PUNA GEOTHERMAL AREA BIOTIC ASSESSMENT

Puna District, County of Hawaii

Final Report
April 1985

Department of Botany
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A report prepared for the
HAWAII STATE DEPARTMENT OF PLANNING AND ECONOMIC DEVELOPMENT

by the
DEPARTMENT OF BOTANY, UNIVERSITY OF HAWAII AT MANOA

The preparation of this report was financed in part by the Coastal Zone Management Act of 1972, as amended, and administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, United States Department of Commerce.

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PUNA GEOTHERMAL AREA BIOTIC ASSESSMENT

INTRODUCTION

The development of geothermal resources in the Puna District of the Island of Hawai'i requires continued extension and/or verification of baseline environmental data and information. Part of this requirement is determination of the status of local flora and fauna with special reference to rare, threatened and endangered birds and higher plants. This is a report on a project which has compiled existing information on the flora and fauna of the area, conducted additional field studies in the areas, identified sites which are of special biological significance, and assessed the probable effects on the biota of geothermal resource development at various places in Puna.

Project Boundaries

Basically the area assessed is the east rift zone of Kilauea Volcano, and the areas downwind of it, (in reference to the prevailing northeast tradewinds), in which changes in emissions associated with geothermal development might be expected to have a significant effect. This area is bounded by a line starting at the coast at Honolulu Landing, extending southwest along Kahakai Boulevard to Pahoa, then northwest along Highway 13 to Ainaloa, southwest along a boundary just south of existing subdivision roads (i.e., along the north boundary of the Puna Forest Reserve and Wao Kele O Puna Natural Area Reserve), eventually reaching the Hawai'i Volcanoes National Park boundary near Thurston Lava Tube; thence extending southward along Crater Rim Road and Chain of Craters Road to the region of Pu'u Huluhulu; from there following the Kalapana Trail southeastward to the coast (See Figure 1).

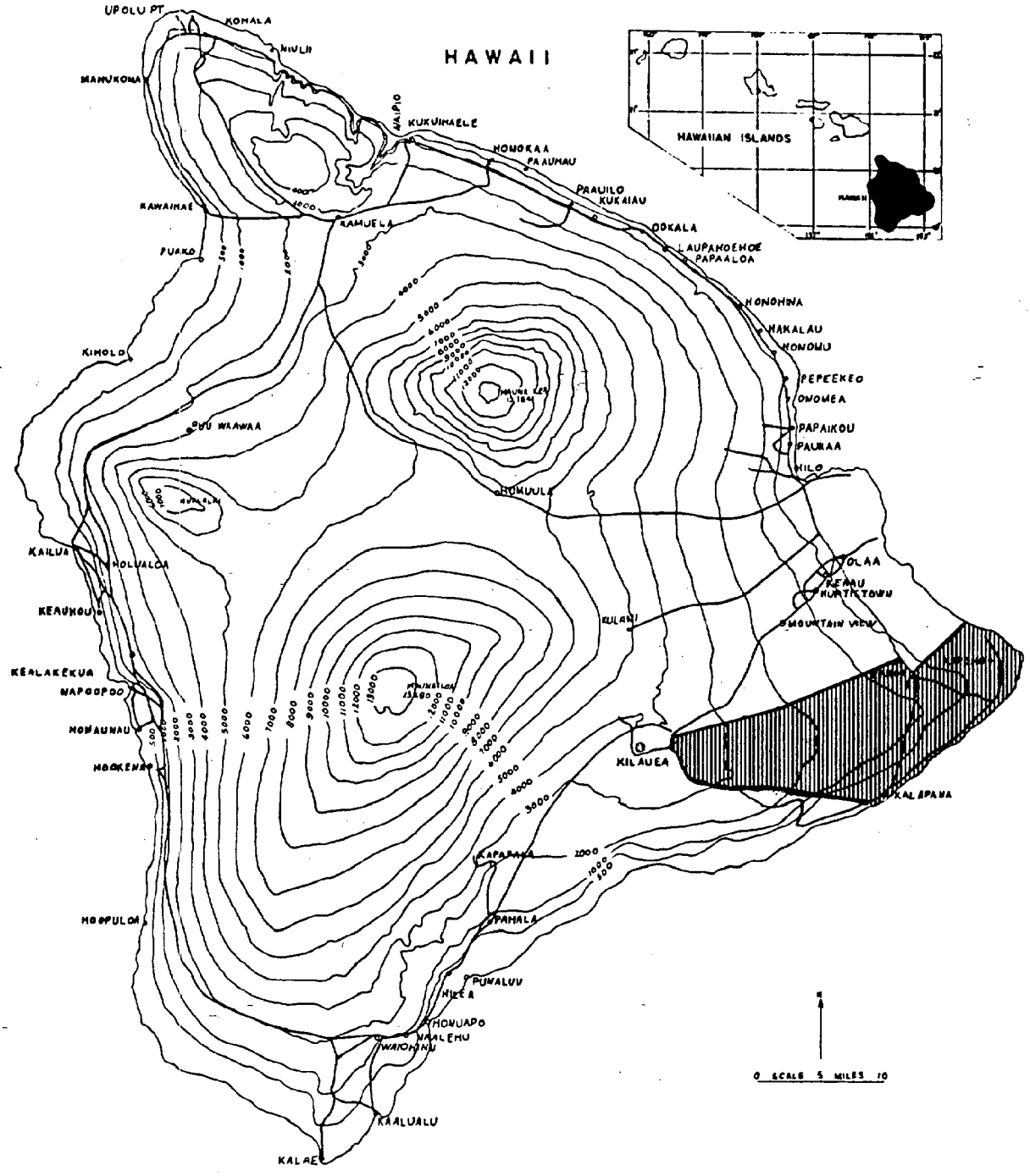

Fig. 1. Project location. Island of Hawaii.

Objectives of the Study

1. To identify, describe, and map the ecosystem types present in the project area.

2. Within each ecosystem type to identify and map the occurrence of rare, threatened, and endangered species of vascular plants.

3. Within each ecosystem type to identify and map the occurrence of rare, threatened, and endangered species of birds.

4. To identify and describe the general structure and status of the communities within which these sensitive species occur.

5. To assess the sites harboring sensitive species in terms of potential risk parameters such as proximity to sites proposed for geothermal exploration and development, effects of such development itself on the sensitive species, and other such potential risks as the accelerated introduction of alien species associated with the habitat disturbances required as part of the geothermal exploration and development process.

METHODOLOGY

Prior to undertaking the survey, a search of the pertinent literature was made to familiarize the investigators with previous studies conducted in the area.

The field survey was conducted from 15 November to 12 December 1984. The survey team varied from a base team of two to as many as seven members when access into remote areas by helicopter was used. A total of 58 person-days were required to gather the technical data contained in this report.

Access into most areas was by paved or unpaved roads and jeep trails using a 4-wheel drive vehicle. A helicopter was employed for the more inaccessible Kahauale'a and Wao Kele O Puna Natural Area Reserve sites. Transects which were walked-through are indicated on the accompanying maps (Appendix B).

Tentative ecosystem types delineated from recent aerial orthophotoquads and from U.S. Fish and Wildlife Services' maps (Jacobi 1985) were ground checked and correlated with the orthophotoquads. Criteria such as the dominant life form and associated plant species were used in identifying and describing each ecosystem type.

Areas which support native ecosystem types were more intensively surveyed since rare species are most likely to occur in such areas. Surveys were not conducted as intensively in the more disturbed ecosystem types such as agricultural and scrub lands. Thus, a few weedy, exotic species may have been omitted from the plant checklist.

Species identification were made in the field. Plants which could not be positively identified were collected for later determination in the herbarium and laboratory. Notation of species present in each ecosystem type was made and is presented in Table 1. The species recorded are indicative of the

season and environmental conditions at the time of the survey. A survey taken at a different season and under varying environmental conditions would no doubt yield slight variations in the species list especially of the annual species. Woody species have been censused to a greater degree of reliability.

FLORA SURVEY

ECOSYSTEM TYPES

Nine broadly defined ecosystem types are recognized. The descriptions are generalized and do not attempt to account for all the different local variations present within the project area. When a development is planned for a specific site, then these descriptions can be "fine-tuned" for that site with a more intensive biological survey.

Of the nine ecosystem types, the 'ohi'a forest is discussed in greatest detail with a number of subcategories recognized. These subcategories are based on structure, associated plant species, disturbance, and the presence of exotic species. The 'ohi'a forests are environmentally significant as they provide critical habitat for a number of rare, threatened or endangered plant and bird species.

The distribution of these ecosystems is presented in the accompanying vegetation maps (Appendix B). The vegetation information assembled and mapped by the U.S. Fish and Wildlife Service (Jacobi 1985) serves as a baseline for the ecosystem types recognized on the Volcano, Kalalu'a, Kalapana, and parts of the South Pahoa maps. Some of the detailed vegetation units presented on the USFWS maps have been grouped into the more generalized ecosystem types recognized in this study. Information from vegetation maps prepared by L. Cuddihy (in Hannah 1984) of the lower Puna area was used in delineating ecosystem types in this portion of the project site. The 1983 Pu'u O'o flows have been accurately mapped using recent information from U.S.F.W.S. and U.S.G.S.; the 1984 flows include only those up to September 20, 1984 and were drawn using only generalized maps of the flows.

1. Lava [lava]

Kilauea Volcano, a broad shield volcano lying against the southeastern slope of Mauna Loa, dominates the Puna landscape. At its summit is a caldera 2.5 miles long and 2 miles wide. Within the caldera lies Halema'uma'u Crater, the principal site of activity. Two rift zones extend southwestward and eastward from the caldera; most flank eruptions have taken place along these two rift zones, particularly along the later (Macdonald and Abbott 1970).

The east rift zone, which runs the length of the study area, trends southeastward from the caldera for five miles but then bends sharply and extends east-northeastward to Cape Kumukahi and onward along the ocean floor (Macdonald and Abbott 1970). Lava flows, pit craters, and spatter and cinder cones of different ages mark the east rift zone.

Pahoehoe flows predominate near the summit of Kilauea because they are close to the vents from which they are issued, but 'a'a flows become more abundant with increasing distance from the summit and the rift zones (Macdonald and Abbott 1970).

For this study, the lava ecosystem includes recent, barren flows as well as slightly older flows which support a pioneer vegetation. There have been several studies of plant succession on lava flows on Hawai'i (Forbes 1912, Clements 1916, MacCaughey 1917, Robyns and Lamb 1939, Skottsberg 1941), however, the information from these studies is still only fragmentary. A few intensive studies of plant succession have been made at selected sites. Doty (1961, 1967) established several study plots on the 1955 lava flows. Smathers and Mueller-Dombois (1974) conducted intensive studies of succession on ash and pahoehoe at the 1959 Kilauea Iki eruption site.

The results of these studies show how diverse are the successional stages involved and how difficult it is to generalize effectively about succession on

lava flows. The great range of environmental conditions available have produced a complex of successional stages.

From these studies it is clear that available moisture plays an important part in succession. Whether a lava flow occurs in a wet or dry locality will determine how rapidly plants are able to colonize it. In wetter areas, the development of vegetation is much more rapid. The whitish-gray lichen, Stereocaulon vulcani, often appears first on some lava flows, however, higher plants such as 'ohi'a (Metrosideros collina) and ferns such as swordfern (Nephrolepis multiflora) may also appear at the same time. 'Ohi'a is the most common pioneer among the flowering plants and may even appear before the lichens. In dry localities colonization of lava flows is exceedingly slow.

Lava flows of different ages and climatic exposures can be observed in the project area. The Pu'u O'o flows (1983 to present) are completely barren for they are too recent and, in fact, newer flows often pour over the earlier flows.

On the 1977 flow near the 1660 ft elevation U.S.G.S. benchmark, plant cover on the 'a'a is very low, 1 to 2%. A few small 'ohi'a plants and swordfern may be found scattered here and there. Lichen cover is also low with Stereocaulon covering 30 to 40% of the rocky surface. Scattered throughout the flow are pockets of vegetation (kipukas) left more or less intact by the lava. These kipukas are of varying sizes. The larger kipukas usually survive with most of its components intact. The smaller kipukas usually have many of its 'ohi'a trees killed but still standing. Ferns such as uluhe (Dicranopteris spp.) and flowering plants such as mamaki (Pipturus hawaiiensis), Buddleja asiatica, and 'ohi'a often take root at the bases of these trees because these standing dead trees act as interceptors during driving rains, causing water to run down the trunks (Smathers and

Mueller-Dombois 1974). Tree molds found scattered throughout the flow also provide shady, damp crevices where young plants may grow.

The Mauna Ulu flows of 1969 to 1974, which issued near the vents, are pahoehoe flows. Pahoehoe flows have smooth, hard crusts and colonization takes place mainly along joint cracks and fissures. The Mauna Ulu flows, at a higher elevation and slightly wetter situation, support such pioneer colonizers as 'ohi'a, 'ohelo (Vaccinium spp.), 'ama'u (Sadleria spp.), 'ae (Polypodium pellucidum), kupaoa (Dubautia scabra), and pawale (Rumex skottsbergii). Stereocaulon may be absent or uncommon on these flows.

The 1955 flow between Keauohana Forest Reserve and 'I'ilewa Crater consists of 'a'a which is densely covered with Stereocaulon. Higher plant cover is 10 to 20%. Vegetation consists of 2 to 4 m tall 'ohi'a with many smaller individuals 15 to 30 cm tall and the introduced swordfern. Other species occasionally seen on the flow include bamboo orchid (Arundina bambusaefolia), broomsedge (Andropogon virginicus), moa (Psilotum nudum), and Buddleja. As one approaches the edge of the flow where it meets the forest, the percentage of plant cover and the number of species increases. Plants from the surrounding forests such as huehue (Cocculus ferrandianus), mamaki, uluhe, and 'uki (Machaerina spp.) slowly invade the flow from the forests.

2. 'Ohi'a woodland

In wetter parts of the study area the 'ohi'a (Metrosideros collina) woodland is composed of widely spaced trees with an almost continuous carpet of uluhe (Dicranopteris spp.), a matted fern, between the trees. In moist mesophytic situations a grass-shrub association occupies the space between the trees. The 'ohi'a woodland may vary in size from low to tall stature trees in different localities but in any one stand the trees are fairly uniform in size. The two types of 'ohi'a woodland are described below.

a. 'Ohia woodland with uluhe [ohia-uluhe]

This ecosystem type covers large areas of Puna, especially on the relatively young lava flows below 1000 ft elevation near Pahoa.

The 'ohi'a woodland with uluhe is interpreted as one of several stages in the normal succession leading to 'ohi'a forest on relatively wet 'a'a and pahoehoe flows. Atkinson (1969, 1970) studied in detail the successional trends on coastal and lowland lava flows of Kilauea Volcano. This ecosystem type is often not uniform. Atkinson (1970) observed that even on the same flow there is a wide variation in the proportions of uluhe and 'ohi'a. It may vary from an uluhe "fernland" with few 'ohi'a trees to an 'ohi'a/uluhe "treeland"; gradations from "fernland" to "treeland" are not uncommon. From his observations of the vegetation on the 1840 flow and the older, nearby 'a'a flows he estimated that the succession from bare 'a'a to "treeland" stage can be reached within 120 years. He noted though that extensive prehistoric pahoehoe flows in the Pahoa area were still in the 'ohi'a/uluhe "treeland" stage rather than mature 'ohi'a forests and concluded that the rate of succession is extremely slow on pahoehoe flows.

In places the 'ohi'a woodlands with uluhe have been burned at some time or another (Atkinson 1970). These disturbed woodlands have large patches of broomsedge (Andropogon virginicus) scattered throughout; clumps or thickets of Malabar melastome (Melastoma malabathricum) and waiawi (Psidium cattleianum) are also common.

The dense fern cover prevents the establishment of many seedlings and as a result only a few scattered plants such as kopiko (Psychotria hawaiiensis), 'uki (Machaerina spp.), Malabar melastome, and bamboo orchid (Arundina bambusaefolia) are found in the thick uluhe mats. The uluhe may be up to 3 m tall in some places. This ecosystem type is difficult (and dangerous) to

botanize as the thick carpet of matted ferns often obscures the large earth cracks, fissures, and tree molds beneath.

In some localities, such as parts of the 1840 flow in the Nanawale Forest Reserve, the uluhe may be thin and may occur in patches. When this occurs, other species such as bamboo orchid, 'uki' and swordfern (Nephrolepis multiflora) become common.

Since this ecosystem type represents an early stage in succession, it does not contain a large number of different species. Rare or endangered species are usually not found in this ecosystem type.

b. 'Ohi'a woodland with grass [ohia-gr]

The total area occupied by this ecosystem type is not large.

At upper elevations along the Napau-Kalapana Trail and especially around Pu'u Huluhulu the vegetation consists of scattered 'ohi'a with broomsedge. Bush beardgrass (Andropogon glomeratus), 'uki, and 'ohelo (Vaccinium reticulatum) are common. Kukae-nene (Coprosma ernodeoides), bamboo orchid, pukiawe (Styphelia tameiameiae), and 'ama'u (Sadleria cyatheoides) are occasional. Scattered patches of uluhe are frequently encountered. A number of other grasses such as velvetgrass (Holcus lanatus), foxtailgrass (Setaria spp.), and Vaseygrass (Paspalum urvillei); and sedges such as Pycreus polystachyos, tall fringe rush (Fimbristylis dichotoma), and kuolohia (Rhynchospora lavarum) are also occasionally seen especially along the trailsides. Firetree (Myrica faya), a noxious weedy tree, is common near Makaopuhi Crater.

These upper elevation 'ohi'a woodlands with grass occur in areas which have been burned; the fires originating naturally from volcanic eruptions or accidentally set by man.

Some of the species found in higher elevation woodlands such as kukae-nene and Hedyotis centranthoides are not found associated with the

warmer, low elevation woodlands. These lower elevation 'ohi'a woodlands occur near the coast and probably receive less rainfall than the higher elevation woodlands. They are also exposed to some degree of salt spray. Swordfern, Pluchea odorata, Buddleja asiatica, and other exotic species increase in numbers. Native species occasionally observed include huehue (Cocculus ferrandianus), mamaki (Pipturus hawaiensis), and naupaka (Scaevola taccada) as well as 'ohelo and pukiawe.

3. 'Ohi'a forest

This ecosystem type covers extensive portions of the Island of Hawai'i and is the principal ecosystem type found within the study area. The dominant tree in this forest is 'ohi'a or 'ohi'a lehua (Metrosideros collina); all three varieties of Metrosideros occur in these forests. However, in older 'ohi'a forests large trees of Metrosideros collina var. macrophylla are often dominant.

'Ohi'a forests occur in moderately moist to wet situations at fairly low to middle elevations and show considerable variation in structure and composition in different habitats. In wet areas older 'ohi'a forests commonly develop a dense understory of tree ferns (Cibotium spp.). Other species of trees also occur within these older forests and often form a distinct subcanopy layer. In moderately moist situations a mesic 'ohi'a forest often develops. A rich assortment of other native tree species occur in these mesic 'ohi'a forests.

The 'ohi'a forest, especially the least disturbed portions, is the principal habitat for large numbers and kinds of native birds. Many rare native plant species are also found in this ecosystem type.

Five different kinds of 'ohi'a forests are recognized in this study and are described in the following sections. Where different kinds of 'ohi'a forests meet, there is very often no sharp boundary between the forest types and one kind usually grades into the other.

a. Wet 'ohi'a forest with native species [ohia-a(1)]

This kind of 'ohi'a forest occurs within Hawaii Volcanoes National Park, Kahauale'a, Wao Kele O Puna Natural Area Reserve, and a small area in upper Kalapana (Volcano, Kalalua and Kalapana orthophotoquads). Extensive unbroken tracts of wet 'ohi'a forests are found principally in the upper elevations of the study area from about 2100 ft to 3700 ft elevation. At lower elevations (1900 to 1000 ft) these wet forests are fragmented by recent lava flows and 'ohi'a forests which have been disturbed to some extent.

The wet 'ohi'a forest with native species is the least disturbed ecosystem type within the study area and is the best example of a more or less intact wet native forest community. Exotics (or introduced) plant species are confined primarily to the trailsides and within the forest (away from trails) they are relatively rare or uncommon except where pigs have rooted or wallowed. Most of these exotic plants are grasses, sedges or herbs and include such species as Hilo grass (Paspalum conjugatum), broomsedge (Andropogon virginicus), Vaseygrass (Paspalum urvillei), Cyperus haspan, water purselane (Ludwigia palustris), Hypericum spp., Drymaria cordata and fireweed (Erechtites valerianaefolia). A few scattered shrubs of strawberry guava (Psidium cattleianum) may sometimes be encountered.

These wet 'ohi'a forests with native species are closed canopy forests (>60% cover) and are composed largely of mature, tall statured (>10 m) 'ohi'a trees. Trees with trunks 1 to 1.5 m in diameter are not uncommon.

Below the 'ohi'a canopy is a subcanopy layer of native trees, 8 to 10 m tall. In upper elevation forests such as Kahauale'a the subcanopy layer is commonly composed of kawau (Ilex anomala), olapa (Cheirdendron trigynum), alani (Pelea clusaefolia), and kopiko (Psychotria hawaiiensis). Trees of 'ohe (Tetraplasandra hawaiensis) may sometimes be found, usually in the more open areas. Tree ferns (Cibotium spp.) form a third layer (3 to 5 m tall) beneath the trees. The tree fern layer is often dense and in these parts of the forest it often appears as if the area were covered by a sea of green umbrellas. A number of shrubs and smaller trees are found scattered among the tree ferns. These commonly include kanawao (Broussaisia arguta), pilo (Coprosma spp.), several Cyrtandra species, Clermontia parviflora, and 'akia (Wikstroemia sandwicensis). Patches of uluhe (Dicranopteris spp.) are found scattered throughout the forest especially in areas where the canopy cover is more open. A large number of terrestrial and epiphytic ferns including the rare Adenophorus periens is found in this type of forest. Liverworts and mosses are abundant and form thick cushions on the trunks of trees.

In lower elevation wet 'ohi'a forests such as those near upper Kalapana the composition of the subcanopy layer begins to change. Lama (Diospyros ferrea) and kopiko become the common elements of this layer. Only small portions of these lower elevation forests now remain intact. These forests are an important biological resource in understanding the dynamics of our native forests (Stemmermann 1983, Mueller-Dombois 1985).

b. Wet 'ohi'a forest with native species and exotic shrubs [ohia-a(2)]

This ecosystem type covers a large portion of the Wao Kele O Puna Natural Area Reserve. It is also found scattered throughout the rest of the study area. The ohia-a(2) forest is more or less similar in composition and structure to the less disturbed ohia-a(1) forest discussed previously.

However, it is generally an open canopy forest (<60% cover). Exotic shrubs, primarily strawberry guava and occasionally Malabar melastome (Melastoma malabathricum) are found throughout the forest but are most abundant in areas which have been disturbed. Patches of uluhe and exotic grasses are also more frequently encountered. The tree fern layer is usually not as well developed as in the ohia-a(1) forest.

Signs of pig activity are often found; feral cattle damage to 'ie'ie (Freycinetia arborea), 'uki (Machaerina angustifolia), and olapa may also be observed in these forests.

Parts of the ohia-a(1) and a(2) forests bordering the recent Pu'u O'o flows have suffered damage from heat, fire, and volcanic fumes and debris (tephra and ash).

c. 'Ohi'a-kukui forest with mixed native and exotic shrubs [ohia-a(3)]

This forest type is similar to the ohia-a(2) forest but contains a certain admixture of kukui (Aleurites moluccana) trees and other exotic tree and shrub species (Mueller-Dombois 1985). These wet 'ohi'a-kukui forest units are easily recognized on the orthophotoquads. The rounded, silvery-green colored kukui canopy appears as whitish, mottled areas on the black and white photoquads.

