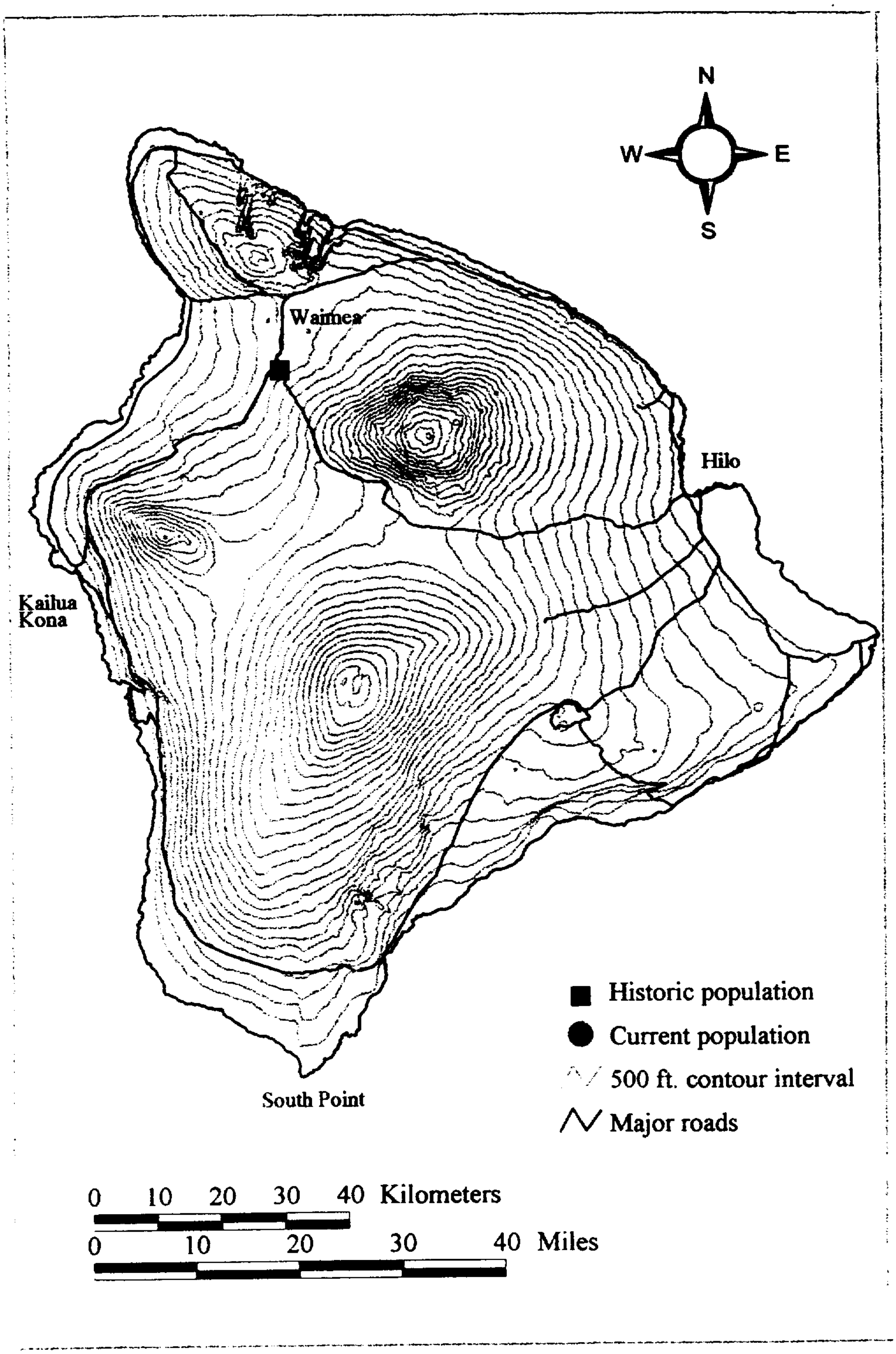


Figure 25. Distribution of *Tetramolopium arenarium* subsp. *arenarium* var. *confertum*.