Kukui is a Polynesian introduction and the Hawaiians most likely cultivated some parts of this forest. The 'ohi'a-kukui forests examined during this survey contained plants of 'awa (Piper methysticum), 'awapuhi-kua-hiwi (Zingiber zerumbet), pi'ia (Dioscorea pentaphylla), Hawaiian bamboo (Schizostachyum glaucifolium), and ti (Cordyline terminalis). More recently introduced plants such as jackfruit (Artocarpus heterophyllus), avocado (Persea americana), and Philodendron sp. were found in these forests. Strawberry guava and Malabar melastome shrubs may form a dense understory in these 'ohi'a-kukui forests.

d. Moderately moist 'ohi'a forest [ohia-a(4)]

The moderately moist (mesic) 'ohi'a forests occur in areas which receive slightly less rainfall (about 75 to 100 inches/yr) than the wet forests but do not suffer an actual moisture deficit and occur on lava flows which have been rather well weathered (Fosberg 1972).

The forests are composed of open (rarely closed), medium to tall stature trees. 'Ohi'a is the predominate tree but a number of native tree species such as lama are also common; these trees may be as tall as the surrounding 'ohi'a trees or they may form a subcanopy layer. A number of dry forest tree species are also found in the mesic forests. Large trees of lama, 'ahakea (Bobea timonioides), olopua (Osmanthus sandwicensis), and 'ohe (Tetraplasandra hawaiensis), 15 to 20 m tall, were found in the mesic forests of the Royal Garden subdivision. Other tree species also observed include hao (Rauvolfia remotiflora), kolea-lau-nui (Myrsine lessertiana), papala (Charpentieria obovata), and papala-kepau (Pisonia umbellifera). In some places kukui trees may also be a part of the canopy cover. Mango (Mangifera indica), breadfruit (Artocarpus altilis), and roseapple (Syzygium jambos) trees may be found in some mesic forests.

Unlike the wet 'ohi'a forests, the mesic 'ohi'a forests do not support a dense understory of tree ferns and shrubs. The tree ferns and shrubs such as alahe'e (Canthium odoratum), kopiko, and mamaki (Pipturus hawaiensis) are usually scattered and the understory is open. Exotic shrubs found in this forest include both species of guava, Pluchea odorata, and lantana (Lantana camara).

Groundcover may consist of swordfern (Nephrolepis multiflora) and various exotic grasses such as Hilo grass and basketgrass (Oplismenus hirtellus).

Large bird's-nest ferns (Asplenium nidus) are occasionally observed on trees. Other epiphytes include 'ie'ie, moa (Psilotum nudum), cheohe (Vittaria elongata) and Elaphoglossum species.

e. 'Ohi'a forest with exotic subcanopy and shrub layers [ohia-b]

Large areas of south Pahoa are covered by 'ohi'a forests dominated by exotic subcanopy and shrub layers. These forests may consist of medium to tall stature trees with open or closed canopies. This type of forest is often hard to distinguish from the ohia-a(2) forests on the orthophotoquads especially if the canopy is closed. The understory layers of this type of forest have at some time in the past been more or less greatly disturbed as exotic species dominate.

Tall strawberry guava forms a dense subcanopy layer, 6 to 7 m tall, while smaller guava plants, 1 to 3 m tall, make up the shrub layer. Malabar melastome is usually a common component of the shrub layer. The ground beneath is usually heavily shaded and groundcover often consists of basketgrass, thimbleberry (Rubus rosaefolius), downy wood fern (Christella dentata), 'awapuhi-kua-hiwi, and strawberry guava seedlings of all sizes. Other exotics found in this type of 'ohi'a forest include honohono (Commelina diffusa), Spathoglottis plicata, fireweed, ti, pi'ia, a number of ginger species (Hedychium spp.), Hilo grass, and rose apple.

Native species such as lama, tree ferns, 'ie'ie, and kopiko are occasional to uncommon.

The more open areas of these forests are usually filled with tangled mats of uluhe.

4. Dry forest [dry for]

The dry forests can be found on the Kalapana and South Pahoa orthophotoquads. The forests occur principally within Hawai'i Volcanoes National Park and the Royal Gardens subdivision and are usually found on relatively steep slopes. These forests generally fall between the 50 and 75 inch rainfall isohyets in the study area.

This ecosystem type is composed primarily of a lama-'ohi'a mixture with other dry forest species on 'a'a lava flows. In some places, however, the forest may consist of almost pure stands of lama (Diospyros ferrea ssp. sandwicensis) or, more infrequently, of 'ohi'a. The dry forest is usually open, the trees of medium stature (5 to 10 m) and with rounded crowns, although in its best development the forest may be closed and consist of tall stature (>10 m) trees.

Among the dryland tree species associated with this forest type are hao (Rauvolfia remotiflora), wiliwili (Erythrina sandwicensis), 'ohe (Reynoldsia hillebrandii), and 'iliahi (Santalum paniculatum). A large population of 'ohe is found in the Royal Gardens subdivision. The trees tend to occur in clumps or groups and are easily differentiated from the rest of the vegetation by their pale-green leaves and thick branches.

Alahe'e (Canthium odoratum), 'akia (Wikstroemia phillyreaefolia var. buxifolia), and a'ali'i (Dodonaea sandwicensis) are the most commonly occurring members of the shrub layer when the forest is open. These three species occur in more or less equal numbers and form a dense thicket between the trees. Under closed canopy conditions, the shrubs become moderate to sparse in cover. Alahe'e is more commonly seen than aki'a, and a'ali'i is uncommon. The alahe'e will often form a subcanopy layer 4 to 5 m tall.

Non-native tree and shrub species occasionally encountered in the dry forests include Java plum (Syzygium cumini), kukui (Aleurites moluccana), Christmas berry (Schinus terebinthifolius), lantana (Lantana camara), guava (Psidium guava) and kolomona (Cassia surattensis).

The native kauna'oa-pehu vine (Cassytha filiformis) often drapes forest trees and shrubs with its long, orange-colored stems and branches. Other native vines found in the dry forests include koali-'awahia (Ipomoea indica), 'awikiwiki (Canavalia sp.), and huehue (Cocculus ferrandianus).

The pakahakaha fern (Pleopeltis thunbergiana) is occasionally observed on the trunks and branches of trees but the kinds of epiphytic species in this forest type are few.

The amount of ground cover in the dry forest will vary depending on several factors such as open or closed canopy, amount of moisture available, age of lava flow, elevation, etc. At lower elevations with less rainfall, 30 to 40 percent of the ground is bare or lichen-covered 'a'a; laua'e fern (Phymatosorus scolopendria), the most abundant species in this layer, may cover 40 to 50 percent of the ground; and leaf litter and other species such as peperomia (Peperomia leptostachya), broomsedge (Andropogon virginicus), spurflower (Plectranthus parviflora), sword fern (Nephrolepis multiflora), and partridge pea (Cassia lechenaultiana) make up the remainder of the cover.

Under slightly wetter conditions at higher elevations, ground cover may be 60 to almost 100 percent. Sword fern is abundant while laua'e, basket grass (Oplismenus hirtellus), and seedlings of dry forest tree and shrub species are common. Other species occasionally encountered are (Carex wahuensis), moa (Psilotum nudum), Spanish clover (Desmodium uncinatum), and Hilo grass (Paspalum conjugatum).

5. Dry scrub community [dry scr]

Within the project area the total area occupied by the dry scrub community is small and, like the dry forest, is found primarily in the drier portions of Hawai'i Volcanoes National Park and the Royal Gardens subdivision.

Shrubs of alahe'e, aki'a, and a'ali'i, 2 to 4 m tall, are the common components of this ecosystem type. Lama and 'ohi'a trees, 4 to 6 m tall, occur as scattered individuals throughout the scrub. Sprawling, tangled mats of 'ulei (Osteomeles anthyllidifolia) are also frequently encountered. Other shrubs and subshrubs found in the dry scrub community include 'ilima (Sida cordifolia), lantana, guava, hi'aloa (Waltheria indica var. americana), and pukiawe (Styphelia tameiameae).

The scrub community occurs on rough a'a. Large areas with sparse ground cover are common on the rocky substrate. The xerophytic kalamoho fern (Pellaea ternifolia) and the succulent spurflower are often found in these areas. In areas with more ground cover, exotic grasses such as broomsedge (Andropogon virginicus), bush beardgrass (Andropogon glomeratus), Natal redtop (Rhynchelytrum repens) and molassesgrass (Melinis minutiflora) dominate.

Other species occasionally found in this ecosystem type are laua'e, swordfern, kauna'oa-pehu, moa, pili grass (Heteropogon contortus), and cayenne vervain (Stachytarpheta australis).

6. Dry grassland [dry gr]

The dry grassland, like the other two preceeding ecosystems types, is found in areas of low to moderate rainfall. Within the project area, it is found largely in the Hawai'i Volcanoes National Park and Royal Gardens Subdivision, Kalapana orthophotoquad.

Grasslands occur on relatively flat coastal areas and extend upslope to as high as 480 m (1580 ft) elevation. Grasslands may be found on 'a'a or pahoehoe substrates.

This ecosystem type is characterized by wide open grassy areas with rocky outcrops and scattered low shrubs and trees. A mixed association of the two Andropogon species, Natal redtop, and pili grass usually makes up the dominant grass cover. Localized patches of molassesgrass are occasionally encountered. Due to drier environmental conditions and exposure, shrubs are usually sprawling or low growing, 1 to 2 m tall. Shrubs associated with this ecosystem type incude 'ulei, a'ali'i, aki'a, noni, lantana, guava, Java plum, Christmas berry, 'iliahi, and alahe'e. Lantana may form solid stands in some places, especially along the boundary of this ecosystem type and the dry forest.

Short- to medium-statured trees of the xerophytic form of 'ohi'a can be found growing on the pahoehoe knolls scattered throughout the grassland. Lama and wiliwili trees are also found in the dry grassland as scatterd individuals or small, open stands.

Other species occasionally observed include smaller shrubs such as indigo (Indigofera suffruticosa), partridge pea, Cayenne vervain, and 'uhaloa; and weedy grasses, forbs, and vines such as Digitaria spp., pigweed (Portulaca oleracea), ironweed (Vernonia cinerea), three-flowered beggarweed (Desmodium triflorum), and pohapoha (Passiflora foetida).

7. Mixed lowland forest [ml for]

Within the project area the mixed lowland forests extend from the Kalapana area to Kapoho and on towards Hilo. This ecosystem type presents a varied mosaic of plant associations rather than an integrated entity. It is fragmented by villages, subdivisions, cultivated lands, and lava flows.

The lowland forest contains many species found in the moist mesophytic 'ohi'a forest in addition to hala (Pandanus spp.), hau (Hibiscus tiliaceus), and other lowland species. Its inland boundaries are difficult to delineate as it overlaps other inland ecosystem types (Fosberg 1972).

The lowland forests have been strongly modified by man. The Polynesians introduced trees such as niu (Cocos nucifera), kukui (Aleurites moluccana), kamani (Calophyllum inophyllum), 'ulu (Artocarpus altilis), milo (Thespesia populnea), and 'ohi'a-'ai (Syzygium malaccensis). They also brought with them ohe (Schizostachyum glaucifolium), mai'a (Musa spp.), yams (Dioscorea spp.), taro (Colocasia esculenta var. antiquorum), 'ape (Alocasia macrorrhiza), noni (Morinda citrifolia) and 'awa (Piper methysticum). These plants are frequently found associated with old Hawaian house sites and agricultural terraces in Puna.

Later post-Cook introductions include trees and shrubs of Java plum (Syzygium cumini), mango (Mangifera indica), avocado (Persea americana), roseapple (Syzygium jambos), guava (Psidium guajava), strawberry guava (Psidium cattleianum), Christmas berry (Schinus terebinthifolius) and monkeypod (Samanea saman). Forestry plantings of trees such as albizia (Albizia spp.), ironwood (Casuarina spp.), gunpowder tree (Trema orientalis), Ceara' rubber (Manihot glaziovii), macaranga (Macaranga spp.), Melochia umbellata, and guarumo (Cecropia spp.) were also made. Many of these introduced species have naturalized and spread.

The mixed lowland forests in Puna today are composed most frequently of a mixture, of native trees--'ohi'a, lama (Diospyros ferrea ssp. sandwicensis), hala--and the introduced trees mentioned above. The height of these forests vary greatly from low stature, almost scrub-like, disturbed forests to medium or tall stature older forests. The understory varies considerably depending

upon the nature of past disturbances and the amount of canopy cover. The shrub layer may consist of the two guava species, Pluchea odorata, Malabar melastome (Melastoma malabathricum), Christmas berry, and the native shrubs kopiko (Psychotria hawaiiensis), mamaki (Pipturus hawaiiensis), and 'akia (Wikstroemia sandwicensis). Noni and hapu'u i'i (Cibotium chamissoi) are occasionally found. Where the understory has been greatly disturbed guava and/or strawberry guava may form a dense shrub layer.

Ground-cover is sparse when the canopy is dense. Basketgrass (Oplismenus hirtellus), 'awapuhi kua hiwi (Zingiber zerumbet), downy woodfern (Christella dentata), swordfern (Nephrolepis multiflora), and smaller shrubs of thimbleberry (Rubus rosaefolius) and Stachytarpheta spp. are commonly observed. Seedlings of the tree and shrub species are numerous. Where canopy cover is less dense such as in disturbed areas, along roadsides, and the peripheries of the forests, the ground cover is denser and may consist of California grass (Brachiaria mutica), molassesgrass (Melinis minutiflora), napiergrass (Pennisetum purpureum), honohono (Commelina diffusa), and sensitive plant (Mimosa pudica var. unijuga). The vines maile pilau (Paederia foetida), ka'e'e (Mucuna gigantea), and white thunbergia (Thunbergia fragrans) are also common in these more open areas.

Locally common are small patches of forest with a single species dominant. These species include ironwood, hau, kukui, and hala. These small patches of forest are usually dense and there are few understory plants. The rocky substrate may be largely covered with leaf litter under hala, hau, and ironwood forests while basketgrass is commonly associated with kukui forests.

This ecosystem type also includes the coastal mixed lowland forest and scrub. The plants along the shore are exposed to salt spray, wind, and larger amounts of solar radiation. Vegetation consists of low, windswept trees and shrubs and low mats or cushions of herbaceous plants.

Most of the Puna coastline is rocky with cliffs plunging down to the sea. These rocky cliffs are frequently bare except for low growing plants such as 'ilima (Sida fallax), Fimbristylis pycnocephala, and 'akulikuli (Sesuvium portulacastrum). Further in from the sea low trees and shrubs of ironwood, naupaka (Scaevola taccada), Pluchea odorata, and Christmas berry may be found.

An excellent example of native coastal lowland scrub is found at Lililoa along coastal Highway 137, just after entering the Malama Ki Forest Reserve from the Hilo side. Here 'ohi'a as well as pukiawe (Styphelia tameiameiae) come down to the coast. Other native species found here include Ischaemum byrone, 'akia (Wikstroemia sp.), 'ulei (Osteomeles anthyllidifolia), alahe'e (Canthium odoratum), lama, kauna'oa-pehu (Cassytha filiformis), and huehue (Cocculus ferrandianus).

8. Scrub [scr]

This ecosystem type is found in areas which have been frequently disturbed or previously cleared. It is usually dominated by exotic species. Scrub vegetation occurs throughout the study site but is more frequently found in lower Puna where there has been much more disturbance and agricultural activities.

The structure of this ecosytem type may vary from open, grassy areas with scattred shrubs and trees to dense, closed scrub.

Broomsedge (Andropogon virginicus), molassesgrass (Melinis minutiflora), or Californiagrass (Brachiaria mutica) are usually the dominant grass species in the open scrub. Napiergrass (Pennisetum purpureum), bush beardgrass (Andropogon glomeratus), and Hilo grass (Paspalum conjugatum) may be locally common in some areas. The most abundant shrub species are Malabar melastome (Melastoma malabathricum) and the two guava species (Psidium guajava, Psidium cattleianum). Other shrubs commonly observed are lantana (Lantana camara),

pluchea (Pluchea odorata), butterfly bush (Buddleja asiatica), and Desmodium cajanifolium. Scattered patches of uluhe (Dicranopteris spp.) may also be found in the scrub vegetation.

Very scattered low (<5 m) to medium (5 to 10 m) statured 'ohi'a trees may occasionally be found in some open scrub. Exotic trees frequently observed in the open scrub include Trema orientalis, albizia (Albizia spp.), Cecropia spp., and Melochia umbellata.

Solid stands of dense, almost impenetrable scrub composed most often of guava (Psidium guajava) and/or strawberry guava (Psidium cattleianum) are found where ever the land has been disturbed. Psidium reproduces and spreads rapidly from root sprouts. In some places this scrub can become as tall as 10 m or more and develop into a forest. Malabar melastome may also form dense scrub, however, this type of scrub does not get as tall as the Psidium scrub.

The density and diversity of the ground cover varies with the amount of light able to penetrate the scrub. The herb layer is poorly developed where the scrub is dense. Much of the ground is bare or covered with litter from the shrubs above. Shade tolerant plants such as basketgrass (Oplismenus hirtellus) and downy woodfern (Christella dentata) are found here. Where the scrub is less dense Glenwoodgrass (Sacciolepis indica), swordfern (Nephrolepis multiflora), thimbleberry (Rubus rosaefolius), Stachytarpheta spp., honohono (Commelina diffusa), as well as basketgrass and downy wood fern, are present.

Few native species are found in this ecosystem type and then these species tend to be found in the more open scrub. Besides 'ohi'a and uluhe other natives sometimes found in the scrub include 'akia (Wikstroemia sandwicensis), lama (Diospyros ferrea spp. sandwicensis), and sedges such as Fimbristylis dichotoma, 'uki (Machaerina angustifolia), kuolohia (Rhynchospora lavarum), Pycreus polystachyos, and Scleria testacea.

9. Agricultural lands [ag]

Much of Puna, especially the lower Puna area, has been cultivated since pre-historic and historic times. All cultivated lands including sugar cane and papaya fields, orchards, anthurium and orchid farms, fallow fields, etc., as well as abandoned fields, pastures, and the network of roads associated with farming activities are designated "Agricultural lands" in this study.

These agricultural lands present a mosaic of different patterns on the orthophotoquads and are in a constant state of change from year to year. Different crops, stages of cultivation, fallow fields, crop rotation, and expansion of existing fields all contribute to the general dynamics of agricultural lands.

Sugar cane (Saccharum officinarum) and papaya (Carica papaya) have been the primary crops grown in the Puna region. However, with the closing of Puna Sugar Company many of these fields have been abandoned or turned over to papaya cultivation. These abandoned fields are in various stages of weedy succession. Recently abandoned fields consist largely of cane with a few scattered trees of Trema orientalis, Cecropia spp., and melochia (Melochia umbellata). Weedy annuals, shrubs, and grasses quickly invade the fields from the roadsides and borders. Shrubs of comb hyptis (Hyptis pectinata) as well as butterfly bush (Buddleja asiatica), and pluchea (Pluchea odorata) are common. Sensitive plant (Mimosa pudica var. unijuga), honohono (Commelina diffusa), kyllinga (Kyllinga brevifolia), and molassesgrass (Melinis minutiflora) are frequently observed in these abandoned fields.

Over time, the sugar cane is replaced by a scrub composed of exotic species. The fields now support scattered, low thickets of guava (Psidium guajava), Java plum (Syzygium cumini), pluchea, and lantana (Lantana camara). Pockets of sugar cane, reproducing from ratoons, are frequently found.

Molassesgrass, Guinea grass (Panicum maximum), California grass (Brachiaria mutica), and several Desmodium spp. form lumpy patches between the thickets.

Papaya fields in various stages of cultivation from newly transplanted seedlings to mature, bearing plants, 2 to 4 m tall, cover large acreages. Abandoned papaya fields are also frequently found, especially around Kapoho and Pohoiki. Like the sugar fields these abandoned papaya fields are in various stages of weedy succession. Melochia umbellata will often quickly invade these fields. Closed, medium-statured Melochia forests are occasionally seen around the Pohoiki area.

Long abandoned fields with their networks of roads and other evidences of human activities can still be delineated on the orthophotoquads if they have not been obscured by the vegetation. Ground check of these areas reveals remnants of the former crops or the weedy tree and shrub species associated with abandoned fields.

Other crops grown in the Puna region include bananas (Musa hybrids), passion fruit (Passiflora edulis), guavas (Psidium guajava cultivars), and oranges (Citrus sinensis cultivars). Hawaiian Holiday has recently planted macadamia nut trees (Macadamia ternifolia var. integrifolia) on 2,500 acres of abandoned cane land.

The Puna region supplies florists with anthurium and vanda orchid flowers. Puna nurseries also supply cut foliage and potted plants.

A number of weedy species are commonly associated with all these cultivated areas. These include several Euphorbia spp., false pimpernel (Lindernia crustacea), Ageratum conyzoides, Polygala paniculata, comb hyptis, and kyllinga. Many fields are periodically treated with herbicides to control these weeds.

Pasture lands are also included in this ecosystem type. They vary in structure and are very diverse in species composition. For example, some pastures may be open savannahs with tall 'ohi'a trees on lands cleared of native forests or they may be scrubby if overgrazed. Most of the pasture grasses and herbs were delibrately introduced and specifically planted or sown to improve the pasture (Fosberg 1972). Pasture grasses commonly seen in the study site include pangola grass (Digitaria decumbens), narrow-leaved carpet grass (Axonopus affinis), and Hilo grass (Paspalum conjugatum).

SPECIES LIST

The species list presented in Table 1 includes species found during this survey as well as those which have been recorded from the project area in previous literature (Stone 1959; Doty and Mueller-Dombois 1966; Fosberg 1975; Clarke et al. 1979, 1981; Lamoureux and Williams 1982; Williams and Lamoureux 1982; Char and Stemmermann 1984; Cuddihy in ed., etc.)

A total of 457 species of vascular plants are known from the project area. The majority of the native species are found in the least disturbed ecosystem types such as the 'ohi'a and dry forests while the weedy exotic species occur in ecosystems which are frequently disturbed such as scrub and agricultural lands.

In the species list, families are arranged alphabetically within each of four groups: Pteridophyta, Gymnospermae, Monocotyledons, and Dicotyledons. Taxonomy and nomenclature of Pteridophyta (ferns and fern allies) follow Lamoureux's unpublished checklist of Hawaiian ferns; taxonomy and nomenclature of the flowering plants (Monocotyledons and Dicotyledons) follow St. John (1973) except where more commonly accepted names are listed. Hawaiian names used in the checklist are in accordance with Porter (1972) or St. John (1973).

Table 1 provides the following information:

I. Botanical name with author citation.

II. Common English or Hawaiian name, when known.

III. Biogeographic status of each species. The following symbols are used:

E = endemic = native to the Hawaiian Islands only, not occurring naturally elsewhere.

I = indigenous = native to the Hawaiian Islands and also to one or more other geographic areas.

P = Polynesian = plants of Polynesian introduction; all those plants brought by the Polynesian immigrants prior to contact with the Western world.

X = exotic or introduced = not native to the Hawaiian Islands; brought here by man, accidentally or deliberately after Western contact.

IV. Presence (+) or absence (-) of species within nine major ecosystem types. The number heading each of the columns refers to the following ecosystem types:

1. Lava
2. 'Ohi'a woodland
3. 'Ohi'a forest
4. Dry forest
5. Dry scrub community
6. Dry grassland
7. Mixed lowland forest
8. Scrub
9. Agricultural lands

TABLE 1. PLANT SPECIES CHECKLIST FOR PUNA GEOTHERMAL AREA

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
PTERIDOPHYTA											
ADIANTACEAE											
Adiantum hispidulum Sw.	Maiden-hair fern	X	-	-	+	-	-	-	-	-	-
Adiantum raddianum Presl	Maiden-hair fern	X	-	-	+	-	-	-	+	-	-
ASPIDIACEAE											
Dryopteris wallichiana (Spreng.) Hyl.	Lau-kahi	I	-	-	+	-	-	-	-	-	-
Tectaria crenata Cav.		X	-	-	-	-	-	-	+	-	-
ASPLENIACEAE											
Asplenium adiantum-nigrum L.	'Iwa'iwa	I	+	-	-	+	-	-	-	-	-
Asplenium contiguum Kaulf.		E	-	-	+	-	-	-	-	-	-
Asplenium lobulatum Mett.	Pi'ipi'i-lau-manamana, 'anali'i	I	-	-	+	-	-	-	-	-	-
Asplenium nidus L.	'Ekaha	I	-	-	+	+	-	-	+	-	-
Asplenium polyodon Forst.		I	-	-	+	-	-	-	-	-	-
Asplenium unilaterale Lamk.	Pamoho	I	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
ATHYRIACEAE											
Athyriopsis japonica (Thunb.) Ching		X	-	-	+	-	-	-	-	-	-
Athyrium microphyllum (J. Sm.) Alston	'Akolea	E	-	-	+	-	-	-	-	-	-
Diplazium esculentum (Retz.) Sw.		X	-	-	-	-	-	-	-	-	+
Diplazium sandwichianum (Presl) Diels	Ho'i'o	E	-	-	+	-	-	-	-	-	-
BLECHNACEAE											
Blechnum occidentale L.	Blechnum fern	X	-	-	+	-	-	-	-	+	-
Sadleria cyatheoides Kaulf.	'Ama'u	E	+	+	+	-	-	-	+	-	-
Sadleria pallida Hook. & Arn.	'Ama'u	E	-	-	+	-	-	-	-	-	-
DENNSTAEDITIACEAE											
Microlepia strigosa (Thunb.) Presl	Palai, palapalai	I	-	-	+	-	-	-	-	-	-
DICKSONIACEAE											
Cibotium chamissoi Kaulf.	Hapu'u-'i'i	E	-	-	+	-	-	-	+	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Cibotium glaucum (J. Sm.) Hook. & Arn.	Hapu'u	E	-	+	+	-	-	-	+	-	-
Cibotium hawaiense Nakai & Ogura	Meu	E	-	-	+	-	-	-	-	-	-
ELAPHOGLOSSACEAE											
Elaphoglossum alatum Gaud. var. parvisquameum (Skottsb.) Ands. & Crosby	'Ekaha-ula, hoe-a-Maui	E	-	-	+	-	-	-	+	-	-
Elaphoglossum crassifolium (Gaud.) And. & Crosby	'Ekaha-ula, hoe-a-Maui	E	-	+	+	-	-	-	-	-	-
Elaphoglossum hirtum (Sw.) C. Chr. var. micans (Mett.) C. Chr.	'Ekaha-ula, hoe-a-Maui	E	-	-	+	-	-	-	-	-	-
Elaphoglossum pellucidum Gaud.	'Ekaha-ula, hoe-a-Maui	E	-	-	+	-	-	-	-	-	-
Elaphoglossum wawrae (Luerss.) C. Chr.	'Ekaha-ula, hoe-a-Maui	E	-	-	+	-	-	-	-	-	-
GLEICHENIACEAE											
Dicranopteris emarginata (Brack.) Rob.	Uluhe	E	+	+	+	-	-	-	+	+	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Dicranopteris linearis (Burm.) Underw.	Uluhe	I	+	+	+	-	-	-	-	-	-
GRAMMITACEAE											
Adenophorus hymenophylloides (Kaulf.) Hook. & Grev.	Pai, palai-huna	E	-	-	+	-	-	-	-	-	-
Adenophorus periens L. E. Bishop	Palai-la'au	E	-	-	+	-	-	-	-	-	-
Adenophorus pinnatifidus Gaud.		E	-	-	+	-	-	-	-	-	-
Adenophorus tamariscinus (Kaulf.) Hook. & Grev.	Wahine-noho-mauna	E	-	+	+	-	-	-	+	-	-
Adenophorus tripinnatifidus Gaud.		E	-	-	+	-	-	-	-	-	-
Grammitis hookeri (Brack.) Copel.	Maku'e-lau-li'i	E	-	-	+	-	-	-	-	-	-
Grammitis tenella Kaulf.	Kolokolo, mahina-lua	E	-	-	+	-	-	-	-	-	-
Xiphopteris saffordii (Maxon) Copel.	Kihi	E	-	-	+	-	-	-	-	-	-
HEMIONITIDACEAE											
Coniogramme pilosa (Brack.) Hieron.	Lo'ulu	E	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Pityrogramma calomelanos (L.) Link	Gold fern, silver fern	X	+	+	-	-	-	-	-	+	-
HYMENOPHYLLACEAE											
Callistopteris baldwinii (Eaton) Copel.		E	-	-	+	-	-	-	-	-	-
Gonocormus minutus (Blume) v. d. Bosch		I	-	-	+	-	-	-	+	-	-
Mecodium recurvum (Gaud.) Copel.	'Ohi'a-ku	E	-	-	+	-	-	-	-	-	-
Sphaerocionium lanceolatum (Hook. & Arn.) Copel.	Palai-hinahina	E	-	-	+	-	-	-	-	-	-
Sphaerocionium obtusum (Hook. & Arn.) Copel.	Palai-lau-li'i	E	-	-	+	-	-	-	-	-	-
Vandenboschia cyrtotheca (Hillebr.) Copel.		E	-	-	+	-	-	-	-	-	-
Vandenboschia davallioides (Gaud.) Copel.	Palai-hihi	E	-	-	+	-	-	-	+	-	-
HYPOLEPIDACEAE											
Pteridium aquilinum (L.) Kuhn var. decompositum (Gaud.) Tryon	Kilau, kilau-pueo, pai'a	E	-	+	-	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
LINDSAEACEAE											
Lindsaea ensifolia Sw. var. ensifolia		I	-	+	-	-	-	-	-	-	-
Sphenomeris chinensis (B.) Maxon	Pala'a, palapala'a	I	-	+	+	-	-	-	-	-	-
LYCOPODIACEAE											
Lycopodium cernuum L.	Wawae-'iole	I	-	+	+	-	-	-	+	+	-
Lycopodium phyllanthum Hook. & Arn.	Wawae-'iole	E	+	+	+	-	-	-	-	-	-
Lycopodium polytrichoides Kaulf.	Wawae-'iole	E	-	-	+	-	-	-	-	-	-
Lycopodium venustulum Gaud.	Wawae-'iole	I	-	-	+	-	-	-	-	-	-
MARATTIACEAE											
Marattia douglasii (Presl) Baker	Pala, kapua'i hoki	E	-	-	+	-	-	-	-	-	-
NEPHROLEPIDACEAE											
Nephrolepis cordifolia (L.) Presl	Ni'ani'au, kupukupu, 'okupukupu	I	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Nephrolepis exaltata (L.) Schott	Ni'ani'au, kupukupu 'okupukupu	I	-	+	+	-	-	-	+	-	-
Nephrolepis multiflora (Roxb.) Jarrett ex Morton	Hairy sword fern	X	+	+	+	+	+	+	+	+	+
OPHIOGLOSSACEAE											
Ophioglossum concinuum Brack.	Pololei	E	+	-	-	-	-	-	-	-	-
Ophioglossum nudicaule L. f.		I	+	-	-	-	-	-	-	-	-
Ophioglossum pendulum L. ssp. falcatum (Presl) Clausen	puapua-moe	E	-	-	+	-	-	-	+	-	-
POLYPODIACEAE											
Phlebodium aureum (L.) J. Sm.	Laua'e-haole	X	-	-	+	-	-	-	-	-	-
Phymatosorus scolopendria (Burm.) Pic.-Ser.	Laua'e, lauwa'e	X	+	+	+	+	+	+	+	-	-
Pleopeltis thunbergiana Kaulf.	'Ekaha-'akolea, pakahakaha	I	+	+	+	+	-	-	+	-	-
Polypodium pellucidum Kaulf.	'Ae, 'ae-lau-nui	E	+	-	-	-	-	-	-	-	-
PSILOTACEAE											
Psilotum complanatum Sw.	Moa, pipi	I	-	-	+	-	-	-	-	-	-
Psilotum nudum (L.) Beauv.	Moa, pipi	I	+	+	+	+	+	-	+	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
PTERIDACEAE											
Pteris vittata L.		X	+	+	+	-	-	-	+	+	-
SELAGINELLACEAE											
Selaginella arbuscula (Kaulf.) Spring	Lepelepe-a-moa	E	-	-	+	-	-	-	-	-	-
SINOPTERIDACEAE											
Doryopteris decipiens (Hook.) J. Sm.	Kumu-niu, manawahua, 'iwa'iwa	E	+	-	-	-	-	-	-	-	-
Doryopteris decora Brack.	Kumu-niu, manawahua, 'iwa'iwa	E	+	-	-	-	-	-	-	-	-
Pellaea ternifolia (Cav.) Link	Lau-kahi	I	-	-	-	+	+	-	-	-	-
THELYPTERIDACEAE											
Amauropelta globulifera (Brack.) Holtt.	Palapalai-a-Kama-pua'a	E	-	-	+	-	-	-	-	-	-
Christella cyatheoides (Kaulf.) Holtt.	Kikawaio	E	-	-	+	-	-	-	-	-	-
Christella dentata (Forsk.) Brownsey & Jermy	Downy woodfern	X	-	-	+	-	-	-	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Christella parasitica (L.) Levl.	Woodfern, oakfern	X	-	-	+	-	-	-	-	-	-
Macrothelypteris torresiana (Gaud.) Ching		X	+	-	+	-	-	-	-	-	-
Pneumatopteris hudsoniana (Brack.) Holtt.	Lau-kahi	E	-	-	+	-	-	-	-	-	-
Pneumatopteris sandwicensis (Brack.) Holtt.		E	-	-	+	-	-	-	-	-	-
Pseudophegopteris keraudreniana (Gaud.) Holtt.	Waimaka-nui	E	-	-	+	-	-	-	-	-	-
VITTARIACEAE											
Vittaria elongata Sw.	Oheohe	I	-	-	+	-	-	-	+	-	-
GYMNOSPERMAE											
ARAUCARIACEAE											
Araucaria spp.	Cook pine, Norfolk Island pine	X	-	-	-	-	-	-	+	-	+
MONOCOTYLEDONAE											
ARACEAE											
Anthurium hybrids	Anthurium	X	-	-	+	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Colocasia esculenta (L.) Schott.	Kalo, taro	P	-	-	-	-	-	-	+	-	+
Monstera deliciosa Liebm.	Monstera	X	-	-	-	-	-	-	+	-	-
Philodendron sp.	Philodendron	X	-	-	+	-	-	-	+	-	-
Scindapsus aureus (Lindl. ex. Andre) Engl.	Taro vine	X	-	-	-	-	-	-	+	-	-
Syngonium auritum (L.) Schott.	Syngonium	X	-	-	-	-	-	-	+	-	-
CANNACEAE											
Canna indica L.	Canna	X	-	-	-	-	-	-	-	-	+
COMMELINACEAE											
Commelina diffusa Burm. f.	Honohono	X	-	-	+	+	-	-	+	+	+
CYPERACEAE											
Bulbostylis capillaris (L.) C. B. Clarke		X	-	+	-	-	-	-	-	-	-
Carex wahuensis C. A. Mey. var. wahuensis		E	-	-	+	+	-	-	-	-	-
Carex wahuensis C. A. mey. var. rubiginosa R. W. Krauss		E	-	-	+	+	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Cyperus compressus L.		X	-	-	-	-	+	-	-	-	-
Cyperus haspan L.		X	-	-	+	-	-	-	-	+	-
Cyperus javanicus Houtt.	'Ahu'awa, 'ehu'awa	I	-	-	+	-	-	-	-	-	-
Cyperus rotundus L.	Nutsedge	X	-	-	-	-	-	-	-	-	+
Fimbristylis dichotoma (L.) Vahl	Tall fringe rush	I	-	+	+	-	-	-	-	+	+
Fimbristylis pycnocephala Hillebr.		I	-	-	-	-	-	-	+	-	-
Kyllinga brevifolia Rottb.	Kili'o'opu, kyllinga	X	-	+	+	+	-	-	+	+	+
Kyllinga nemoralis (J. R. & G. Forst.) Dandy ex Hutch. & Dalziel	Kili'o'opu, kyllinga	X	-	-	+	+	-	-	+	+	+
Machaerina angustifolia (Gaud.) Koyama	'Uki	I	+	+	+	-	-	-	+	+	-
Machaerina gahniaeformis (Gaud.) Kern.	'Uki	E	-	+	-	-	-	-	-	-	-
Machaerina mariscoides (Gaud.) Kern ssp. meyenii (Kunth) Koyama	'uki, 'aha-niu	I	+	+	+	-	-	-	+	+	-
Pycreus polystachyos (Rottb.) Beauv.		I	+	+	+	-	-	-	+	+	+
Rhynchospora lavarum Gaud.	Kuolohia, pu'uko'a	E	-	+	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Rhynchospora sclerioides Hook. & Arn.	Hawaiian beak rush	E	–	–	+	–	–	–	–	–	–
Rhynchospora spicaeformis Hillebr.	Kuolohia	E	–	+	–	–	–	–	–	–	–
Rhynchospora sp.		X	–	–	+	–	–	–	–	–	–
Scleria testacea Nees	Scleria	E	–	–	–	–	–	–	+	+	–
Uncinia uncinata (L. f.) Kuek.		I	–	–	+	–	–	–	–	–	–
DIOSCOREACEAE											
Dioscorea pentaphylla L.	Pi'ia, pi'a	P	–	–	+	–	–	–	+	+	–
GRAMINEAE											
Andropogon glomeratus (Walt.) BSP.	Bush beardgrass	X	–	+	–	+	+	+	–	+	+
Andropogon virginicus L.	Broomsedge	X	+	+	+	+	+	+	+	+	+
Agrostis avenacea Gmel.	Bentgrass, he'u-pueo	X	–	+	–	–	–	–	–	–	–
Axonopus affinis Chase	Narrow-leaved carpetgrass	X	–	+	+	–	–	–	–	+	+
Axonopus compressus (Sw.) Beauv.	Broad-leaved carpetgrass	X	–	+	–	–	–	–	–	+	+
Bambusa spp.	Bamboo	X	–	–	–	–	–	–	+	+	+
Brachiaria mutica (Forsk.) Stapf.	Californiagrass	X	–	–	–	–	–	–	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Brachiaria reptans (L.) Gard. & C. E Hubb.		X	-	-	-	-	-	-	-	-	+
Briza minor L.	Little quakinggrass	X	-	+	-	-	-	-	-	-	-
Chloris radiata (L.) Sw.	Radiate fingergrass	X	-	-	-	-	-	-	-	-	+
Chrysopogon aciculatus (Retz.) Trin.	Pilipili-'ula, goldenbeardgrass	X	-	-	-	-	+	+	+	-	-
Coix lachryma-jobi L.	Pu'ohe'ohe, Job's tears	X	-	-	-	-	-	-	+	+	+
Cynodon dactylon (L.) Pers.	Manienie, Bermudagrass	X	-	+	-	+	-	-	-	-	+
Deschampsia australis Nees ex Steud.		E	-	+	-	-	-	-	-	-	-
Digitaria adscendens (HBK.) Henr.	Henry's crabgrass	X	-	-	-	+	-	+	-	-	+
Digitaria decumbens Stent	Pangolagrass	X	-	-	-	-	-	-	-	+	+
Digitaria eriantha Steud.		X	-	-	-	-	-	-	-	-	+
Digitaria fuscescens (Presl) Henr.	Creeping kukaepua'a	X	-	+	-	-	-	+	-	+	+
Digitaria radicosa (Presl) Miq.		X	-	+	-	-	-	+	+	-	-
Digitaria setigera Roth ex R. & S.		X	-	-	-	-	-	+	-	-	+
Digitaria timorensis (Kunth) Balansa		X	-	-	-	-	-	+	-	-	+
Digitaria sp.		X	-	+	-	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Eleusine indica (L.) Gaertn.	Goosegrass	X	-	-	-	-	-	-	-	+	+
Eragrostis brownei (Kunth) Nees	Brown's lovegrass	X	-	+	-	-	-	-	-	-	-
Eragrostis sp.		X	-	-	-	-	-	-	-	+	+
Heteropogon contortus (L.) Beauv. ex R. & S.	Pili, piligrass	I	-	-	-	-	+	+	-	-	-
Holcus lanatus L.	Velvetgrass	X	-	+	-	-	-	-	-	-	-
Hyparrhenia rufa (Nees) Stapf	Thatchinggrass, jaragua	X	-	-	-	-	-	-	-	+	+
Isachne distichophylla Munro ex Hillebr.	Ohe	E	-	+	+	-	-	-	+	-	-
Ischaemum byrone (Trin.) Hitch.	Ischaemum	E	-	-	-	-	-	-	+	-	-
Melinis minutiflora Beauv.	Molassesgrass	X	-	+	-	+	+	+	+	+	+
Microlaena stipoides (Labill.) R. Br.	Pu'u lehua, meadow ricegrass	X	-	-	-	-	-	-	-	-	+
Oplismenus hirtellus (L.) Beauv.	Honohono-kukui, basketgrass	X	-	-	+	+	-	-	+	+	-
Panicum maximum Jacq. var. maximum	Guineagrass	X	-	-	-	-	-	-	-	+	+
Panicum repens L.	Wainakugrass	X	-	-	-	-	-	-	-	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Paspalum conjugatum Berg.	Mau'u-Hilo, Hilo grass	X	-	+	+	+	-	-	+	+	+
Paspalum dilatatum Poir.	Dallisgrass, Australian watergrass	X	-	-	-	-	-	-	-	-	+
Paspalum orbiculare Forst. f.	Mau'u-laiki, ricegrass	X	-	+	+	-	-	-	+	-	+
Paspalum urvillei Steud.	Vaseygrass	X	-	+	+	+	-	-	+	+	+
Pennisetum purpureum Schumach.	Napiergrass, elephantgrass	X	-	-	-	-	-	-	+	+	+
Pennisetum setaceum (Forsk.) Chiov.	Fountaingrass	X	+	-	-	-	-	-	-	-	-
Poa annua L.	Annual bluegrass	X	-	-	-	-	-	-	-	-	+
Rhynchelytrum repens (Willd.) C. E. Hubb.	Natal redtopgrass	X	-	+	-	+	+	+	-	+	+
Saccharum officinarum L.	Ko, sugarcane	P	-	-	-	-	-	-	-	+	+
Sacciolepis indica (L.) Chase	Glenwoodgrass	X	-	+	+	-	-	-	+	+	+
Schizostachyum glaucifolium (Rupr.) Munro	Ohe, Hawaiian bamboo	P	-	-	+	-	-	-	+	-	-
Setaria geniculata (Poir.) Beauv.	Perennial. foxtailgrass	X	-	+	+	+	-	-	-	+	+
Setaria glauca (L.) Beauv.	Yellow foxtailgrass	X	-	+	-	+	-	-	-	+	+
Setaria palmaefolia (Koen.) Stapf	Palmgrass	X	-	-	+	-	-	-	+	-	+
Sporobolus africanus (Poir.) Robyns & Tournay	African dropseedgrass	X	-	+	-	-	-	-	-	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Sporobolus diander (Retz.) Beauv.	Indian dropseedgrass	X	-	-	-	-	+	-	-	-	+
IRIDACEAE											
Tritonia crocosmaeflora Nichols.	Montbretia	X	-	-	+	-	-	-	-	-	-
JOINVILLEACEAE											
Joinvillea ascendens Brong. & Gris.	'Ohe	E	-	-	+	-	-	-	-	-	-
JUNCACEAE											
Juncus effusus L.	Bog rush	X	-	+	+	-	-	-	-	-	-
Juncus planifolius R. Br.		X	-	+	+	-	-	-	-	-	-
Juncus tenuis Willd.		X	-	-	+	-	-	-	-	-	-
Luzula hawaiiensis Buch.	Luzula	E	-	+	-	-	-	-	-	-	-
LILIACEAE											
Astelia menziesiana Sm.	Pa'iniu	E	-	-	+	-	-	-	-	-	-
Cordyline terminalis (L.) Kunth var. terminalis	Ki, ti	P	-	+	+	+	-	-	+	+	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Cordyline terminalis (L.) Kunth var. ferrea (L.) J. G. Baker	Red ti	X	-	-	-	-	-	-	-	-	+
Dianella sandwicensis Hook. & Arn.	'Uki, 'uki-'uki	E	-	+	+	-	-	-	-	-	-
Smilax sandwicensis Kunth	Hoi-kuahiwi	E	-	-	+	-	-	-	-	-	-
MUSACEAE											
Musa spp.	Mai'a, banana	P	-	-	+	-	-	-	+	-	+
ORCHIDACEAE											
Anoectochilus sandvicensis Lindl.	Honohono	E	-	-	+	-	-	-	-	-	-
Arundina bambusaefolia (Roxb.) Lindl.	Bamboo orchid	X	+	+	+	+	+	+	+	+	+
Phaius tankevilliae (Banks ex L'Her.) Bl.		X	-	+	+	-	-	-	-	-	-
Spathoglottis plicata Bl.	Philippine ground orchid	X	+	+	+	+	+	-	+	+	+
Vanda terres Lindl. x V. hookeriana Reichb. f.	Vanda	X	-	-	-	-	-	-	-	-	+
PALMAE											
Archontophoenix alexandrae (F. Muell.) H. Wendl. & Drude	Alexandra palm	X	-	-	-	-	-	-	+	+	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Cocos nucifera L.	Niu, coconut palm	P	-	-	-	+	+	-	+	-	+
PANDANACEAE											
Freycinetia arborea Gaud.	'Ie'ie	E	-	-	+	+	-	-	+	-	-
Pandanus ordoratissimus L. f.	Hala, pandanus	I	-	-	+	-	+	-	+	-	-
Pandanus sp.	Hala, pandanus	E	-	-	-	-	-	-	+	-	-
XYRIDACEAE											
Xyris complanata R. Br.		X	-	+	-	-	-	-	-	-	-
ZINGIBERACEAE											
Alpinia purpurata (Vieill.) K. Schum.	Red ginger, 'awapuhi-'ula'ula	X	-	-	-	-	-	-	-	+	+
Hedychium coronarium Koenig	'Awapuhi ke'oke'o, white ginger	X	-	-	-	-	-	-	+	-	-
Hedychium flavescens Carey	'Awapuhi melemele, yellow ginger	X	-	-	+	-	-	-	+	+	-
Hedychium gardnerianum Roscoe	Kahili ginger	X	-	-	+	-	-	-	-	-	-
Zingiber zerumbet (L.) Roscoe	'Awapuhi kua hiwi	P	-	-	+	-	-	-	+	-	-
DICOTYLEDONAE											
ACANTHACEAE											
Nicoteba betonica (L.) Lindau	White shrimp plant	X	-	-	-	-	-	-	-	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Odontonema strictum (Nees) Ktze.	Odontonema	X	-	-	-	-	-	-	-	+	+
Thunbergia fragrans Roxb.	White thunbergia	X	-	-	+	-	-	-	+	+	+
AIZOACEAE											
Sesuvium portulacastrum	'Akuli'kuli	I	-	-	-	-	-	-	+	-	-
AMARANTHACEAE											
Alternanthera sessilis (L.) R. Br. ex R. & S.		X	-	-	-	-	-	-	-	-	+
Amaranthus spinosus L.	Spiny amaranth, pakai-kuku	X	-	-	-	-	-	-	-	+	+
Amaranthus viridis L.	Slender amaranth, pakai	X	-	-	-	-	-	-	-	-	+
Charpentiera obovata Gaud.	Papala	E	-	-	+	-	-	-	-	-	-
ANACARDIACEAE											
Mangifera indica L.	Mango	X	-	+	+	+	-	-	+	+	+
Rhus sandwicensis Gray	Neneleau	E	-	+	-	-	-	-	-	-	-
Schinus terebinthifolius Raddi	Christmas berry	X	-	-	+	+	+	+	+	+	+