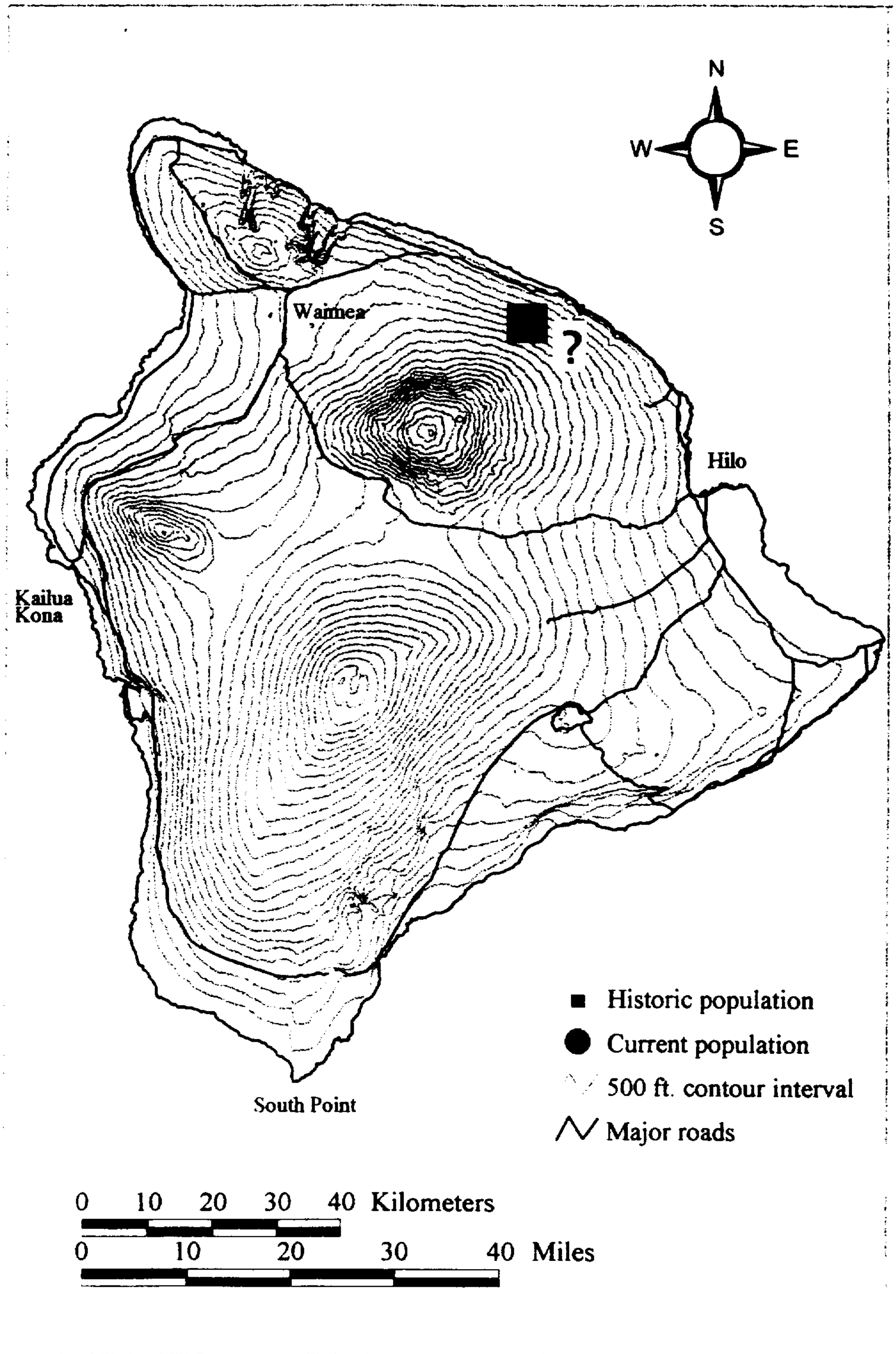


Figure 26. Distribution of *Tetramolopium arenarium* subsp. *laxum*.