APOCYNACEAE											
Alyxia olivaeformis Gaud.	Maile	E	-	-	+	-	-	-	-	-	-
Rauvolfia remotiflora Deg. & Sherff	Hao	E	-	-	-	+	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
AQUIFOLIACEAE											
Ilex anomala Hook. & Arn.	Kawa'u	E	-	+	+	-	-	-	-	-	-
ARALIACEAE											
Brassaia actinophylla Endl.	Octopus tree, umbrella tree	X	-	-	-	-	-	-	+	-	-
Cheirodendron trigynum (Gaud.) Heller	Olapa	E	-	-	+	-	-	-	-	-	-
Reynoldsia hillebrandii Sherff	'Ohe makai	E	-	-	-	+	-	-	-	-	-
Tetraplasandra hawaiensis Gray var. hawaiensis	'Ohe	E	-	+	+	-	-	-	+	-	-
ASCLEPIADACEAE											
Asclepias curassavica L.	Butterfly weed	X	-	-	-	-	-	-	-	+	+
BALSAMINACEAE											
Impatiens sultani Hook. f.	Impatiens	X	-	-	-	-	-	-	+	+	+
BEGONIACEAE											
Begonia sp.	Begonia	X	-	-	+	-	-	-	+	-	-
BIGNONIACEAE											
Spathodea campanulata Beauv.	African tuliptree	X	-	-	-	-	-	-	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
CAPRIFOLIACEAE											
Lonicera japonica Thunb.	Honeysuckle	X	-	-	+	-	-	-	-	-	-
CARICACEAE											
Carica papaya L.	Papaya, mikana	X	-	-	+	-	-	-	+	+	+
CARYOPHYLLACEAE											
Cerastium vulgatum L.	Larger mouse ear chickweed	X	-	+	-	-	-	-	-	-	-
Drymaria cordata (L.) Willd. ex R. & S.	Drymaria, pipili	X	-	-	+	-	-	-	-	+	+
CASUARINACEAE											
Casuarina cunninghamiana Miq.	River-oak casuarina	X	-	-	-	-	-	-	+	+	-
Casuarina equisetifolia Stickman	Ironwood	X	+	-	-	-	-	-	+	+	-
Casuarina littoralis Salisb.	Black she-oak casuarina	X	-	-	-	-	-	-	+	-	-
CELASTRACEAE											
Perrottetia sandwicensis Gray	Olomea	E	-	-	+	-	-	-	-	-	-
COMPOSITAE											
Adenostemma lavenia (L.) Ktze.	Kamanamana	I	-	-	+	-	-	-	+	-	-
Ageratum conyzoides L.	Ageratum, maile-hohono	X	-	+	+	+	-	-	-	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Ageratum houstonianum Mill.	Ageratum	X	-	-	+	-	-	-	-	+	+
Bidens pilosa L. var. pilosa	Spanish needle	X	-	-	-	+	-	-	-	+	+
Bidens pilosa L. var. minor (Bl.) Sherff		X	-	-	-	-	-	-	-	-	+
Bidens skottsbergii Sherff	Ko'oko'olau	E	-	-	-	+	-	-	-	-	-
Cirsium vulgare (Savi) Tenore	Bull thistle	X	-	-	+	-	-	-	-	-	-
Crassocephalum crepidioides (Benth.) S. Moore		X	-	-	+	-	-	-	-	-	+
Crepis sp.		X	-	-	-	-	-	-	+	-	-
Dubautia ciliolata (DC.) Keck	Kupaoa	E	+	+	-	-	-	-	-	-	-
Dubautia ciliolata X D. scabra	Hybrid dubautia	E	+	-	-	-	-	-	-	-	-
Dubautia scabra (DC.) Keck	Kupaoa	E	+	+	+	-	-	-	-	-	-
Eclipta alba (L.) Hassk.	False daisy	X	-	-	-	-	-	-	-	-	+
Emilia fosbergii Nicol.	Red pua-lele	X	-	+	-	+	-	-	+	-	+
Emilia sonchifolia (L.) Raf.	Lilac pua-lele	X	-	-	-	-	-	-	+	-	+
Erechtites hieracifolia (L.) Raf.	Fireweed	X	-	+	+	+	-	-	-	+	+
Erechtites valerianaefolia (Wolf) DC.	Fireweed	X	-	+	+	-	-	-	+	-	+
Erigeron bonariensis L.	Hairy horseweed, ilioha	X	-	+	+	+	-	+	-	+	+
Erigeron canadensis L.	Canada fleabane	X	-	+	-	-	-	-	-	+	+
Erigeron pusillus Nutt.	Dwarf horseweed	X	-	-	-	-	-	-	-	+	-
Eupatorium riparium Regel	Hamakua pamakani	X	+	+	+	-	-	-	-	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Gnaphalium hawaiiense Deg. & Sherff	'Ena'ena	E	+	+	-	-	-	-	-	-	-
Gnaphalium japonicum Thunb.	Cudweed	X	-	-	-	-	-	-	-	-	+
Gnaphalium purpureum L.	Purple cudweed	X	-	+	-	-	-	-	-	-	-
Gnaphalium sandwicensium Gaud.	'Ena'ena, Hawaiian cudweed	E	-	+	-	-	-	-	-	-	-
Hypochoeris radicata L.	Gosmore, hairy cats-ear	X	-	+	-	-	-	-	-	-	-
Pluchea odorata (L.) Cass.	Pluchea, shrubby fleabane	X	+	+	+	+	-	-	+	+	+
Sonchus oleraceus L.	Sow thistle, pua-lele	X	-	-	-	-	-	-	-	-	+
Veronia cinerea (L.) Less.	Ironweed	X	-	+	-	-	-	+	+	-	+
Wedelia trilobata (L.) Hitchc.	Wedelia	X	-	-	-	-	-	-	+	+	+
Youngia japonica (L.) DC.	Oriental hawksbeard	X	-	+	+	-	-	-	-	+	+
CONVOLVULACEAE											
Argyreia nervosa (Burm. f.) Bojer	Small wood rose	X	-	-	-	-	-	-	+	-	-
Cuscuta sandwichiana Choisy	Kauna'oa, dodder	E	-	-	-	-	-	-	+	-	-
Ipomoea alba L.	Moonflower	X	-	-	-	-	-	-	+	+	+
Ipomoea batatas (L.) Poir.	'Uala, sweet potato	P	-	-	-	-	-	-	-	-	+
Ipomoea indica (Burm.) Merr.	Koali-'awahia	I	-	-	-	+	+	-	+	+	+
Ipomoea triloba L.	Little bell	X	-	-	-	-	-	-	-	+	+
Merremia aegyptia (L.) Urban	Hairy merremia, koali-kua-hulu	I	-	-	-	-	-	-	-	+	+
Merremia tuberosa (L.) Rendle	Wood rose	X	-	-	-	-	-	-	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
CRASSULACEAE											
Kalanchoe pinnata (Lam.) Pers.	Air plant, 'oliwa-ku-kahakai	X	-	-	-	-	-	-	+	+	-
CRUCIFERAE											
Cardamine flexuosa With. forma umbrosa (Gren. & Godr.) O. E. Schultz	Bitter cress	X	-	-	-	-	-	-	-	-	+
CUCURBITACEAE											
Momordica charantia L. var. pavel Crantz	Balsam apple, peria	X	-	-	-	-	-	-	-	+	+
EBENACEAE											
Diospyros ferrea Bakh. ssp. sandwicensis (A. DC.) Bakh.	Lama	E	-	-	+	+	+	+	+	+	-
EPACRIDACEAE											
Styphelia tameiameiae (Cham.) F. Muell.	Pukiawe	I	-	+	+	+	+	+	+	+	-
ERICACEAE											
Vaccinium calycinum Sm.	'Ohelo-kau-la'au	E	-	+	+	-	-	-	-	-	-
Vaccinium reticulatum Sm.	'Ohelo	E	+	+	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
EUPHORBIACEAE											
Aleurites moluccana (L.) Willd.	Kukui	P	-	-	+	+	+	-	+	-	-
Antidesma platyphyllum Mann	Hame, mehame	E	-	-	+	-	-	-	+	-	-
Euphorbia glomerifera (Millsp.) L. C. Wheeler		X	-	-	-	-	-	-	-	-	+
Euphorbia hirta L.	Garden spurge, koko-kahiki	X	-	-	-	+	-	-	-	-	+
Euphorbia prostrata Ait.	Prostrate spurge	X	-	-	-	-	-	-	-	-	+
Euphorbia thymifolia L.	Thyme-leaved spurge	X	-	-	-	-	-	-	-	-	+
Macaranga grandifolia (Blanco) Merr.	Bingabing	X	-	-	-	-	-	-	+	-	-
Macaranga tanarius (Stickm.) Muell.-Arg.		X	-	-	-	-	-	-	+	-	-
Manihot glaziovii Muell.-Arg.	Ceara rubber	X	-	-	-	-	-	-	+	-	-
Phyllanthus debilis Klein ex Willd.	Phyllanthus weed	X	-	-	-	+	-	+	-	+	+
Ricinus communis L.	Castor bean, koli	X	-	-	-	-	-	-	-	+	+
GESNERIACEAE											
Cyrtandra lysiosepala (Gray) C. B. Clarke		E	-	-	+	-	-	-	-	-	-
Cyrtandra paludosa Gaud. var. integrifolia Hillebr.		E	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Cyrtandra paludosa Gaud. var. irrostrata St. John		E	-	-	+	-	-	-	+	-	-
Cyrtandra platyphylla Gray		E	-	-	+	-	-	-	-	-	-
Cyrtandra sp. 1		E	-	-	+	-	-	-	-	-	-
Cyrtandra sp. 2		E	-	-	+	-	-	-	-	-	-
Cyrtandra sp. nov.		E	-	-	+	-	-	-	+	-	-
GOODENIACEAE											
Scaevola chamissoniana Gaud. var. bracteosa Hillebr.	Naupaka-kauhiwi	E	-	+	+	-	-	-	-	-	-
Scaevola taccada (Gaertn.) Roxb.	Naupaka-kahakai	I	-	-	-	-	-	-	+	-	-
GUTTIFERAE											
Calophyllum inophyllum L.	Kamani	P	-	-	-	-	-	-	+	-	-
Hypericum degeneri Fosb.		X	-	-	+	-	-	-	-	-	-
Hypericum mutilum L.	St. Johnswort	X	-	+	+	-	-	-	-	+	+
LABIATAE											
Coleus blumei Benth.	Coleus	X	-	-	-	-	-	-	+	-	-
Hyptis pectinata (L.) Poit.	Comb hyptis	X	-	+	-	-	-	-	+	+	+
Phyllostegia vestita Benth.	Ulihi	E	-	-	+	-	-	-	-	-	-
Plectranthus parviflorus Willd.	'Ala'ala-wai-nui wahine	I	-	-	-	+	+	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Salvia coccinea Juss. ex Murr.	Scarlet sage	X	-	-	-	+	-	-	-	-	-
Stenogyne calaminthoides Gray		E	-	+	+	-	-	-	-	-	-
LAURACEAE											
Cassytha filiformis L.	Kauna'oa, kauna'oa-pehu	I	-	+	-	+	+	+	+	-	-
Persea americana Mill	Avocado	X	-	-	+	+	-	-	+	+	+
LEGUMINOSAE											
Abrus precatorius L. forma precatorius	Rosary pea	X	-	-	-	+	-	-	-	-	-
Acacia confusa Merr.	Formosan koa	X	-	-	-	-	-	-	+	-	-
Albizia falcataria (L.) Fosb.	Molucca albizia	X	+	-	-	-	-	-	+	+	-
Albizia sp.		X	-	-	-	-	-	-	+	+	-
Caesalpinia major (Medic.) Dandy & Excell	Kakalaioa, gray nickers	I	-	-	+	+	-	-	-	-	-
Canavalia sp.	'Awikiwiki	E	-	-	-	+	-	-	-	-	-
Cassia alata L.	Candlebush	X	-	-	-	-	-	-	-	+	-
Cassia lechenaultiana DC. var. lechenaultiana	Partridge pea, lauki	X	-	+	-	+	-	+	+	+	+
Cassia occidentalis L.	Coffee senna, 'auko'i	X	-	-	-	-	-	-	-	+	+
Cassia surattensis Burm.	Kolomona	X	-	-	-	+	+	+	-	-	-
Crotalaria berteriana DC.	Rattlebox, tawny crotalaria	X	-	-	-	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Crotalaria incana L.	Fuzzy rattlepod	X	-	-	-	-	-	-	+	+	+
Crotalaria pallida Aiton		X	-	-	-	+	+	-	-	+	+
Crotalaria retusa L.	Rattlebox, sauni	X	-	-	-	-	-	-	-	-	+
Crotalaria spectabilis Roth	Rattlepod	X	-	-	-	-	-	-	-	+	+
Desmanthus virgatus L.	Virgate mimosa	X	-	-	-	-	-	-	-	+	+
Desmodium cajanifolium (HBK.) DC.	Tree desmodium	X	-	-	-	-	-	-	-	+	+
Desmodium discolor Vogel		X	-	-	-	-	-	-	-	-	+
Desmodium heterophyllum (Willd.) DC.		X	-	-	-	-	-	-	+	+	+
Desmodium tortuosum (Sw.) DC.	Florida beggarweed	X	-	-	-	-	-	-	-	+	+
Desmodium triflorum (L.) DC.	Three-flowered beggarweed	X	-	+	-	-	-	+	-	+	+
Desmodium uncinatum (Jacq.) DC.	Spanish clover	X	-	+	+	+	+	+	+	+	+
Desmodium sp.		X	-	-	-	-	-	-	-	+	+
Erythrina sandwicensis Deg.	Wiliwili	E	-	-	-	+	-	+	-	-	-
Indigofera suffruticosa Mill.	Indigo, 'iniko	P	-	-	-	+	+	+	-	+	+
Leucaena leucocephala (Lam.) de Wit	Kao-haole, ekoa	X	-	-	-	-	+	+	-	+	+
Mimosa pudica L. var. unijuga (Duchass. & Walp.) Griseb.	Sensitive plant, pua-hilahila	X	-	-	-	-	-	-	+	+	+
Mucuna gigantea (Willd.) DC.	Ka'e'e, ka'e'e'e	I	-	-	-	-	-	-	+	+	-
Phaseolus lathyroides L.	Cowpea	X	-	-	-	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Samanea saman (Jacq.) Merr.	Monkeypod	X	-	-	-	+	-	-	+	-	-
LOBELIACEAE											
Clermontia hawaiiensis (Hillebr.) Rock	'Oha-kepau	E	-	-	+	-	-	-	-	-	-
Clermontia parviflora Gaud. ex Gray		E	-	-	+	-	-	-	-	-	-
Cyanea pilosa Gray		E	-	-	+	-	-	-	-	-	-
Cyanea tritomantha Gray	'Aku'aku, 'aku	E	-	-	+	-	-	-	-	-	-
Cyanea sp.		E	-	-	+	-	-	-	-	-	-
Laurentia longifolia (L.) Engl.	Star of Bethlehem	X	-	-	-	-	-	-	-	+	+
LOGANIACEAE											
Buddleja asiatica Lour.	Butterflybush, huelo-'ilio	X	+	+	+	+	-	-	+	+	+
Labordia hedyosmifolia Baill.		E	-	-	+	-	-	-	-	-	-
LYTHRACEAE											
Cuphea carthagenensis (Jacq.) Macbride	Cuphea, puakamoli	X	-	+	+	-	-	-	-	+	+
Lythrum maritimum HBK.	Pukamole	X	-	-	-	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
MALVACEAE											
Hibiscus tiliaceus L.	Hau	I	-	-	-	-	-	-	+	-	-
Hibiscus youngianus Gaud. ex Hook. & Arn.	Hau-hele, 'akiohala	E	-	-	-	-	-	-	-	+	-
Malvastrum coromandelianum (L.) Garcke	False mallow	X	-	-	-	-	-	-	-	-	+
Malvaviscus arboreus Cav.	Turk's cap	X	-	-	-	-	-	-	-	-	+
Sida acuta Burm. f.		X	-	+	-	+	-	-	-	-	-
Sida cordifolia L.	'Ilima	I	-	-	-	+	+	-	-	-	-
Sida fallax Walp. var. fallax	'Ilima	I	-	-	-	-	-	+	+	-	-
Sida rhombifolia L.	Cuba jute	X	-	-	-	+	-	-	-	+	-
Thespesia populnea (L.) Soland. ex Correra	Milo	P	-	-	-	-	-	-	+	-	-
MELASTOMATACEAE											
Clidemia hirta (L.) D. Don	Koster's curse	X	-	-	+	-	-	-	-	+	-
Heterocentron subtriplinervium (Link & Otto) A. Br. & Bouche	Pearl flower	X	-	+	+	-	-	-	-	-	-
Melastoma malabathricum L.	Malabar melastome	X	-	+	+	-	-	-	+	+	-
Pterolepis sp.		X	-	-	-	-	-	-	-	+	-
Tetrazygia bicolor (Triana) Cogn.		X	-	-	+	-	-	-	-	-	-
Tibouchina urvilleana (DC.) Cogn.	Lasiandra, glorybush	X	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
MENISPERMACEAE											
Cocculus ferrandianus Gaud.	Huehue, hue'ie	E	-	+	+	+	+	+	+	+	-
MORACEAE											
Artocarpus altilis (Park.) Fosb.	Breadfruit, 'ulu	P	-	-	-	+	-	-	+	-	-
Artocarpus heterophyllus Lam.	Jackfruit	X	-	-	+	-	-	-	-	-	-
Cannabis sativa L.	Marijuana, pakalolo, pot	X	-	-	+	+	-	-	+	-	-
Cecropia obtusifolia Sandmark	Guarumo	X	-	+	+	-	-	-	+	+	+
Cecropia peltata Sandmark	Trumpet tree	X	-	-	+	-	-	-	+	+	+
Ficus microcarpa L. f.	Chinese banyan	X	-	-	-	-	-	-	+	-	-
MYRICACEAE											
Myrica faya Ait.	Firetree, faya	X	-	+	-	-	-	-	-	-	-
MYRSINACEAE											
Ardisia humilis Vahl	Shoebutton ardisia	X	-	-	-	-	-	-	+	-	-
Embelia pacifica Hillebr.	Kilioe	E	-	-	+	-	-	-	-	-	-
Myrsine lessertiana A. DC.	Kolea-lau-nui	E	-	+	+	-	-	-	-	+	-
Myrsine sandwicensis A. DC.	Kolea-lau-li'i	E	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
MYRTACEAE											
Melaleuca quinquenervia (Cav.) Blake	Paperbark	X	-	+	-	-	-	-	+	-	-
Metrosideros collina (J.R. & G. Forst.) Gray var. glaberrima (Levl.) Rock	'Ohi'a-lehua	E	+	+	+	+	+	+	+	+	-
Metrosideros collina (J.R. & G. Forst.) Gray var. incana (Levl.) Rock	'Ohi'a-lehua	E	+	+	+	+	+	+	+	+	-
Metrosideros collina (J.R. & G. Forst.) Gray var. macrophylla Rock	'Ohi'a-lehua	E	-	+	+	+	+	+	+	+	-
Psidium cattleianum Sabine forma cattleianum	Strawberry guava	X	-	+	+	+	-	-	+	+	+
Psidium cattleianum Sabine forma lucidum Deg.	Yellow strawberry guava, waiawi	X	-	+	+	+	-	-	-	+	-
Psidium guajava L.	Guava, kuawa	X	-	+	+	+	+	+	+	+	+
Syzygium cumini (L.) Skeels.	Java plum, palama	X	-	-	-	+	+	+	+	+	+
Syzygium jambos L.	Rose apple, 'ohi'a-loke	X	-	+	+	-	-	-	+	-	-
Syzygium malaccense (L.) Merr. & Perry	'Ohi'a-'ai, mountain apple	P	-	-	-	-	-	-	+	-	-
Tristania conferta R. Br.	Brush box	X	-	-	-	-	-	-	+	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
NYCTAGINACEAE											
Pisonia umbellifera (J.R. & G. Forst) Seem.	Papala-kepau	I	-	-	+	-	-	-	-	-	-
Pisonia sp.	Papala-kepau	I	-	-	+	-	-	-	-	-	-
OLEACEAE											
Osmanthus sandwicensis (Gray) Knobl.	Olopua, pua	E	-	-	-	+	-	-	-	-	-
ONAGRACEAE											
Ludwigia octivalvis (Jacq.) Raven	Kamole, primrose willow	I	-	-	+	-	-	-	-	+	+
Ludwigia palustris (L.) Ell.	Water purselane	X	-	-	+	-	-	-	-	-	-
OXALIDACEAE											
Oxalis corniculata L.	Yellow wood sorrel, 'ihi	I	-	+	-	+	-	-	-	-	+
Oxalis martiana Zucc.	Pink wood sorrel, 'ihi pehu	X	-	-	-	+	-	-	-	-	-
PASSIFLORACEAE											
Passiflora edulis Sims forma flavicarpa Deg.	Yellow liliko'i	X	-	+	+	+	-	-	+	+	+
Passiflora foetida L.	Scarlet-fruited passionflower	X	-	+	-	-	-	+	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
PIPERACEAE											
Peperomia cookiana C. DC.	'Ala'ala-wai-nui	E	-	-	+	-	-	-	-	-	-
Peperomia hypoleuca Miq. var. hypoleuca	'Ala'ala-wai-nui	E	-	-	+	+	-	-	+	-	-
Peperomia hypoleuca Miq. var. pluvigaudens (C. DC.) Yuncker	'Ala'ala-wai-nui	E	-	-	+	-	-	-	-	-	-
Peperomia latifolia Miq.	'Ala'ala-wai-nui	E	-	-	+	-	-	-	-	-	-
Peperomia leptostachya Hook. & Arn.	'Ala'ala-wai-nui	I	-	-	-	+	-	-	+	-	-
Peperomia tetraphylla (Forst. f.) Hook. & Arn.	'Ala'ala-wai-nui	I	-	-	+	-	-	-	-	-	-
Peperomia sp.	'Ala'ala-wai-nui	E	-	-	+	-	-	-	-	-	-
Piper methysticum Forst. f.	'Awa	P	-	-	+	-	-	-	+	-	-
PITTOSPORACEAE											
Pittosporum confertiflorum Gray	Ho'awa	E	-	-	+	-	-	-	-	-	-
Pittosporum sulcatum Sherff var. remyi Sherff	Ho'awa	E	-	-	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
PLANTAGINACEAE											
Plantago lanceolata L.	Narrow-leaved plantain	X	-	+	-	-	-	-	-	-	+
Plantago major L.	Broad-leaved plantain, lau-kai	X	-	-	+	-	-	-	+	+	+
POLYGALACEAE											
Polygala paniculata L.	Polygala	X	-	-	-	-	-	-	-	+	+
POLYGONACEAE											
Polygonum capitatum Ham. ex Don	Polygonum	X	+	+	+	-	-	-	-	-	+
Rumex skottsbergii Deg. & Deg.	Pawale	E	+	-	-	-	-	-	-	-	-
PORTULACACEAE											
Portulaca oleracea L.	Common purselane, 'ihi	X	-	-	-	-	-	+	-	-	-
PROTEACEAE											
Grevillea robusta A. Cunn.	Silk oak, 'oka-kilika	X	-	-	-	-	-	-	+	-	-
Macadamia ternifolia F. Muell. var. integrifolia (Mdn. & Bet.) Mdn. & Bet.	Macadamia	X	-	-	-	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
RANUNCULACEAE											
Anemone hupehensis (Lem. & Lem. f.) Lem. & Lem. f.	Hupeh anemone	X	-	-	+	-	-	-	-	-	-
ROSACEAE											
Fragaria vesca L. forma alba (Ehrh.) Rydb.	Strawberry	X	-	+	-	-	-	-	-	-	-
Osteomeles anthyllidifolia (Sm.) Lindl.	'Ulei, eluehe	I	-	+	-	+	+	+	+	-	-
Rubus ellipticus Sm. var. obcordatus Focke	Yellow Himalayan raspberry	X	-	-	+	-	-	-	-	-	-
Rubus penetrans Bailey	Florida blackberry	X	-	+	-	-	-	-	-	-	-
Rubus rosaefolius Sm.	Thimbleberry	X	-	+	+	-	-	-	+	+	-
RUBIACEAE											
Bobea timonioides (Hook. f.) Hillebr.	'Ahakea	E	-	-	+	-	-	-	-	-	-
Canthium odoratum (Forst. f.) Seem.	Alahe'e, walahe'e	I	-	-	+	+	+	+	+	-	-
Coffea arabica L.	Arabian coffee	X	-	-	+	-	-	-	-	-	-
Coprosma ernodeoides Gray	Kukae-nene	E	-	+	-	-	-	-	-	-	-
Coprosma menziesii Gray	Pilo, kopa	E	-	+	+	-	-	-	-	-	-

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Coprosma ochracea Oliver var. rockiana Oliver	Pilo, kopa	E	-	-	+	-	-	-	-	-	-
Coprosma sp.	Pilo, kopa	E	-	-	+	-	-	-	-	-	-
Gardenia augusta (L.) Merr.	Gardenia, kiele	X	-	-	+	-	-	-	-	-	-
Gouldia terminalis (Hook. & Arn.) Hillebr.	Manono	E	-	-	+	-	-	-	-	-	-
Hedyotis centranthoides (Hook. & Arn.) Steud. forma centranthoides	Kilauea hedyotis	E	+	+	+	-	-	-	-	-	-
Hedyotis corymbosa (L.) Lam.		X	-	-	-	-	-	-	-	-	+
Morinda citrifolia L.	Noni	P	-	-	-	+	-	+	+	-	-
Paederia foetida L.	Maile pilau	X	-	-	+	-	-	-	+	+	+
Psychotria hawaiiensis (Gray) Fosb.	Kopiko	E	-	+	+	-	-	-	+	-	-
Richardia brasiliensis Gomez	Richardsonia	X	-	-	-	-	-	-	-	-	+
Spermacoce assurgens R. & P. [=Borreria laevis (Lam.) Griseb.]	Buttonweed	X	-	-	-	-	-	-	+	+	+
Spermacoce sp. [=Borreria sp.]		X	-	-	-	-	-	-	+	+	+
RUTACEAE											
Citrus limonia Osbeck	Lemon	X	-	-	+	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
Citrus sp.		X	-	-	+	-	-	-	-	-	+
Pelea clusiaefolia Gray var. cuneata St. John & Hume	Alani	E	-	-	+	-	-	-	-	-	-
Pelea radiata St. John	Alani	E	-	-	+	-	-	-	-	-	-
Pelea sp.		E	-	-	+	-	-	-	-	-	-
SANTALACEAE											
Santalum paniculatum Hook. & Arn.	'Iliahi	E	-	+	-	+	+	+	-	-	-
SAPINDACEAE											
Cardiospermum halicacabum L.	Balloon vine, 'inalua	X	-	-	-	-	-	-	-	+	+
Dodonaea viscosa L.	A'ali'i	I	-	+	-	+	+	+	-	-	-
SAXIFRAGACEAE											
Broussaisia arguta Gaud.	Kanawao	E	-	-	+	-	-	-	-	-	-
SCROPHULARIACEAE											
Castilleja arvensis Schlecht. & Cham.	Field Indian paintbrush	X	-	+	-	-	-	-	+	+	+
Lindernia crustacea (L.) F. Muell.	Lindernia	X	-	-	-	-	-	-	-	-	+
Torenia asiatica L.	Ola'a beauty, nani-o-Ola'a	X	-	-	-	-	-	-	-	-	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
SOLANACEAE											
Cestrum nocturnum L.	Night cestrum, 'ala-aumoe	X	-	-	-	-	-	-	+	+	-
Physalis peruviana L.	Cape gooseberry, poha	X	-	+	+	-	-	-	-	-	-
Solanum nigrum L.	Popolo, black nightshade	I	-	-	-	-	-	-	-	-	+
STERCULIACEAE											
Melochia umbellata (Houtt.) Stapf.	Melochia	X	-	+	-	-	-	-	+	+	+
Waltheria indica L. var. americana (L.) R. Br. ex Hosaka	Hi'aloa, 'uhaloa	I	-	+	-	+	+	+	+	-	-
THYMELAEACEAE											
Wikstroemia phillyreaefolia Gray var. buxifolia (Gray) Skottsb.	'Akia	E	-	+	-	-	-	-	-	-	-
Wikstroemia phillyreaefolia Gray var. phillyreaefolia	'Akia	E	-	+	-	+	+	+	-	-	-
Wikstroemia sandwicensis Meisn.	'Akia	E	-	+	+	-	-	-	+	+	-
ULMACEAE											
Trema orientalis (L.) Bl.	Gunpowder tree	X	-	+	-	-	-	-	+	+	+

BOTANICAL NAME	COMMON NAME	STATUS	1	2	3	4	5	6	7	8	9
UMBELLIFERAE											
Centella asiatica (L.) Urban	Asiatic pennywort, pohekula	X	-	-	-	-	-	-	-	+	+
Hydrocotyle verticillata Thunb.	Pohepohe	X	-	-	-	-	-	-	-	-	+
URTICACEAE											
Pipturus hawaiensis Levl.	Mamaki	E	+	+	+	+	-	-	+	+	+
Pipturus sp.	Mamaki	E	-	-	+	-	-	-	-	-	-
Touchardia latifolia Gaud.	Olona	E	-	-	+	-	-	-	-	-	-
Urera sandvicensis Wedd.	Opuhe	E	-	-	+	-	-	-	-	-	-
VERBENACEAE											
Lantana camara L.	Lantana, lakana	X	-	+	-	+	+	+	+	+	+
Stachytarpheta australis Mold.	Cayenne vervain	X	-	-	+	+	+	+	+	+	+
Stachytarpheta jamaicensis (L.) Vahl	Jamaica vervain, owi	X	-	-	-	+	-	-	+	+	+
Stachytarpheta urticaefolia (Salisb.) Sims	Nettle-leaved vervain	X	-	-	-	-	-	-	+	+	+
Verbena litoralis HBK.	Verbena, ha'uowi	X	-	+	-	-	-	-	+	+	+

AVIFAUNA SURVEY

An assessment of the birds known to occur in the east rift zone is presented by Dr. A. J. Berger in the following report. The report focuses primarily on the bird species found in the native 'ohi'a forests.

Additional information on bird distribution (Tables 2 and 3) was made available by Maile S. Kjargaard, who accompanied the botanical team into the more inaccessible portions of the project area.

For several years the U.S. Fish and Wildlife Service has been conducting studies of the distribution of forest birds throughout the Hawaiian Islands. The results of this project, containing distribution maps of all native forest birds on the island of Hawaii are now in press (Scott, Ramsay and Kepler, 1985).

BIRDS OF THE EAST RIFT ZONE (by Andrew J. Berger)

This assessment of the birds of the east rift zone of Kilauea Volcano was prepared at the request of Dr. Charles Lamoureux. My latest field survey of this area was conducted on December 1 and 2, 1984; this included two elevations (2200 feet and 1700 feet) in the Kahauale'a forest adjacent to old and new lava flows, as well as studies conducted at lower elevations. I had previously made extensive bird surveys in Hawai'i Volcanoes National Park and adjacent areas in the Puna district of Hawai'i between 1965 and 1984 (e.g., Berger 1969a, 1969b, 1969c, 1972a, 1972b, 1972c, 1980, 1981, 1984). I also made a bird survey by helicopter and ground search in the Kahauale'a forest on September 18, 1982. In addition, I have made extensive use of all literature available on the birds of the east rift zone, as well as some unpublished observations by several people.

Three general groups of birds occur in the Hawaiian Islands: 1) endemic species, those that are unique to the Hawaiian Islands and, therefore, do not occur naturally in any other part of the world; 2) indigenous birds, those whose total range in the Pacific basin includes the Hawaiian Islands; and 3) introduced or exotic birds, those that have been brought to the islands by man (Berger 1981). Because the east rift zone extends from approximately 4000 feet to sea level, there is a striking difference in the occurrence of the species according to elevation and forest types.

1. Endemic birds

Of these unique Hawaiian birds, about 85 percent are either extinct or are threatened with extinction. Although there are a few exceptions, most of the surviving forest birds occur primarily in native forests; that is, 'ohi'a (Metrosideros collina), koa (Acacia koa), and treefern (Cibotium spp.). However, some of the endangered bird species are now found only at elevations above that of most of the east rift zone. There are some postulated (e.g., the occurrence of mosquitoes and bird malaria) and some unknown reasons for the present distribution of the Hawaiian forest birds. I propose to discuss 12 endemic species that were found, or were thought to have occurred, in the rift zone region in the past; some of them now occupy the forests along the several lava flows. Special attention will be given to the following:

I. Order Anseriformes

A. Family Anatidae; ducks, geese, and swans

1. Nene or Hawaiian Goose, Branta sandvicensis

Henshaw (1902) wrote that "the greater number [of Nene], probably all, leave the upper grounds beginning early in the fall, and resort to lower altitudes, from about 1200 feet downwards, for the breeding season." The

present range of the Nene on the Island of Hawai'i extends from approximately 3800 feet to 8000 feet on the slopes of Mauna Loa (Kear and Berger 1980). The National Park Service initiated a plan in 1972 to determine if a lowland population of Nene could be reestablished in its former lowland habitat. The results of this program have been summarized by Banko (1982). Stone et al. (1982, 1983) discussed the nesting of the Nene in the Ka'u desert and the management steps that are necessary to insure the continued success of the Nene on the Island of Hawai'i. However, I know of no evidence that the Nene has ever nested in, or inhabited, the lands of the proposed geothermal zone.

II. Order Falconiformes

A. Family Accipitridae; Hawks

1. Hawaiian Hawk or 'I'o, Buteo solitarius

The 'I'o occurs on the slopes of Mauna Loa, on both the windward and leeward coasts, less commonly on Mauna Kea. Scott et al. (in press) wrote that the 'I'o "occupies a broad range of habitats from papaya and macadamia orchards through virtually all types of forest including ohia rainforest and subalpine mamane-naio woodland." They found the hawk from sea level to 2600 meters elevation. Although now classified as an endangered species, Scott and his coauthors remarked that: "Given the abundance, wide distribution, and high reproductive success of this species (C. Griffin, pers. comm.), it seems appropriate to

reevaluate its endangered status" (see also Griffin 1984, who estimated a wild population of 1,400 to 2,500 birds).

The 'I'o occurs in the geothermal project zone. Hawks were seen during early December 1984 at elevations between 2400 feet and 1500 feet. Conant (1980) saw individuals "regularly in two localities: Pua'i'ālua Crater and in the closed 'ohi'a forest near the eastern boundary of the Kalapana Extension. This latter area is traversed by the paved roads of the Hawaiian Homes Kalapana 'subdivision'." The 'I'o has a very wide home range where it forages for food. It is an adaptable species, feeding on spiders, insects, mammals, and both native and introduced birds (Berger 1981). There would be no significant impact on the 'I'o because of geothermal development.

III. Order Strigiformes

A. Family Strigidae; Typical Owls

1. Hawaiian Short-eared Owl or Pueo, Asio flammeus sandwichensis

The Pueo is a permanent resident on all main islands in the Hawaiian Chain. The birds occur from sea level to at least 8000 feet on Mauna Loa and Mauna Kea, and the birds are tolerant of wide climatic conditions. The Division of Forestry and Wildlife considers the Pueo to be endangered on O'ahu but not on Hawai'i. The Pueo differs from most other owls in that it is diurnal in habit; hence, they are seen much more often than the nocturnal introduced Barn Owl (Tyto alba). Nevertheless, I have never seen the

Pueo in the project area, Conant (1980) does not discuss this species, and Scott et al. (in press) did not find this owl in the Puna district. Scott et al. (in press) said that "The species was most often in grasslands, shrublands, and montane-parklands. Less frequently, it was seen quartering low over the canopy of closed forests." Geothermal development certainly would have no adverse effects on the Pueo.

IV. Order Passeriformes

A. Family Turdidae; Thrushes and Bluebirds

1. Hawaiian Thrush or 'Oma'o, Phaeornis obscurus obscurus

The Hawai'i race of the endemic thrush is the most common of the surviving races; it is not considered to be endangered. Scott et al. (in press) wrote that: "Two well-established populations occur on Hawaii, the 56,000 Kau birds weakly separated from the 113,000 Hamakua-Puna birds by the degraded Kapapala Tract...Fairly high numbers of Omao at lower elevations in Kau and Puna indicate a robust population not threatened by extinction...High Omao densitites in mosquito-infested Puna indicate some populations have resistance to avian disease" (see also, van Riper and Scott 1979). The 'Oma'o is a common species in the Kahauale'a forest in suitable habitat at all elevations, and I have seen it at an elevation of 1000 feet in the Puna Forest Reserve. Conant (1980) found "the highest densities (20-30 birds/40 ha) of 'Oma'o...in closed 'ohi'a forests above 490 m (1600 feet)." Because of its

high population numbers and its distribution in relation to probable geothermal operations, the 'Oma'o should not suffer any significant impact from geothermal development.

B. Family Muscicapidae; Old World Flycatchers

1. 'Elepaio, Chasiempis sandwichensis sandwichensis

The 'Elepaio is one of the few native bird species that has been able to adapt to mixed endemic and introduced vegetation and even to almost entirely introduced vegetation in some lowland areas on O'ahu. The 'Elepaio is not an endangered species.

During her study of the Kalapana Extension, Conant (1980) estimated densities of 6 to 10 birds per 40 ha in suitable habitat at elevations between 2400 and 2900 feet, noting that the 'Elepaio occurred in "rather low densities." Conant (1982) did not find the 'Elepaio in the "south central portion of the proposed [by Campbell Estate] geothermal development area (between power stations B & D in the Kahaualea Forest)" during censuses conducted in January 1982, nor did I see or hear 'Elepaio in this region on September 18, 1982 (at elevations between 2000 and 2900 feet). Conant (1980) also remarked that "the spread of aggressive exotic plants, such as guavas (Psidium cattleianum Sabine, P. guajava L.), which may form dense monospecific stands, can be viewed as a threat to the survival of the 'Elepaio. In the Kalapana Extension, low elevation mesic and rain forests are seriously threatened by exotic plant invasion." Scott et al. (in press)

estimated a total population of 'Elepaio on the Island of Hawai'i to amount to 214,989 birds. They remarked that "the windward Hawaii population of 124,000 birds also shows marked avoidance of disturbed understories in the upper northwest corner of the Hamakua study area, and in the dry scrubland of Puna and Kapapala." The possible occurrence of a few 'Elepaio in the proposed geothermal zone is inconsequential.

C. Family Drepanididae; Hawaiian Honeycreepers

This is Hawaii's endemic bird family. About 40 percent of the family are extinct and another 40 percent are classified as threatened or endangered.

1. 'O'u, Psittirostra psittacea

The 'O'u is considered to be the rarest of the surviving honeycreepers on the Big Island by the Hawai'i Forest Bird Studies recovery team (Scott et al. 1983). Moreover most of the 'O'u in recent years have been found at elevations well above 3000 feet. Scott et al. (in press) wrote that "on Hawai'i the Ou is most abundant from 1,300 to 1,500 m elevation, but was recorded at 900 m [2900 feet] in Puna." They also noted that "Ou are associated with low elevation, mosquito-free forests that have a high canopy and lie outside the koa and koa-ohia zones...The tendency of the Ou to wander into mosquito-infested areas and its very low numbers make its survival precarious." Mosquitos are abundant in the Kahauale'a forest, as well as at both lower and higher elevations (Goff and van Riper

1980; van Riper et al. 1982). Even above 3000 feet elevation, 'O'u populations are widely separated, and it is problematical that the species will be able to survive far into the future. The very small, isolated population of 'O'u that may exist at the upper elevations of the Kahauale'a forest are in even greater danger of extinction, partly because of the abundance of mosquitoes there and because there are so few birds there. Moreover, they are so isolated from any other population at higher elevations that there undoubtedly is no gene flow between th populations. Therefore, the inbreeding among the few birds at these lower elevations could rapidly lead to poorer reproductive success or other factors that would lead naturally to the extinction of the population. In brief, the proposed geothermal zone would have no adverse effects on the survival of the 'O'u.

2. Common 'Amakihi, Hemignathus virens virens (formerly Loxops virens virens)

This is the second most common of the surviving honeycreepers. Scott et al. (in press) estimated the total population on Hawai'i to be 870,000 birds. The 'Amakahi shows tolerance towards people at Hawai'i Volcanoes National Park. It is most common at higher elevations, although I have found 'Amakihi at an elevation of 250 feet in Malama Ki Forest Reserve. However, Conant (1982) did not mention the 'Amakihi in her discussion of the Kahuale'a forest, nor did I see or hear this species during my field

work in this area in 1982 or 1984. The possible occurrence of the 'Amakihi at lower elevations certainly is irrelevant to the determination of a geothermal zone.

3. 'Akiapola'au, Hemignathus munroi (formerly H. wilsoni)

I mention this species only because Baldwin (1941) found it in Hawai'i Volcanoes National Park; Baldwin found it in Kipuka Kulalio at elevations between 5400 and 6700 feet. Scott et al. (in press), however, did not find the 'Akiapola'au in the Puna district. Berger (1972c) found a few birds in the Kilauea Forest Reserve at much higher elevations than the proposed geothermal zone.

4. Hawai'i Creeper, Oreomystis mana (formerly Loxops maculata mana)

Baldwin (1941) considered this creeper to be an "uncommon, permanent resident" of Hawai'i Volcanoes National Park. However, Scott et al. (in press) wrote that "the Hawaii Creeper apparently suffered a dramatic decline in numbers in the vicinity of Kilauea Crater in the late 1930's to early 1940's. It has been suggested that this decline was due to interspecific competition with the Japanese White-eye (Dunmire 1961)...In this area other factors probably caused the decline of this species." Scott and his co-workers did not find the Hawai'i Creeper in the lower Puna district.

5. 'Akepa, Loxops coccineus

Baldwin (1941) found the 'Akepa to be "rare or absent" from Hawai'i Volcanoes National Park. Berger found it to

be an uncommon species in the Kilauea Forest Reserve during 1972. Scott et al. (in press) also found a population in the Kilauea Forest Reserve, but they did not find it at lower elevations in the Puna district.

6. 'I'iwi, Vestiaria coccinea

The 'I'iwi is the most striking in appearance of the common surviving honeycreepers, and it is not an endangered species. Scott et al. (in press) estimated a total population on Hawai'i of 340,417 birds. In the entire Puna district, however, they estimated the population to number no more than 191 birds. Conant (1982) reported only three 'I'iwi in her studies in the Kahauale'a Forest, and I did not see or hear it there in 1982 or 1984. The 'I'iwi is of no concern for establishing a geothermal zone.

7. 'Apapane, Himatione sanguinea sanguinea

This is the most common bird among the surviving species of honeycreepers. Scott et al. (in press) estimated a total population of more than one million birds on the Island of Hawai'i. Of these, more than 132,000 birds occur in the Puna district. Scott and his co-workers wrote that: "On Hawaii, Apapane occur from sea level below the Puna and Kona study areas to 2,900 m elevation on Mauna Kea." They noted that "the maximum densities we found for Apapane, 2,000 birds/km^2 in the Kau area, are the highest bird densities ever recorded for a noncolonial species."

2. Indigenous birds

This group of birds includes the seabirds and the migratory shorebirds and ducks that spend their nonbreeding season in the Hawaiian Islands. None

of these migratory species are of any concern for establishing a geothermal zone. I will discuss briefly two species of seabirds only because they were mentioned in the Campbell Estate geothermal hearings during October and November 1982.

I. Order Procellariiformes

A. Family Procellariidae; Shearwaters, Petrels, Fulmars

1. Manx or Newell's Shearwater, Puffinus puffinus newelli

King and Gould (1967) wrote that "Kauai is now the primary and possibly unique breeding locality of Newell's Shearwater." More recently, Kepler et al. (1979) wrote of possible breeding colonies of this shearwater on the Island of Hawai'i, but these possible small colonies are located on the Hamakua coast and in the Kohala Mountains. There is no evidence for the occurrence of this shearwater in the Puna district.

2. Dark-rumped Petrel, Pterodroma phaeopygia sandwichensis

The primary nesting area for this petrel is in Haleakala Crater on Maui (Buxbaum 1973; Berger 1981); a small colony also apparently occurs on Lana'i (Hirai 1978); and Winston E. Banko found four occupied nesting burrows high on Mauna Loa in 1968, and in 1970 he found birds on Mauna Kea. There is no evidence, however, that there is now, or was in the past, a nesting colony in the Puna district below 4000 feet elevation.

3. Introduced birds

More than 170 species of alien birds have been introduced to the Hawaiian Islands by man since 1796 (Berger 1981). Approximately 50 species have

established breeding populations on one or more islands. A number of these may legitimately be called "pest birds." Some (e.g., Spotted Munia, House Finch; see below) have caused considerable destruction to experimental small grain crops in the state. Doves and the Myna have been implicated in spreading the seeds of such noxious plants as Lantana camara. The Japanese White-eye often is a problem for fruit growers. Other examples could be cited, and two relatively new seed- and/or fruit-eating birds on Hawai'i pose problems for the future. For example, Rose-ringed Parakeets (Psittacula krameri) were reported to be nesting at the Mauna Loa Macadamia Nut Orchards south of Hilo in 1981 (Paton et al. 1982). These parakeets eat both seeds and fruits, and Paton and his co-workers estimated that "potential annual crop losses could reach $50,000" if a large population of these birds were to become established. Warbling Silverbills (Lonchura malabarica cantans) were first reported on the Big Island by Berger (1975). Not only has this primarily seed-eating bird increased its range greatly on Hawai'i but it also has spread to Maui, Lana'i, and Moloka'i. Such birds will make the growing of small grain crops essentially impossible. Finally, some of the alien species (e.g., Japanese White-eye, Melodious Laughing-thrush) occur from sea level to at least 8000 feet elevation on Hawai'i, including the 'ohi'a forests; their role in the spread of avian diseases and in competing with endemic species is incompletely known at this time. However, it is reasonable to conclude that all of the introduced bird species are irrelevant in the determination of a geothermal zone.

I. Order Columbiformes

A. Family Columbidae; Pigeons and Doves

1. Lace-necked or Spotted Dove, Streptopelia chinensis chinensis

This Asian dove was introduced to the Hawaiian Islands at an early date; the exact date apparently is unknown, but the birds are said to have been common on O'ahu by 1879 (Caum 1933). The species is now common to abundant on all of the islands, and, like the other doves in the state, is classified as a game bird. This dove occurs where the rainfall exceeds 100 inches per year, but the highest densities are found in drier areas where such introduced plants as koa-haole (Leucaena leucocephala) and kiawe (Prosopis pallida) flourish. Although a very common species on Hawai'i, the Spotted Dove is not an inhabitant of the 'ohi'a forests.