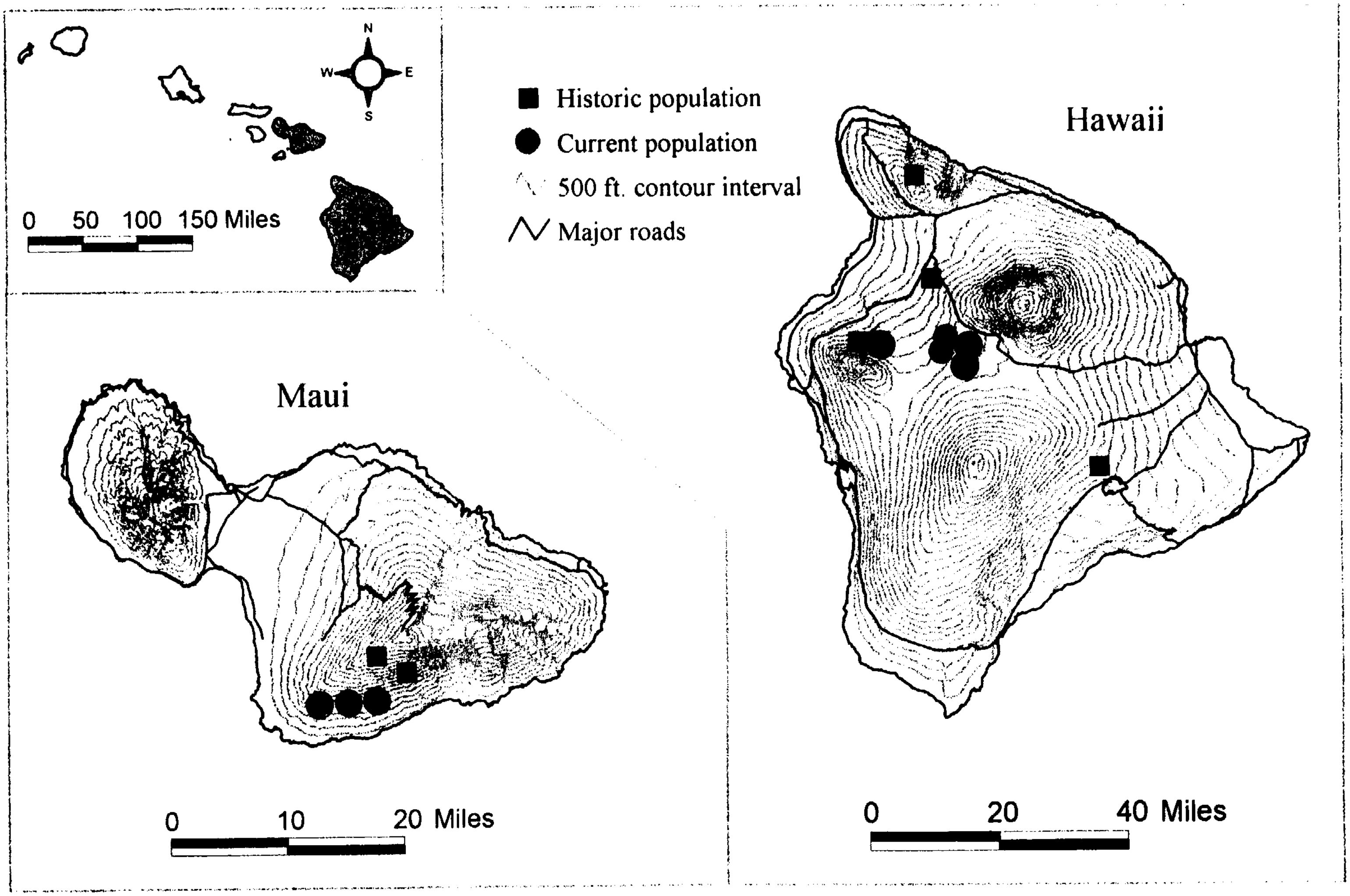


Figure 27a. Distribution of *Zanthoxylum hawaiiense* (Maui and Hawaii).