2. Barred or Zebra Dove, Geopelia striata striata

This small dove is said to have been introduced to the islands sometime after 1922 (Bryan 1958). It has been a very successful species and is now abundant on all of the islands. Schwartz and Schwartz (1949) estimated densities as high as 400 to 800 birds per square mile in dry areas in O'ahu and Moloka'i only 25 years after their introduction. One study of their food habits revealed that the diet consisted of 97 percent seeds and other plant materials; the 3 percent animal matter included several species of beetles, weevils, and wireworm larvae. The doves contract intestinal roundworms and tapeworms from the insects in their diet (as does the Spotted Dove), and Kocan and Banko (1974) reported on Barred Doves in Hawai'i that were infected with trichomonas, a parasite that has

"catastrophic" effects in North America. Like the Spotted Dove, the Barred Dove is not an inhabitant of dense forests. They are most common in urban areas, and in relatively open rural areas such as pineapple and cane fields, pastures, cutover forests, and truck gardens.

3. Rock Dove, Columba livia

All varieties of the domestic pigeon are derived from the European Rock Dove. They apparently were first brought to the islands in 1796. I saw several flocks of pigeons in the lowland area of the east rift zone. Their only significance is because of potential public health problems. For example, Kishimoto and Baker (1969) found a fungus, Cryptococcus neoformans, in 13 or 17 samples taken from pigeon droppings on O'ahu. This fungus causes a chronic cerebrospinal meningitis in man. Hull (1963) noted that "in all but the cutaneous form the prognosis is very grave" for man (see also Abou-Gabal and Atia 1978). Schwartz and Schwartz (1949) found heavy parasitism of the doves by tapeworms, which not only retards proper nutrition of the host but also "occludes the intestine, produces undesirable toxins, and hinders breeding." The presence of such parasites certainly has implications for other birds. both introduced and endemic.

II. Order Passeriformes

A. Family Alaudidae; Larks

1. Skylark, Alauda arvensis arvensis

Henshaw (1902) wrote that the introduction of the Skylark to O'ahu had been a "great success", and that some

birds had been released on the windward side of Hawai'i, "but their fate is at present unknown". The Skylark is now common to abundant in suitable habitat on Hawai'i. I have seen this species in open country from sea level at South Point to above treeline (approximately 9300 feet) on Mauna Kea. There is no open habitat in the forested lands of the east rift zone. Conant (1980) found the Skylark to be uncommon "but widely distributed in grasslands" in the Kalapana Extension.

B. Family Timaliidae; Babblers and Laughing-thrushes

1. Melodious Laughing-thrush, Garrulax canorus

This bird is a member of the babbler family even though it long has been called the Chinese Thrush (Hwa-mei) in the islands. THe species is native to the Yangtze Valley in China and southward to Laos, and it occurs in Formosa. The birds were brought to the islands as cage birds. "A number obtained their freedom at the time of the great fire in the Oriental quarter of Honolulu in 1900, and took to the hills behind the city" (Caum 1933). Birds were later released on Hawai'i and the other islands. This laughing-thrush is now common on the Island of Hawai'i, where the birds prefer fairly dense vegetation. Scott et al. (in press) found that in the vicinity of Kilauea Crater, this species has "increased from occasional vagrants to fairly common breeders in the 1980-1983 period." Conant (1980) found this laughing-thrush to be "uncommon (1-5 birds/40 ha) in both open and closed 'ohi'a forests" in the east rift zone region.

C. Family Zosteropidae; White-eyes and Silver-eyes

1. Japanese White-eye, Zosterops japonicus japonicus

This race of the white-eye is native to the main islands of Japan from Kyushu to Honshu and the islands lying between Japan and Korea. The first Japanese White-eyes (Mejiro) were released on O'ahu by the Territorial Board of Agriculture and Forestry in 1929 (Caum 1933). At least 252 White-eyes were released on the Island of Hawai'i during June 1937 (Berger 1975b). The White-eye presents an example par excellence of the success of an introduced species. It now occurs on all of the main islands, is found from sea level to tree line on Hawai'i, and inhabits very dry areas (e.g., Kawaihae) and those having 300 or more inches of rainfall per year. There is virtually no habitat in the islands that is not inhabited by White-eyes and I believe it to be the most abundant song bird in the islands. White-eyes eat insects, fruit, the pulp of berries, buds, and nectar, so that they can be a serious threat to farmers. The California State Department of Agriculture (Keffer et al. 1976; Audubon Magazine September 1982) is greatly concerned about the accidental release of a related species (Gray-backed White-eye, Z. palpebrosa) at San Diego. Two pairs escaped in 1973 or 1974; 150 offspring have been captured since then. "Estimates of the potential loss in soft-fruit crops, should white-eyes ever begin to multiply rapidly and establish large populations, run as high as $2 million a

year." Scott et al. (in press) estimated a population of more than one million birds on Hawai'i, alone; hence, all that fruit farmers can do is to control the birds in a limited area. The white-eye is of no concern in making a determination of a suitable geothermal zone.

D. Family Sturnidae; Mynas and Starlings

1. Common Indian Myna, Acridotheres tristis tristis

The myna is native to Sri Lanka, India, West Pakistan, Nepal, and adjacent regions. The Common Myna was introduced from India "in 1865 by Dr. William Hillebrand to combat the plague of army worms that was ravaging the pasture lands of the islands" (Caum 1933). The Myna is common to abundant, especially in lowland areas of the inhabited islands, being most common in the vicinity of houses and barns in outlying districts. It also occurs at elevations up to at least 8000 feet but is found in pastures, the edges of forests, and in disturbed areas in general. It is common at the Hawai'i Volcanoes National Park Headquarters but is not found in the 'ohi'a forests of the east rift zone.

E. Family Ploceidae; Weaverbirds and Allies

1. Spotted Munia or Ricebird, Lonchura punctulata

This Asian species was brought to Hawaii by Dr. William Hillebrand about 1865 (Caum 1933). Caum wrote that the Ricebird "feeds on the seeds of weeds and grasses and does considerable damage to green rice." Rice is, of course, no longer grown in the islands, but the Ricebird

has been a serious pest by eating the seeds of sorghum (see also House Finch). The Ricebird is an abundant species on all of the islands, and it is tolerant of both wet and dry habitats. The birds tend to be nomadic during the nonbreeding season, moving over large areas in search of seeds. The birds are prolific, nesting during every month of the year. The birds occur from sea level to at least 7500 feet, but they do not inhabit the 'ohi'a forests. They are birds of pastures, cane fields, cutover forests, and other disturbed areas.

2. House Sparrow, Passer domesticus

Also called the English Sparrow, the House Sparrow was first imported to O'ahu in 1871, when nine birds were brought in from New Zealand (where the species had previously been introduced from England). Caum (1933) wrote that "whether or not there were further introductions is not known, but the species was reported to be numerous in Honolulu in 1879." The House Sparrow in North America (first introduced in Brooklyn in 1852) became a serious pest, and many thousands of dollars were spent in attempting to control the population. This sparrow apparently never became a serious pest in the Hawaiian Islands; it is omnivorous in diet, eating weed seeds as well as insects and their larvae. The House Sparrow typically is found in the vicinity of man and his buildings. In Hawai'i Volcanoes National Park, it is found primarily around the headquarters buildings, less commonly

around the camp grounds and picnic areas. I know of no records of its occurrence in the 'ohi'a forests of the east rift zone.

F. Family Fringillidae; Sparrows, Cardinals, and Buntings

1. Cardinal, Cardinalis cardinalis

This bird also is called the Kentucky Cardinal, Virginia Cardinal, and the Redbird. Cardinals were released several times on Kaua'i, O'ahu, and Hawai'i between 1929 and 1931. On Hawai'i, it is found from sea level to at least 7500 feet on Mauna Kea. It inhabits both very dry areas and those with a high annual rainfall. Scott et al. (in press) wrote that "Cardinals have infiltrated most of the forest in the Puna study area. This was facilitated by three factors--the Puna forest has extensive edges with disturbed habitat along its north, east, and south boundaries; a rift zone located through the middle of the forest supporting disturbed habitat; and widespread localized marijuana (Cannabis sativa and indica) cultivation by feral man throughout the forest interior that creates numerous canopy openings and provides seeds for the diet." Conant (1980) wrote that she felt it doubtful that the Cardinal "has any adverse competitive effects on native birds," a sentiment with which I agree.

2. House Finch, Carpodacus mexicanus frontalis

This finch is native to North America. Birds were first brought to the islands "prior to 1870" (Caum 1933). It is now an abundant species in both residential and rural

areas, in wet and dry regions, and in the high ranch country and open forest lands on Maui and Hawai'i. They do not inhabit dense forests. Because of their fondness for ripe papaya, the bird is called the Papayabird in the islands. Despite this liking for soft fruits, however, the House Finch is predominantly a seed eater, frequently also eating flower buds. When experimental crops of sorghum were planted in former sugarcane fields at Kohala during 1972, Spotted Munias and House Finches destroyed 50 tons of grain from an experimental plot that had been expected to produce 60 tons. There is very little habitat in the upper reaches of the east rift zone for House Finches, although Conant (1980) wrote: "On a few occasions I was surprised to find birds in the open 'ohi'a-hapu'u (Metrosideros-Cibotium) areas because, for the most part, these habitats are surrounded by closed forests."

DETRIMENTAL FACTORS FOR THE ENDEMIC BIRDS

Most of the potential geothermal sites in the east rift zone will be at elevations below 3000 feet. The majority of all of the endemic forest birds now are found at elevations above 3000 feet. Therefore, it seems pertinent to consider those factors that threaten the forests and the birds that are found at elevations less than 3000 feet, that is, even if no additional geothermal development took place in the east rift zone.

1. The effects of the large numbers of mosquitoes (especially Culex quinquefasciatus) on the endemic birds already have been mentioned (pages 75, 77, 78: see also, Goff and van Riper 1980; van Riper and Goff 1982). The

avian diseases (particularly malaria and pox) transmitted by the mosquitoes are a threat to the survival of most of the endemic bird species.

2. The small Indian mongoose (Herpestes auropunctatus), the roof or black rat (Rattus rattus), the Norway rat (Rattus norvegicus), the house mouse (Mus musculus), the feral cat (Felis catus), and the feral dog (Canis familiaris) have been studied in the Kilauea Forest Reserve at a higher elevation (Mueller-Dombois et al. 1981). It is certain that all also occur at lower elevations along the east rift zone (Tomich 1969). All of these introduced pests are predators on birds and their eggs or young (Berger 1972c, 1981).

3. Pigs (Sus scrofa) were brought to the Hawaiian Islands by the early Polynesian settlers; later, the English released European pigs (Tomich 1969). Mueller-Dombois et al. (1981: 310) noted that "In the Kilauea forest, the effect of feral pigs is very noticeable." They added (page 316): "There is little doubt that the widespread pig digging in the Kilauea forest has been a major factor in reducing the native ground-cover vegetation. The present total cover was estimated as only 7.7 percent...Pig digging undoubtedly has an effect on the invasion of exotic plant species. Several exotic grasses (Holcus lanatus, Anthoxanthum odoratum, and Axonopis affinis) and composite weeds (Erechtites valerianaefolia, Hypochaeris radicata, Gnaphalium purpureum, and Senecio sylvaticus) occurred sporadically in forest openings where the ground was disturbed by pigs." The pigs also eat the seedlings of Acacia koa, and the stomach contents of seven pigs contained from 70 to 95 percent tree fern parts. These effects of pig activities occurred in the Kilauea Forest Reserve which "was soon recognized by IBP participants as the best intact example of this forest type remaining in the state" (Mueller-Dombois et al. 1981: 217; underlining mine). Conant (1980), in writing about the east rift

zone region, said: "This change [vulcanism], as well as extensive alteration in forest habitats wrought by feral pig and goat activity and exotic plant invasion, may account, at least in part, for the disappearance of several forest bird species from the Kalapana Extension. It is probably botanically acceptable to say that there are virtually no 'unimpaired' habitats remaining today." In her report on the Kauhahale'a forest, Conant (1982) noted that "some degree of disturbance is evidence by the numerous trails that traverse the area. Presumably the trails are used by hikers, hunters, and pigs. Exotic plant species are common along the trails, less so in the remainder of the forest." Thus, it seems safe to conclude that both pigs and exotic plants present a threat to the integrity of the few endemic forests that remain in Hawai'i. Scott and his co-authors (in press) discuss various Hawaiian ecosystems, with special attention to understory and ground vegetation, in relation to the distribution of both endemic and exotic bird species.

SUMMARY

1. Only a very few endemic forest bird species inhabit the forests of the east rift zone of Kilauea Volcano, and their populations are low in comparison to their numbers at higher elevations. None of these endemic forest birds is considered to be endangered or threatened with extinction. A small number of Hawaiian hawks (presently considered to be an endangered species) do occur in the east rift zone. The hawk, however, is a wide-ranging species, and it seems certain that the birds would simply shift their home range if a geothermal plant produced any conditions that the hawks found objectionable. The hawk now inhabits papaya and macadamia nut orchards, thus showing that the birds are able to adapt to people and to highly disturbed habitats.

2. There is no evidence that any species of native sea bird nests in the east rift zone of Kilauea Volcano, nor that they have done so historically.

3. The many introduced or alien bird species that occur in the entire rift zone (that is, to sea level) are irrelevant to a determination of a suitable geothermal zone. This is true because none are endangered species, they exist in very large numbers; a large number have proven to be pest birds in Hawai'i, and some may be important in harboring parasites and diseases that could pose a threat to the endemic bird species.

4. The introduced mongoose, rats, feral cats, and feral dogs are predators on birds, their nests and eggs. The roof rat and the other two introduced rats (Norway and Polynesian, Rattus exulans) cause considerable damage to agriculture as well as to homes and commercial buildings.

5. Pigs not only destroy the ground cover and tree ferns in the native forests but their rooting also opens up areas where exotic plants can become established in forested areas.

ORNITHOLOGICAL FIELD NOTES — Kahauale'a, Upper Kalapana & Wao Kele O Puna Natural Area Reserve

Ten bird species were observed in Kahauale'a and the upper Kalapana-Wao Kele O Puna Natural Area Reserve (NAR). Tables 2 and 3 summarizes these findings. Nomenclature and phylogenetic order used in the tables follow A. J. Berger's treatment in the preceding report.

The following information is presented in the tables:

I. Taxa, i.e., common name as well as scientific name and family.

II. Status (symbols after Pyle (1977))

Re = Resident species, native, endemic at the species level.

Fl = Foreign introduced species, long established and breeding in the Hawaiian Islands (for more than 25 years).

E = Currently on the Federal List of Endangered Species.

III. Abundance indices are scaled from 1 (rare) to 10 (very abundant).

IV. Occurrence of species on a transect.

The smaller number of species recorded from the Kahauale'a area is in large part due to the limited number of transects.

Among the introduced species, the Japanese White-eye and the Melodious Laughing-thrush occurred in all twelve transects in moderate numbers.

The 'Apapane and the 'Oma'o are the most frequently encountered native species.

Mosquitoes were abundant on the upper Kalapana (1240 to 1400 ft elevation) and Wao Kele O Puna NAR transects. Fewer mosquitoes were noted on the two, higher elevation Kahauale'a transects.

Table 4 presents avifauna distribution among the different ecosystem types (refer to Flora section).

Introduced species occur in the very open 'ohi'a-uluhe association as well as the forested areas while native species, with the exception of the 'I'o, occur in the 'ohi'a forest. The less disturbed types of 'ohi'a forest ('ohi'a-a(1), 'ohi'a-a(2)) support more native species.

TABLE 2. BIRD SPECIES OCCURRING IN KAHAUALE'A

Common Name	Species; Family	Status	Abundance	No. Transects Observed / Total No. of Transects
Hawaiian Hawk, 'I'o	Buteo solitarius; Accipitridae	Re, E	1	1/2
Hawaiian Thrush, 'Oma'o	Phaeornis obscurus obscurus; Turdidae	Re	5	2/2
'Elepaio	Chasiempis sandwichensis sandwichensis; Muscicapidae	Re	2	2/2
'Apapane	Himatione sanguinea sanguinea; Drepanididae	Re	9	2/2
Melodious Laughing-thrush	Garrulax canorus; Timaliidae	Fl	2	2/2
Japanese White-eye	Zosterops japonicus japonicus; Zosteropidae	Fl	4	2/2

TABLE 3. BIRD SPECIES OCCURRING IN UPPER KALAPANA AND WAO KELE O PUNA NATURAL AREA RESERVE

Common Name	Species; Family	Status	Abundance	No. Transects Observed / Total No. of Transects
Hawaiian Hawk, 'I'o	Buteo solitarius; Accipitridae	Re, E	1	3/10
Hawaiian Thrush, 'Oma'o	Phaeornis obscurus obscurus; Turdidae	Re	2	6/10
'Amakihi	Hemignathus virens virens; Drepanididae	Re	5	6/10
'Apapane	Himatione sanguinea sanguinea; Drepanididae	Re	4	8/10
'I'iwi	Vestiaria coccinea; Drepanididae	Re	1	2/10
Melodius Laughing-thrush	Garrulax canorus; Timaliidae	Fl	4	9/10

Common Name	Species; Family	Status	Abundance	No. Transects Observed / Total No. of Transects
Japanese White-eye	Zosterops japonicus japonicus; Zosteropidae	Fl	5	10/10
Northern Cardinal	Cardinalis cardinalis; Fringillidae	Fl	1	4/10
House Finch	Carpodacus mexicanus frontalis; Fringillidae	Fl	1	1/10

TABLE 4. BIRD SPECIES FOUND IN VARIOUS ECOSYSTEM TYPES OF KAHAUALE'A, UPPER KALAPANA, AND WAO KELE O PUNA NATURAL AREA RESERVE

Common Name	Lava	'Ohi'a-uluhe woodland	'Ohi'a Forest		
			'ohi'a-a(1)	'ohi'a-a(2)	'ohi'a-a(3)
Hawaiian Hawk, 'I'o	+	+	+	+	+
Hawaiian Thrush, 'Oma'o	-	-	+	+	-
'Elepaio	-	-	+	-	-
'Amakihi	-	-	+	+	+
'Apapane	-	-	+	+	+
'I'iwi	-	-	+	+	-
Melodious Laughing-thrush	-	+	+	+	+
Japanese White-eye	-	+	+	+	+
Northern Cardinal	-	+	-	+	+
House Finch	-	-	-	+	-

ENDANGERED SPECIES

FLORA

Several rare, threatened or endangered plant species are known to occur or to have occurred in the past within the project area. A list of such plants from the Southeast Rift Zone has been compiled by Dr. C. Corn (State Botanist, Division of Forestry, Department of Land and Natural Resources) using information obtained from the botanical literature and herbarium sheet labels. The following species have been collected in the project area:

*Rauvolfia remotiflora

*Reynoldsia hillebrandii

*Tetraplasandra hawaiiensis var. hawaiiensis

Bidens skottsbergii var. conglutinata

*Bidens skottsbergii var. skottsbergii

Clermontia hawaiiensis

*Cyanea rollandioides

*Sesbania tomentosa var. tomentosa

*Cyrtandra ramosissima

*Scaevola kilaueae

*Ophioglossum concinnum

Peperomia lilifolia var. obtusata

*Ischaemum byrone

*Adenophorus periens

Alphitonia ponderosa var. kauila

*Bobea timonioides

*Pelea pickeringii

Zanthoxylum dipetalum var. geminicarpum

*Bidens hawaiensis

Not all collections had precise location data and the following species may occur or may have occurred in the project area:

*Bidens campylotheca

Clermontia peleana

*Cyanea tritomantha var. tritomantha

*Cyrtandra giffardii

*Labordia hedyosmifolia var. kilaueana

*Portulaca sclerocarpa

*Pelea zahlbruckneri

*Pelea parvifolia var. apoda

*Nothocestrum breviflorum var. breviflorum

*Nothocestrum longifolium var. rufipilosum

*Wikstroemia perdita

*Cyanea giffardii

*Trematolobelia wimmeri

Hedyotis manii var. scaposa

*Labordia hedyosmifolia var. magnifolia

Those species currently under review by the U.S. Fish and Wildlife Service (1980) are denoted by an asterisk.

A number of the species listed occur within the Hawai'i Volcanoes National Park boundary or at higher elevations outside the project area.

During the course of this survey eight plant species currently under review were located and are discussed on the following pages.

ADENOPHORUS PERIENS L. E. BISHOP

This fern is a member of a genus endemic to the Hawaiian Islands. In the 19th century it was known to be fairly common from rainforest areas on Kaua'i, O'ahu, Moloka'i, Lanai'i, Maui and Hawai'i. For the past 60 years only two

populations have been known. A small population (probably less than 100 plants) still occurs on Moloka'i, near Pepe'opae Bog, Kamakou. The major population, consisting of several thousand plants, occurs entirely within the Puna District, largely within Kahauale'a, and extending from there a short distance eastward into the Wao Kele O Puna Natural Area Reserve (Fig. 2).

Adenophorus periens was listed by Fosberg and Herbst (1975) as "population apparently decreasing, very rare." In the latest Fish and Wildlife Service determination (1980) it is listed as a Category 1 candidate for listing as an endangered species. A Category 1 species is one for which the Service had sufficient information to support the biological appropriateness of listing, but for which data still needed to be collected concerning the environmental and economic impacts of listing and designation of Critical Habitats.

Recent studies (Lamoureux 1982a, 1982b, 1984a; Williams 1982; Williams and Lamoureux 1982) have delimited the area occupied by this species in Puna, and have provided estimates of population size in this area. Prior to the Pu'u O'o eruptions of 1983-85 population size was estimated at between 65,000 and 100,000 plants. Our field studies in late 1984, conducted for purposes of the present report, revealed that a small part (perhaps 5%) of the habitat had been destroyed when covered by lava flows from Pu'u O'o. More significantly, a combination of tephra deposited and volcanic gases emitted in large amounts during Pu'u O'o eruptions has had rather severe effects on the nearby forests, and resulted in the loss of many individuals of Adenophorus periens. By November 1984 nearly all A. periens in the forests nearest Pu'u O'o seemed to be dead, while those in the northern part of Kahauale'a, near the end of Captain's Drive, appeared to have been unaffected by recent volcanic activity. We were not able to conduct a census of sufficient scope to allow us to give a

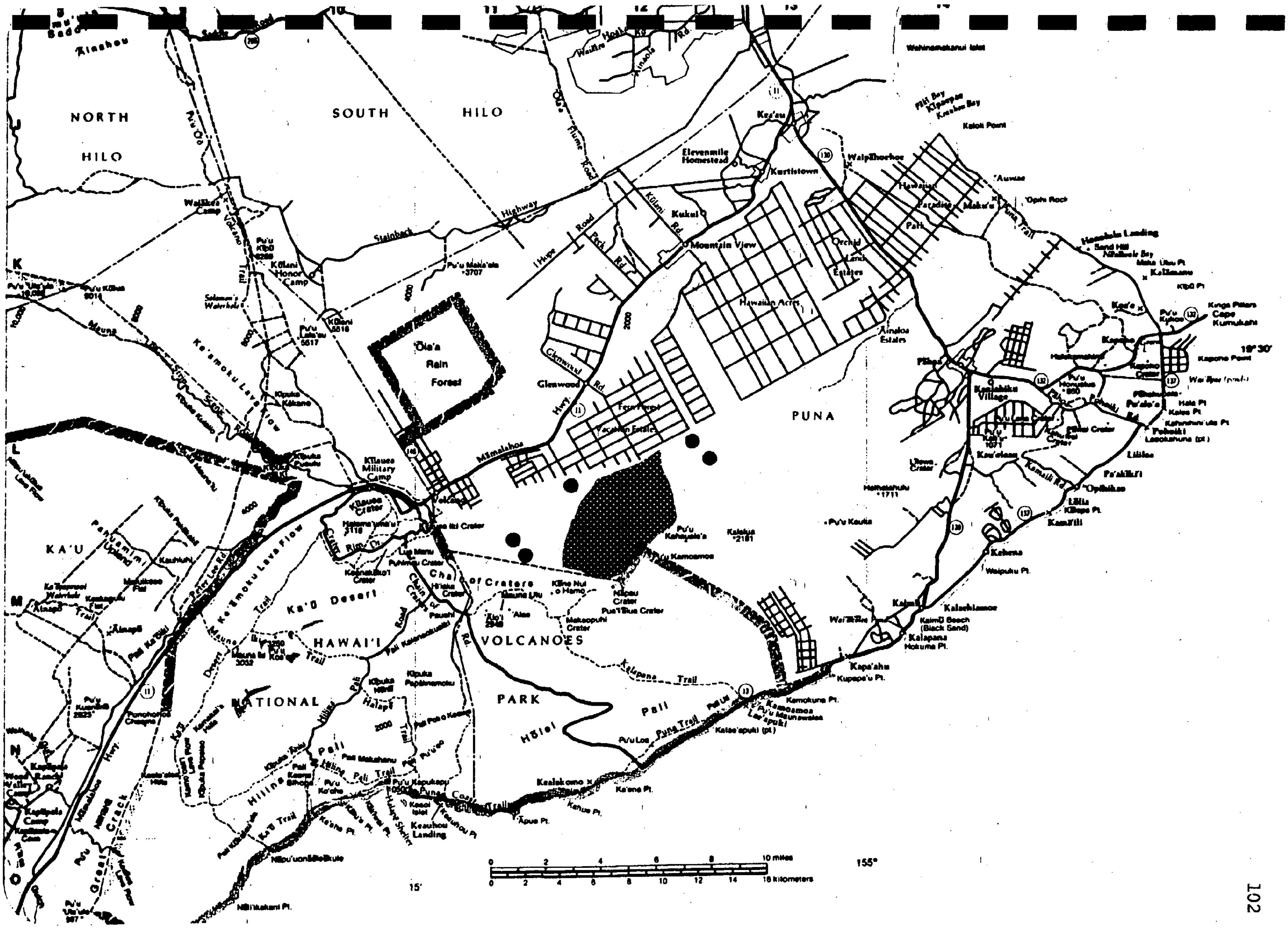

Fig. 2. Distribution of Adenophorus periens in project area.
Shaded area designates major population concentration.
Dots show locations of more scattered plants.

reliable estimate of present population size, nor are we able to predict the time that may be required for the population to recover to its pre-eruption size.