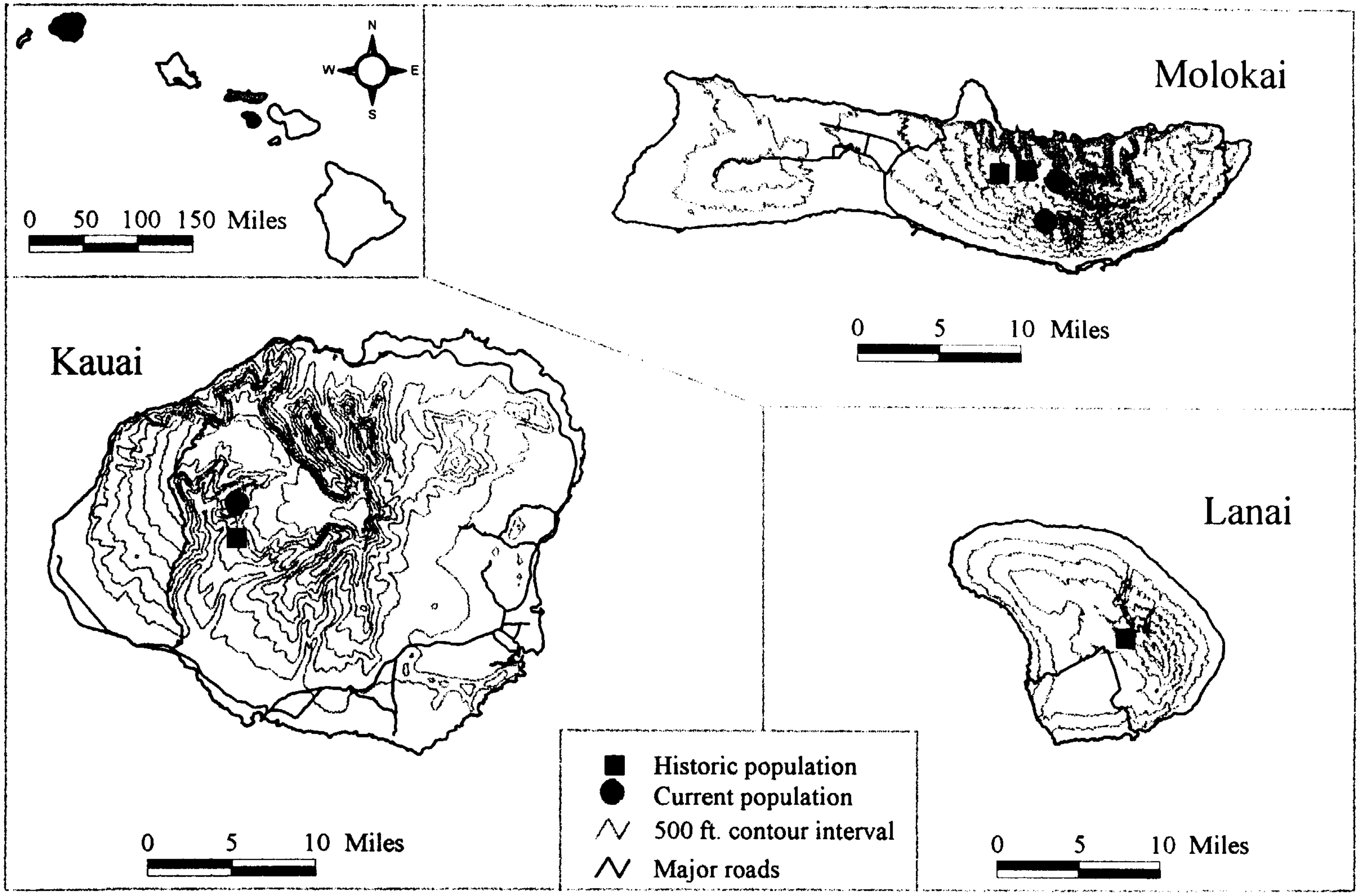


Figure 27b. Distribution of *Zanthoxylum hawaiiense* (Kauai, Molokai and Lanai).