The studies made in 1982 by Lamoureux and Williams revealed a number of details of habitat requirements for A. periens. It is an epiphyte which seems to be confined to a layer of mosses, liverworts and small ferns that forms a mat up to 2 inches thick on the lower trunks of 'ohi'a-lehua (Metrosideros) trees in areas where the tree canopy is well-developed and where a subcanopy of hapu'u ferns (Cibotium) provides heavy enough shade to allow the development of the thick moss/fern mat on the lower tree trunks. This sort of habitat is encountered essentially only in the forest type we have classified and mapped as 'ohi'a forest-a(1). This is a very sensitive habitat type, since any changes which would result in removing either the 'ohi'a-lehua trees or the hapu'u ferns would also have the effect of destroying the moss/fern mat and the Adenophorus periens which lives in it.

BIDENS SKOTTSBERGII SHERFF VAR. SKOTTSBERGII

Bidens skottsbergii var. skottsbergii (ko'oko'olau) is a small to medium shrub, 1 to 1.5 m tall, with bright yellow flowers belonging to the daisy family (Compositae). It has been placed in the Category 1 status by the U.S. Fish and Wildlife Service (1980) and is listed by Fosberg and Herbst (1975) as "depleted, rare, and endangered".

It is very restricted in distribution, usually found in the dry forest or dry scrub community although it may occur very rarely in the mixed lowland forest (Fig. 3). An easily accessible population is found mauka of the Waha'ula heiau within Hawai'i Volcanoes National Park.

The ko'oko'olau is not likely to be directly impacted by geothermal development as it is not found in areas with high geothermal energy potential.

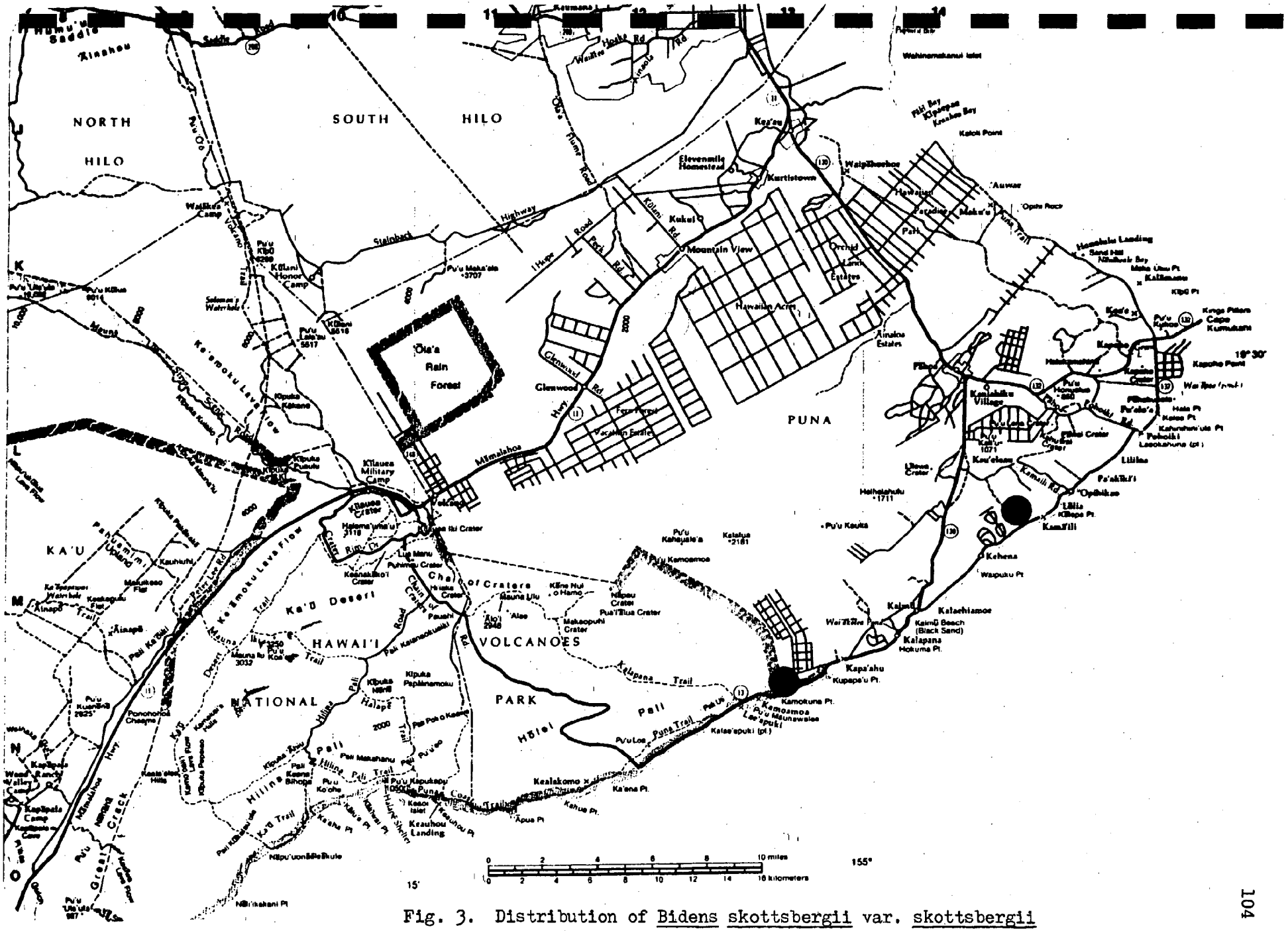

Fig. 3. Distribution of Bidens skottsbergii var. skottsbergii in project area.

BOBEA TIMONIOIDES (HOOK. F.) HILLEBR.

A medium-statured tree, 6 to 8 m tall, with pale green leaves and a whitish to gray colored bark, Bobea timonioides ('ahakea) is found in all 'ohi'a forest types but reaches its best development in the moderately moist (mesic) 'ohi'a forests on the palis above Waha'ula Heiau. Several straight-trunked trees of 'ahakea, 24 to 27 m tall, were found in the Royal Gardens subdivision among 'ohi'a, lama (Diospyros ferrea ssp. sandwicensis) and olupua (Osmanthus sandwicensis). This particular stand of trees composed of the species mentioned above was 20 to 27 m tall, all straight-trunked (30 to 45 cm in diameter) and branching high above the ground.

The 'ahakea is presently under review (Category 1) by the U.S. Fish and Wildlife Service (1980); Fosberg and Herbst (1975) list it as "very local, endangered".

The 'ahakea is located in areas already designated or proposed for geothermal development. Roads, wells, power plants and other geothermal facilities should be sited so that they avoid those locations with 'ahakea trees.

CYANEA TRITOMANTHA GRAY VAR. TRITOMANTHA

Cyanea tritomantha var. tritomantha ('aku'aku) was found only once during the course of this survey in an 'ohi'a-a(2) forest (Fig. 5). Although the surrounding forest had signs of pig damage, the area with several of the Cyanea plants was not damaged and also contained a number of Cyrtandra species. The substrate on which the Cyanea occurred consisted of very rough 'a'a, this probably deterred the pigs.

This Cyanea is a very striking plant. The population we found had pure white flowers in dense clusters and the leaves and stems were covered with almost-translucent prickles.

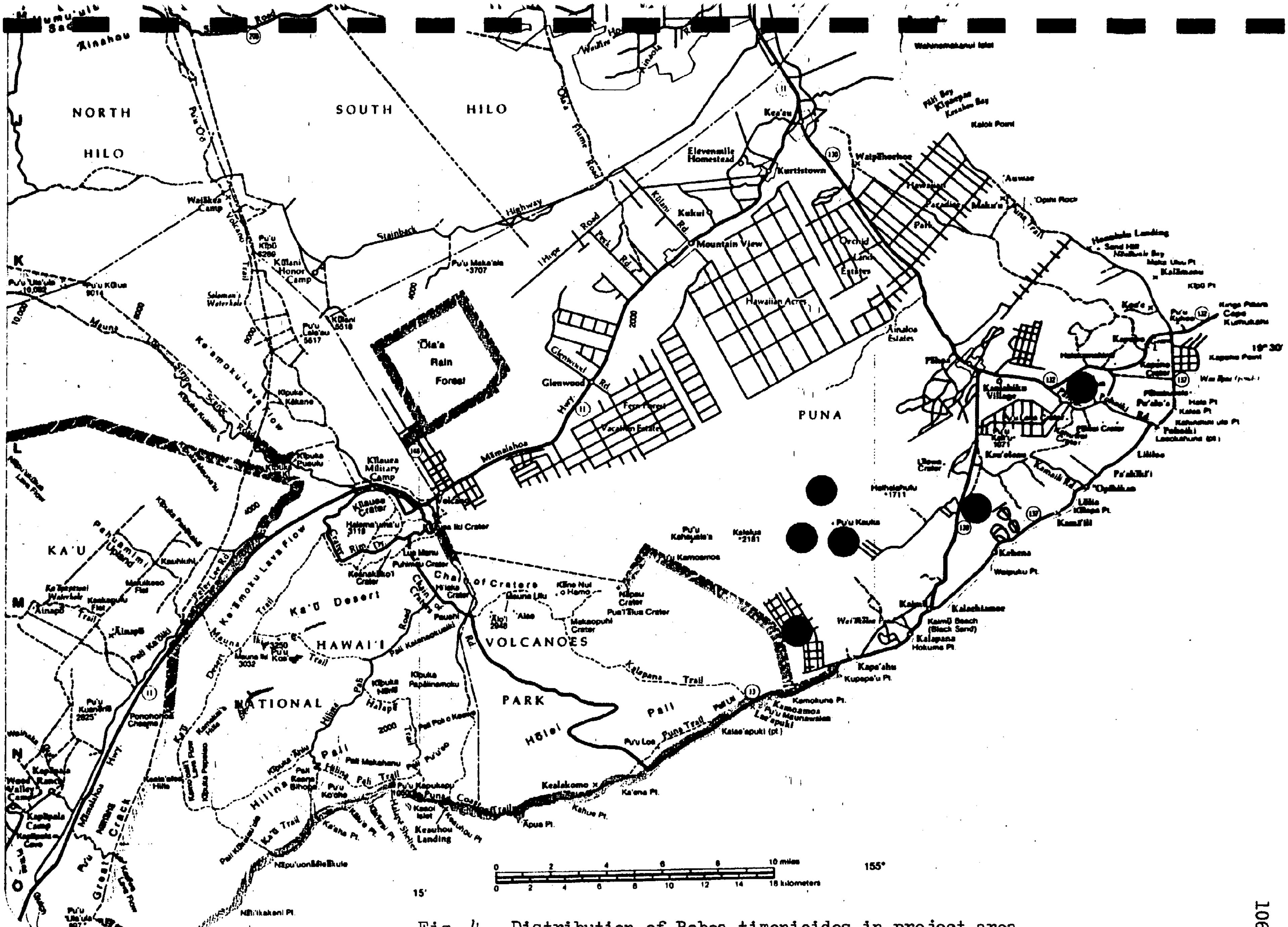

Fig. 4. Distribution of Bobea timonioides in project area.

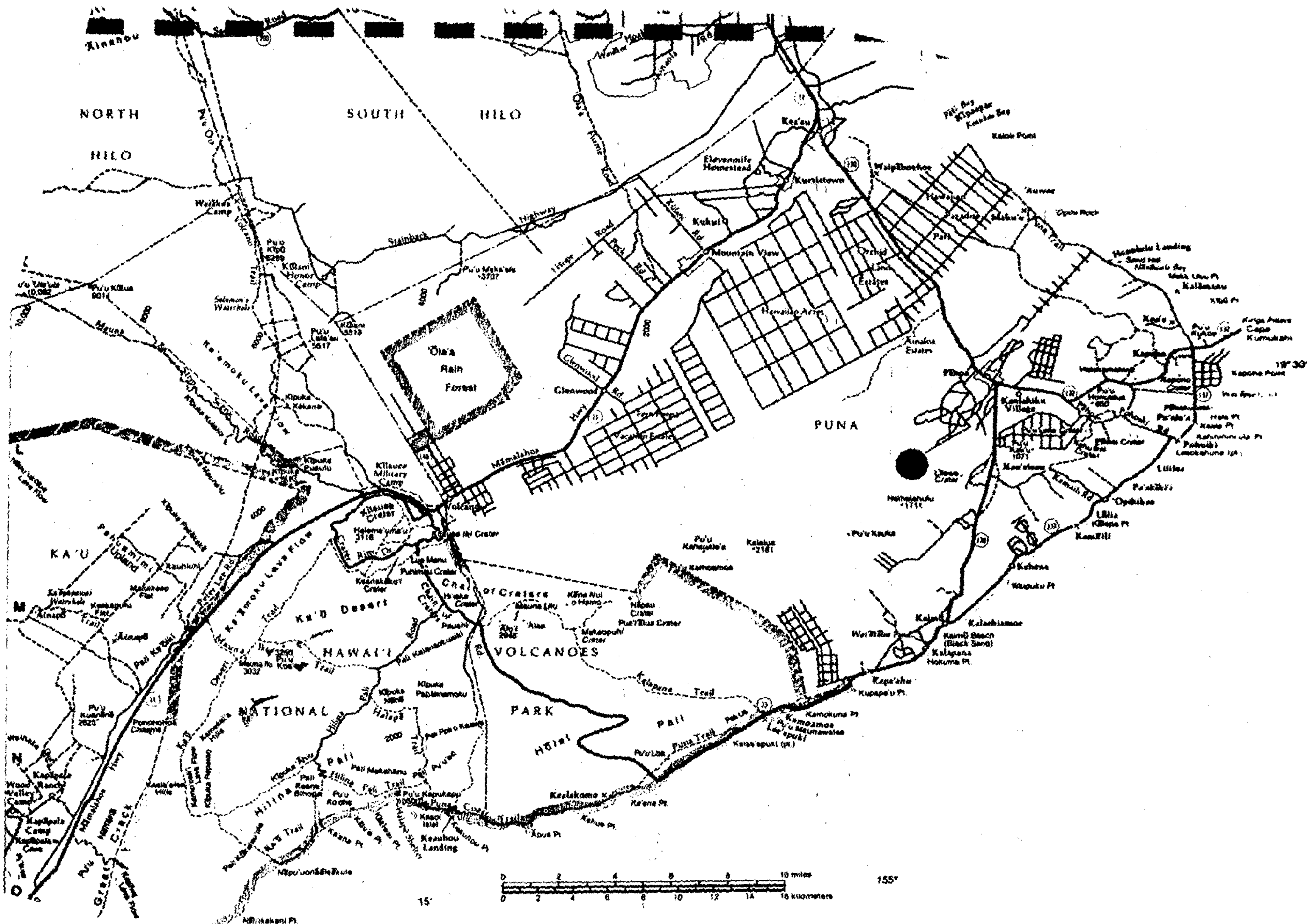

Fig. 5. Distribution of <u>Cyanea tritomantha</u> var. <u>tritomantha</u> in project area.

Cyanea tritomantha var. tritomantha has been placed in Category 1 by the U.S. Fish and Wildlife Service (1980). Fosberg and Herbst (1975) list it as "rare, total population low, whether dangerously so or not; endangered, in considerable danger of disappearance". This species is very rare in the project area and is probably restricted to 'ohi'a-a(1) and a(2) forests. Since it is very rare and its population appears to be limited any direct disturbance by geothermal development would be detrimental.

ISCHAEMUM BYRONE (TRIN.) HITCHC.

This is a grass endemic to the Hawaiian Islands, which is restricted to coastal areas and usually grows on sand or rocks within a hundred yards or so of the sea. It was known in the past from O'ahu, Moloka'i, Maui, and Hawai'i and may still be present in small numbers on all these islands. Fosberg and Herbst (1975) listed it as "depleted, rare, endangered". The latest Fish and Wildlife Service review (1980) includes it as a Category 1 species for listing as endangered. It occurs sporadically along the coast of Puna; recent collections have been made near Honolulu Landing, in Malama-Ki Forest Reserve, and at Kamoamoa (Fig. 6). Because it grows only in close proximity to the coast, away from areas proposed for geothermal development, it is unlikely that such development will have any effect on its prospects for long-term survival.

RAUVOLFIA REMOTIFLORA DEG. & SHERFF

Rauvolfia remotiflora is a medium sized tree with milky sap and light green leaves. The flowers are small, whitish-yellow and occur in clusters.

Within the project area it is found in the dry forests behind Waha'ula Heiau and in the Royal Gardens subdivision (Fig. 7).

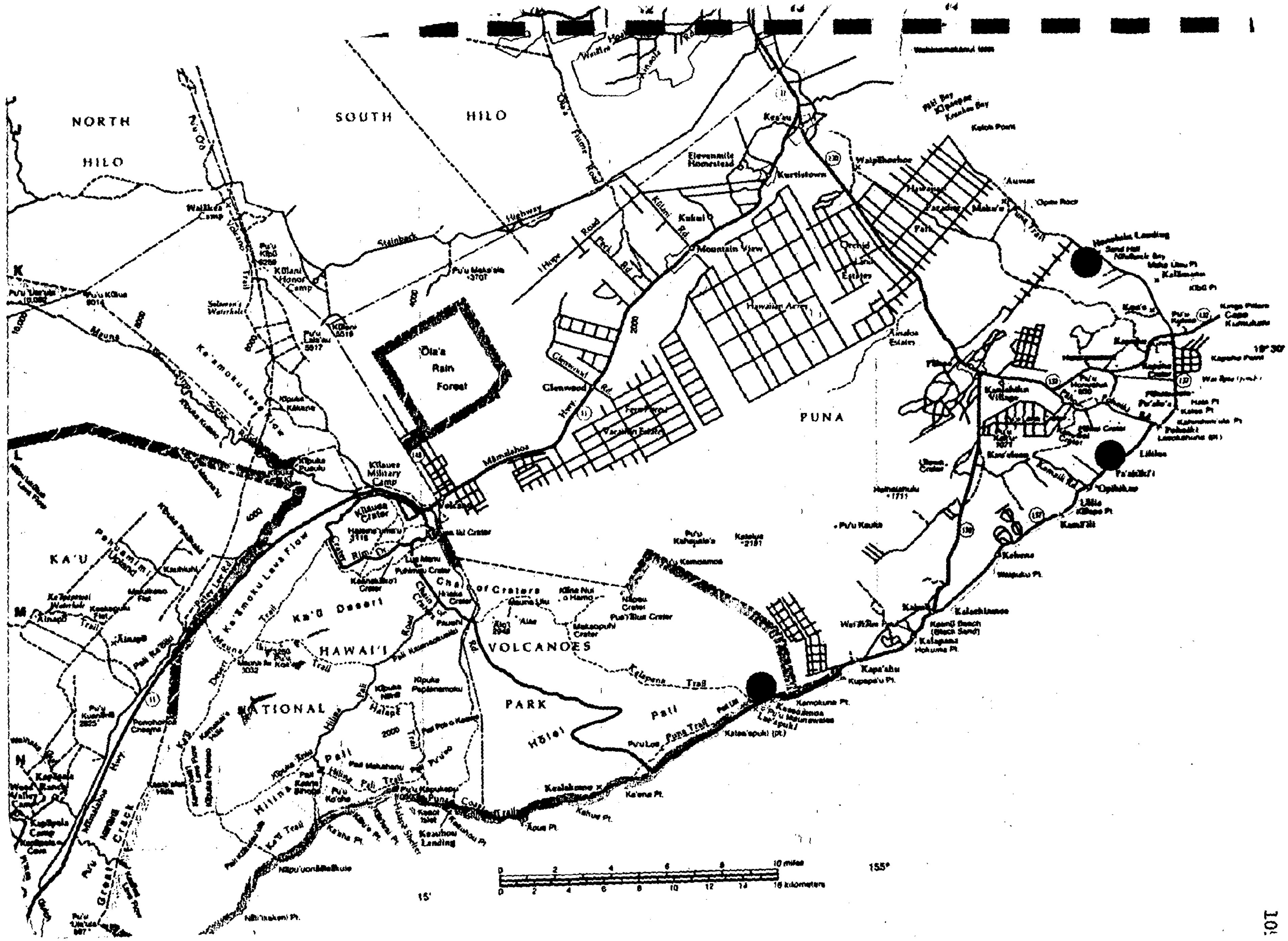

Fig. 6. Distribution of Ischaemum byrone in project area.