APPENDIX E - TABLE OF LAND OWNERSHIP AND DISTRIBUTION OF TAXA

Table 1. Current and historic island distributions, and land stewards of current populations of the Big Island plant cluster taxa. Asteriks indicate associated comments.

| Taxon | Total Populations and Individuals | Populations by Land Steward | | | Number of Populations by Island (H = Historic) | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Federal | State | Private | K | O | Mo | L | Ma | H | |
| *Clermontia lindseyana* | 12, 400-430 | 2 | 9 | 1 | | | | | 1 | 11 | |
| *Clermontia peleana* | 4, 8 | 1 | 3 | | | | | | H | 4 | |
| *Clermontia pyrularia* | 1-2, 3, 30 outplanted | 1* | 2 | | | | | | | 2 | *Hakalau National Wildlife Refuge |
| *Cyanea copelandii* spp. *copelandii* | 1, ? | | | | | | | | | 1 | *Exact location unkown |
| *Cyanea hamatiflora* spp. *carlsonii* | 3, 14, 51 outplanted | | 3 | | | | | | | 3 | |
| *Cyanea shipmanii* | 4, <10 | 1* | 1 | 2 | | | | | | 4 | *Hakalau National Wildlife Refuge |
| *Cyanea stictophylla* | 3, <20, 46 outplanted | | 2 | 2 | | | | | | 3 | |
| *Delissea undulata* | 1, 1, 50 outplanted | | 1 | | H | | | | H | 1 | |
| *Colubrina oppositifolia* | 3, 14, 51 outplanted | | 6 | 4 | | 3 | | | 1 | 6 | |
| *Cyrtandra giffardii* | 11, >1,000 | 4* | 7 | | | | | | | 11 | *Hawaii Volcanoes National Park |

Table 1. Current and historic island distributions, and land stewards of current populations of the Big Island plant cluster taxa. Asteriks indicate associated comments.

| Taxon | Total Populations and Individuals | Populations by Land Steward | | | Number of Populations by Island (H = Historic) | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Federal | State | Private | K | O | Mo | L | Ma | H | |
| *Cyrtandra tintinnabula* | 3, 18 | | 2 | 1 | | | | | | 3 | |
| *Ischaemum byrone* | 17, >2,000 | 6 | 5 | 6 | 1 | H | 2 | | 6 | 8 | |
| *Isodendrion pyrifolium* | 1, 50-60 | | | 1 | | H | H | H | H | 1 | |
| *Mariscus fauriei* | 4, 45-60 | | 2 | 2 | | | 1 | H | | 3 | |
| *Nothocestrum breviflorum* | 6, ? | | 2 | 4 | | | | | | 6 | |
| *Ochrosia kilaueaensis* | 1, ? | | 1 | | | | | | | 1 | |
| *Plantago hawaiensis* | 8, >5,000 | 2* | 6 | | | | | | | 8 | *Hawaii Volcanoes National Park |
| *Portulaca sclerocarpa* | 12, >1,000 | 6* | | 6 | | | | 1 | | 11 | *Pohakuloa Training Area, Hawaii Volcanoes National Park |
| *Pritchardia affinis* | 8, 50-65 | 1* | | 7 | | | | | | 8 | *Hawaii Volcanoes National Park |
| *Silene hawaiiensis* | 11, 11,000 | 7* | 2 | 2 | | | | | | 11 | *Pohakuloa Training Area, Hawaii Volcanoes National Park |

Table 1. Current and historic island distributions, and land stewards of current populations of the Big Island plant cluster taxa. Asteriks indicate associated comments.

| Taxon | Total Populations and Individuals | Populations by Land Steward | | | Number of Populations by Island (H = Historic) | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Federal | State | Private | K | O | Mo | L | Ma | H | |
| *Tetramolopium arenarium* | 3, <400 | 3* | | | | | | | H | 3 | *Pohakuloa Training Area |
| *Zanthoxylum hawaiiense* | 11, >250 | 4* | 4 | 3 | 1 | | 2 | H | 3 | 5 | *Pohakuloa Training Are |

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(*) - Persons and agencies who provided information necessary for development of the plan.

## APPENDIX G - SUMMARY OF COMMENTS

The USFWS received comments on the Draft Recovery Plan for the Big Island Plant Cluster from Hawaii DOFAW, the Hawaii Department of Agriculture, County of Hawaii Fire Department, University of Hawaii-Cooperative National Parks Resources Studies Unit, State of Hawaii - Land Use Commission, Bishop Museum Greenwell Botanical Garden, State of Hawaii - Department of Hawaiian Home Lands, NTBG, CEMML, and the U.S. Department of the Air Force. Most of these comments consisted of additional information on numbers of populations/individuals, distribution of certain taxa, cost estimates for tasks in the Implementation Schedule, and editorial changes. Most of these comments have been incorporated into the final plan. Additional comments are addressed below:

Comment 1: Hawaii DOFAW indicated that *Ischaemum byrone* is sufficiently abundant to warrant downlisting to threatened status.

Service Response: The recovery objective for downlisting is 5-7 populations with at least 300 individual plants in each population. Only 4 populations are known to have more than 300 individuals. No specific information was provided in the comments to indicate if any additional populations now have more than 300 individuals; therefore, the needed action identified in Table 31 of increasing the number of individuals in one additional population is valid.

Comment 2: Hawaii DOFAW noted that the estimated costs given in the Implementation Schedule are much higher than the current DLNR budget will allow.

Service Response: Recovery plans should recommend the actions necessary to recover threatened and endangered species. Recommending appropriate actions should not be limited by the availability of funds. Additionally, the costs given in the Implementation Schedule are rough estimates. In many cases, it may be possible to combine tasks carried out for a number of species, and thus minimize costs.

Comment 3: Hawaii DOFAW commented that the threats shown in the Federal Register listing package for these plants did not always agree with those shown in this Recovery Plan.

Service Response: This information was incorporated into the Taxon Accounts and Table 2.

Comment 4: Hawaii DOFAW commented that a table would be helpful that shows the species and the number of populations and plants that fall under each land ownership and jurisdiction. This would allow better coordination of recovery actions.

Service Response: Such a table was incorporated as Appendix E of this recovery plan.

Comment 5: Hawaii DOFAW commented that the ranges of plants often fall outside recommended management units (Figure 15), and the present ranges of some species will require habitat acquisition.

Service Response: The management areas identified in Figure 15 were selected because they are areas owned by State or Federal agencies with mandates for management of biological resources, and where there are high concentrations of populations of plants in this Recovery Plan. Many of the plants and areas identified by DOFAW are located on private lands. While the Service encourages and offers incentives to private landowners to aid in the recovery of these plant species it does not necessarily identify private lands as the primary management area for listed plant species.

Comment 6: Hawaii DOFAW commented that a matrix showing the number of plant populations and individuals by each management unit should be included. In addition, a matrix showing which alien plant threatens each listed plant in the Recovery Plan should also be included.

Service Response: The management areas and population/number of plants information and alien plants are already included in the text and tables in the discussion for each species. The Service believes that additional summary tables would be unnecessarily redundant.

Comment 7: Hawaii DOFAW commented that insufficient recovery emphasis is given to populations of these plants that occur on islands other than the Big Island.

Service Response: In the Recovery Objectives section, for those taxa not endemic to the Big Island, the objectives require that populations be secured on at least one additional island. In some cases, the majority or even all populations could occur on an island other than the Big Island.