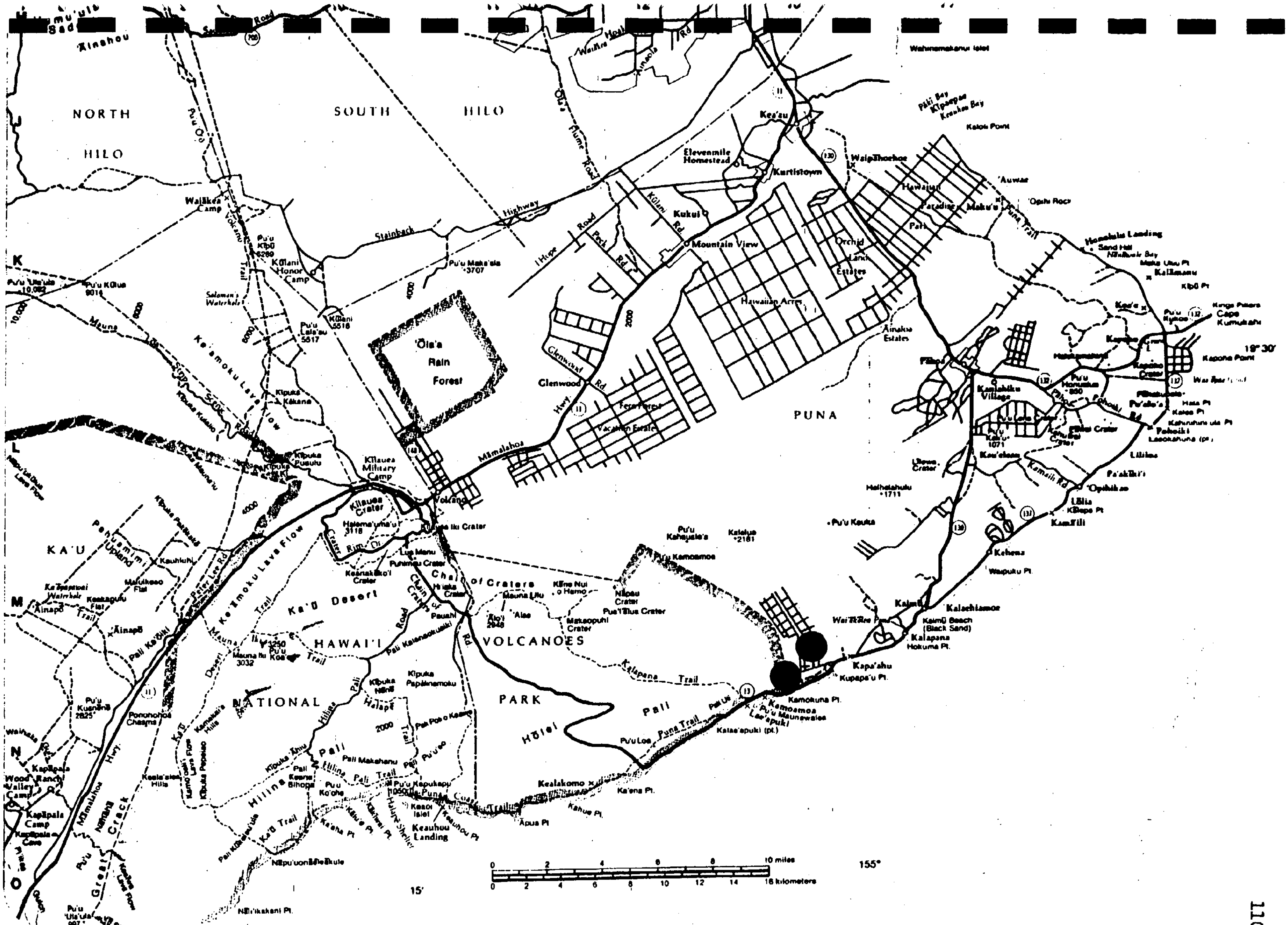

Fig. 7. Distribution of Rauvolfia remotiflora in project area.

It has been placed in Category 1 by the U.S. Fish and Wildlife Service (1980). Rauvolfia remotiflora has a very restricted distribution and Fosberg and Herbst (1975) note that it is "very local (found only or principally in one or more restricted areas), very rare, and endangered."

The Rauvolfia is not located in an area proposed for geothermal development.

REYNOLDSIA HILLEBRANDII SHERFF

Reynoldsia hillebrandii ('ohe) is a medium-sized tree from 5 to 30 m tall with thickish branches. The trees often shed their leaves for a short period of time during the winter months and begin flowering just before the leaves appear, usually in early summer. However, we did find trees in the Royal Gardens subdivision with flower, fruit and leaves during our field survey in late November.

The 'ohe has a limited distribution range and is usually found in the dry forests and very rarely in mixed lowland forests (Fig. 8).

It is currently under review (Category 1) by the U.S. Fish and Wildlife Service (1980) and is listed by Fosberg and Herbst (1975) as "local, rare, and endangered.".

It is unlikely that geothermal development would have a detrimental effect on its population as the 'ohe is located at lower elevations, away from areas proposed for geothermal development.

TETRAPLASANDRA HAWAIIENSIS VAR. HAWAIIENSIS GRAY

Tetraplasandra hawaiiensis var. hawiiensis ('ohe) is a large tree, 12 to 26 m tall, often unbranched for some distance above the ground and towering above the 'ohi'a trees. Each leaf is divided into 5 to 9 leaflets. The leaflets are leathery, green and smooth above but tawny woolly beneath.

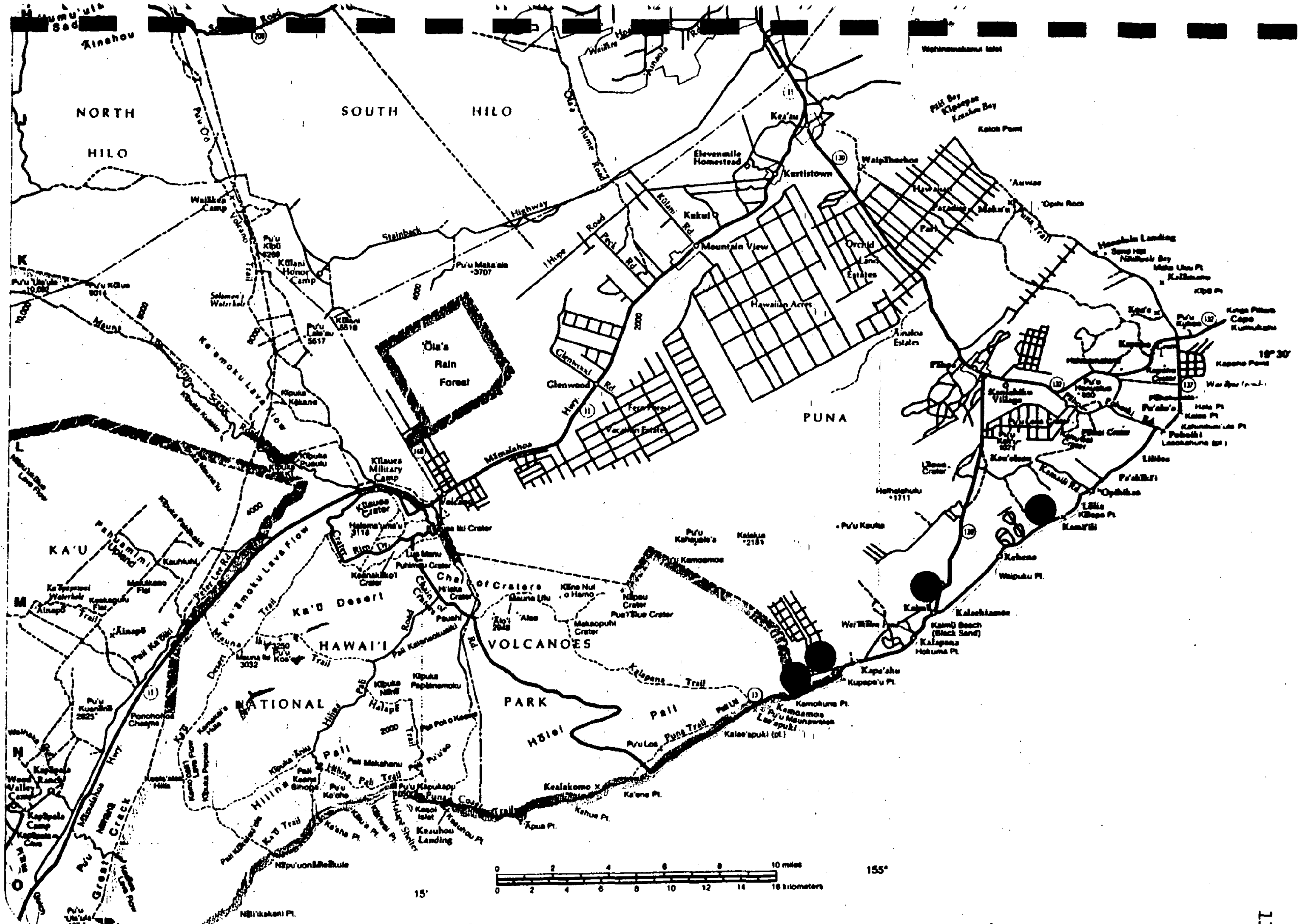

Fig. 8. Distribution of Reynoldsia hillebrandii in project area.

Within the study area it is very widespread, usually occurring as scattered individuals or small groups of trees. It can be found over a wide range of elevations (from 100 to 3100 ft elevation) and ecosystem types—'ohi'a woodland, all five kinds of 'ohi'a forest and mixed lowland forest.

Although it has been listed for review by the U.S. Fish and Wildlife Service (1980) it is not considered a high priority item as its range is more extensive than had been previously believed. It is listed by Fosberg and Herbst (1975) as "depleted, much less common over all or most of its range than formerly, the depletion directly or indirectly the results of human activities; uncertain, insufficient information available to us to decide if endangered; possible endangered."

FAUNA

PSITTIROSTRA PSITTACEA

The 'O'u formerly occurred in the 'ohi'a-lehua forests of the six major Hawaiian Islands. It is now extinct on O'ahu, Moloka'i, Lana'i, and Maui. Small populations still exist on Kaua'i and Hawai'i, and the bird has been officially listed as Endangered.

In recent years a few scattered sightings have been made in the project area, in Kahauale'a, in Wao Kele O Puna Natural Area Reserve, and in Hawai'i Volcanoes National Park, both near Pu'u Kamoamoa and near the Park residence area. It is not known whether a breeding population of 'O'u still exists in the project area. It is probably the rarest native bird which now occurs there, however.

BUTEO SOLITARIUS

Buteo solitarius ('I'o or Hawaiian Hawk) is the only remaining member of the family of raptors (Accipitridae) to have reached the Hawaiian Islands.

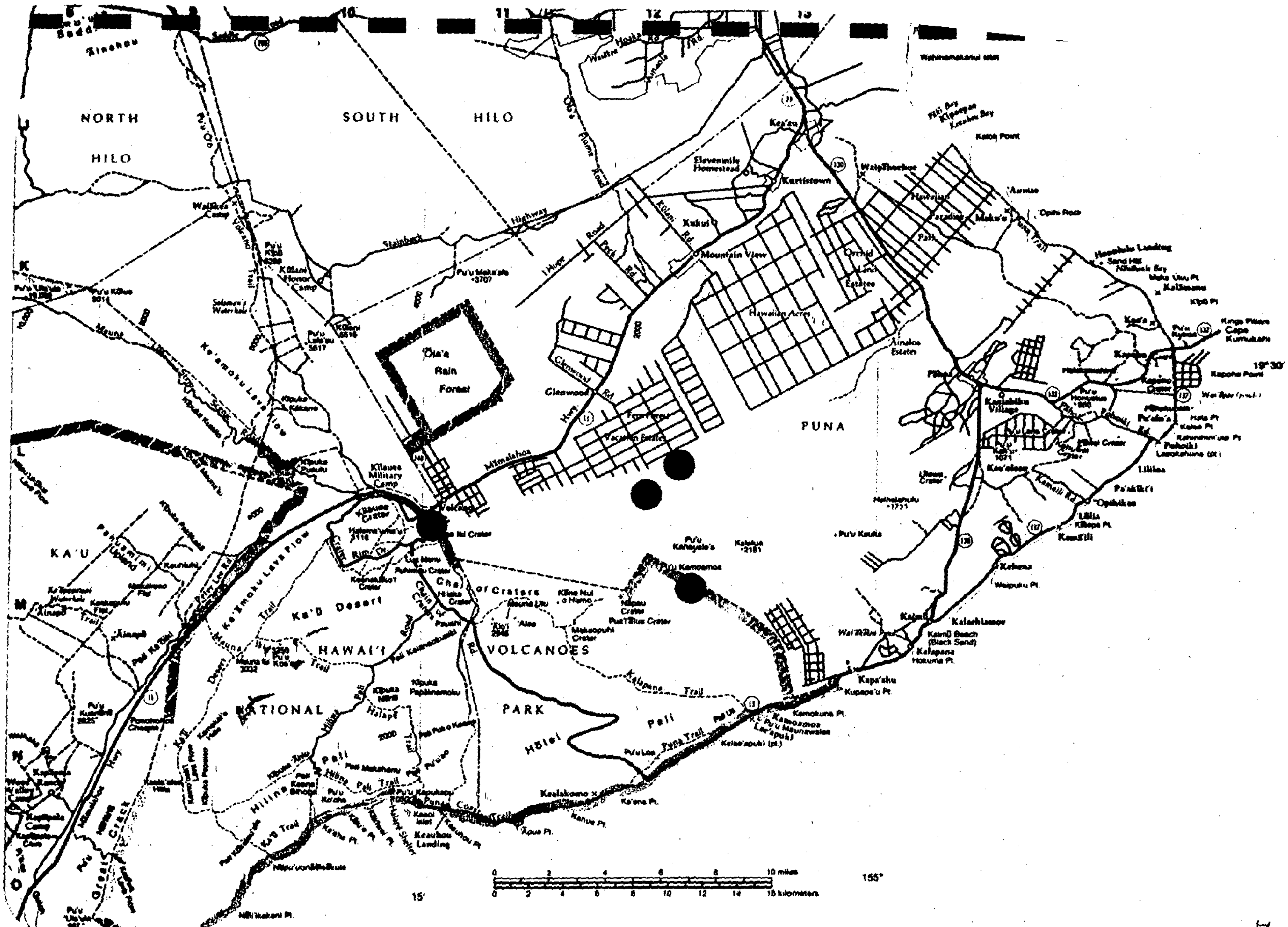

Fig. 9. Distribution of Psittirostra psittacea in project area.

The 'I'o is a large, heavy-set bird with broad wings and a broad, relatively short, rounded tail. Its plumage may be dark brown above and below or dark brown above and pale buff below, frequently streaked with darker feathers (Berger 1972).

'I'o were frequently seen during this survey; occurring over a wide range of ecosystem types including agricultural lands particularly papaya fields. The district of Puna supports a dense breeding population.

The 'I'o is considered endangered but its present status may be re-evaluated (refer to Avifauna section).

Geothermal development would have a negative impact on the nesting areas of the 'I'o. The 'I'o often uses the same nest or nests in the same locality. Noise from geothermal operations may affect hawk breeding (Char and Kjargaard 1984). Well sites and power plants should be located in open areas such as lava flows or scrub, away from tall trees, if 'I'o are known to nest in the nearby forests. The effects of well emissions on 'I'o are not clear. Monitoring of 'I'o population size and breeding activities around geothermal sites is recommended (Char and Kjargaard 1984).

ENVIRONMENTAL RISKS TO BIOTA ASSOCIATED WITH GEOTHERMAL DEVELOPMENT

The development of geothermal resources within the project area will carry with it certain risks to the plants and animals found there. Of special concern are the risks to native species, particularly the endemic species, those which occur only in Hawaii and nowhere else in the world, several of which are listed, or have been propoed for listing, as endangered or threatened species under state and federal endangered species legislation.

In order to minimize such risks, it may become necessary to employ certain mitigating measures, and it will be necessary to undertake continued monitoring on a site-specific basis for each site proposed for development. Such monitoring should begin before development commences, and should continue during construction and operational phases.

Possible detrimental effects of geothermal development, and possible mitigating measures include:

A. Direct loss of habitat, and destruction of native organisms, as a consequence of land clearing during construction of access roads, pipelines, wells, power plants, and transmission lines. This can be mitigated by avoiding, as much as possible, land clearing in highly sensitive areas supporting forests dominated by native species, such as the 'ohi'a forests which we have identified as 'ohi'a-a(1) (highest quality habitat for native species), and 'ohi'a-a(2) (high quality habitat for native species). Such practices as locating access roads and drilling sites on recent, less densely vegetated, lava flows, and planning construction activity in sensitive areas to disturb the smallest possible areas, would significantly mitigate this risk.

B. Acceleration of invasion by introduced plants and animals which move into the disturbed habitats created during development. Weedy plants frequently

invade areas formerly dominated by native species when they become established in such disturbed sites as roadsides, and then move from there into small openings in the forest. Mitigation would consist of continual monitoring of developed areas and utilization of some effective and environmentally compatible method of weed control approriate to the specific site.

C. Compaction of soils associated with construction activities, (and some structures themselves), may permit accumulation of standing water which can provide additional breeding sites for the mosquitoes that are vectors of certain avian diseases. While standing water is frequent in some parts of the project area, such as the eastern part of the Puna Forest Reserve, it is more rarely encountered in the parts of the rainforest which support the richest populations of native birds. All construction sites should be monitored to assure that drainage remains unimpeded, particularly in areas with high native bird populations.

D. Physical damage to plants during construction and maintenance activities may provide sites for infection by pathogens and help spread plant diseases. Such construction work as bulldozing, and such maintenance work as cutting roadside vegetation, should be designed to damage remaining plants as little as possible.

E. Emissions from geothermal wells may differ sufficiently in quantity or composition from the natural geothermal emissions now occurring in the area to have detrimental effects on native organisms. The native organisms which now occupy sites subject to geothermal development have by evolution become adapted to the conditions that have persisted for thousands of years in the southeast rift zone of Kilauea volcano. They have become adapted to at least the typical "background" emissions in the rift zone, although considerable local damage may occur during eruptive cycles when emissions may increase by

two or three orders of magnitude. Until the composition of the emissions of geothermal wells in a particular site is known, it will be impossible to predict the effects of these emissions. It will be necessary to monitor the emissions, and to design appropriate mitigation measures, in order to meet federal and state emissions standards which may be adopted. As more experience is gained, it may become necessary to modify such standards to prevent local damage to the environment, but as yet there is no indication that significant damage to plants and animals in the area would be likely to occur if emissions were controlled to the extent necessary to meet standards designed primarily on a basis of human health requirements.

ACKNOWLEDGEMENTS

Many agencies and individuals provided assistance during this study. We wish especially to acknowledge the cooperation of J.D. Jacobi of the U.S. Fish and Wildlife Service for sharing his vegetation maps of the forested parts of the study site. The U.S. National Park Service allowed us to use their lab facilities and Herbarium for identification and preparation of botanical specimens. The Hawaii State Department of Land and Natural Resources, its Natural Area Reserves System, and the U.S. National Park Service permitted us all necessary access to public lands in the project site, and several private landowners were most cooperative in providing access to their lands. Special thanks are in order for Tamotsu Nakata, who prepared the final copies of the vegetation maps; for Geraldine Ochikubo, who handled numerous administrative details; and for JoAnn Hokama who typed the final report.

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APPENDICES

APPENDIX A

(Photographs)

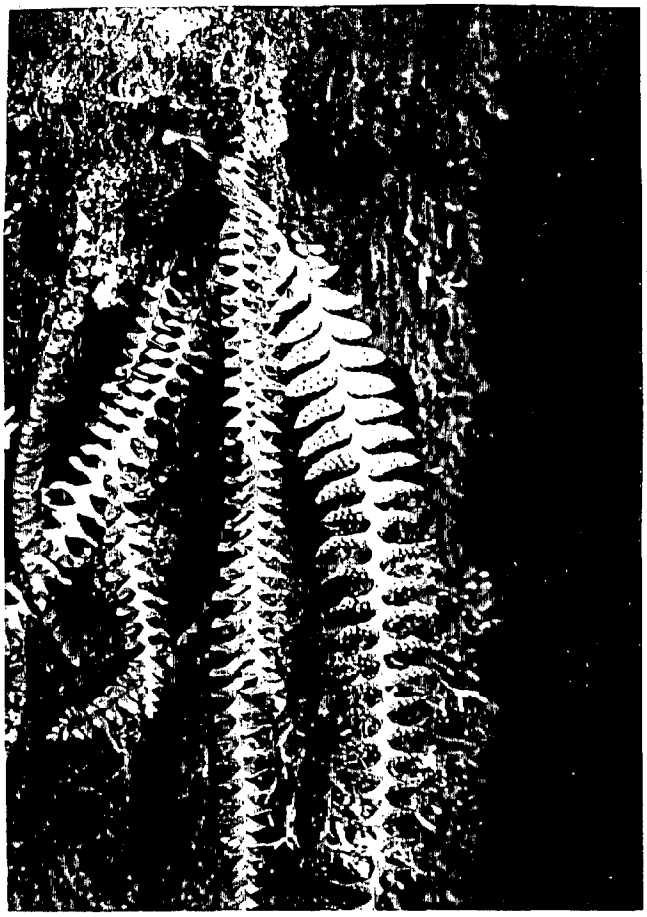
The four species pictured on the following page are presently under review by the U.S. Fish and Wildlife Service (U.S.F.W.S.) for listing as endangered or threatened and are discussed in detail in the text.

Photo. 1. Adenophorus periens. An epiphytic fern found in wet 'ohi'a-a(l) forests, Kahauale'a.

Photo. 2. Bidens skottsbergii var. skottsbergii (ko'oko'olau). Shrub growing behind Waha-'ula Heiau in dry forest, Kalapana.

Photo. 3. Cyanea tritomantha var. tritomantha ('aku'aku). A strikingly beautiful specimen with pure white flowers found in wet 'ohi'a forest above Kaumuki, South Pahoa.

Photo. 4. Ischaemum bryone. An endemic grass found along the Puna coast; this specimen in Malama-Ki Forest Reserve.



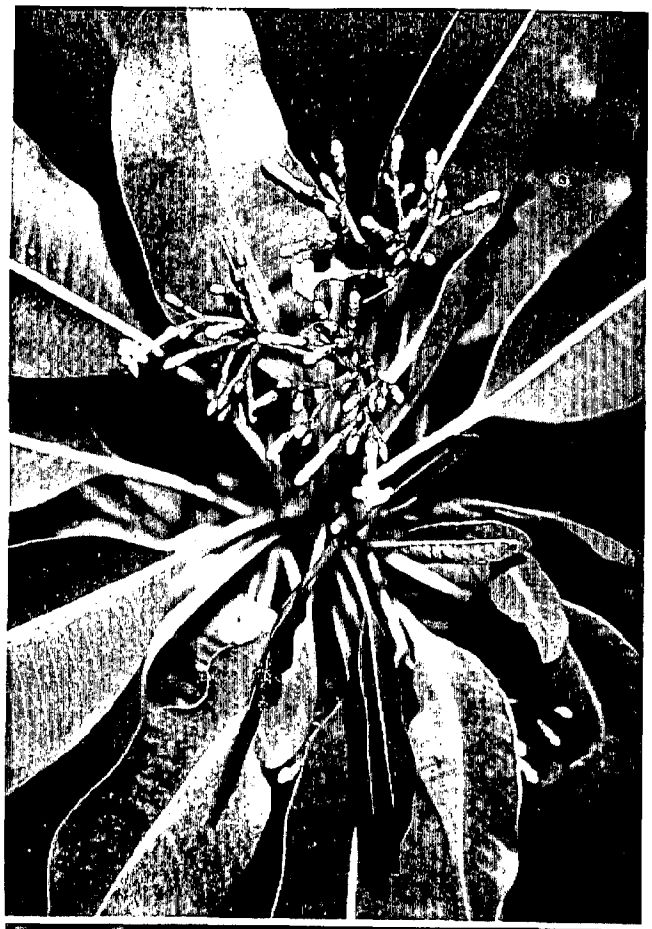
The first two species pictured (Photos 5 & 6) are presently under review by U.S.F.W.S.

Photo 5. Rauvolfia remotiflora. A medium-sized tree of the dry forests, Royal Gardens subdivision.

Photo. 6. Reynoldsia hillebrandii ('ohe). Flowers, fruit, and leaves from tree in dry forest, Royal Gardens subdivision.

Photo. 7. Clermontia hawaiiensis ('oha-kepau). Considered rare. Found in higher elevation wet 'ohi'a forests within project area.

Photo. 8. Cyrtandra sp. nov. A rare, new species found in the lower Puna forests.



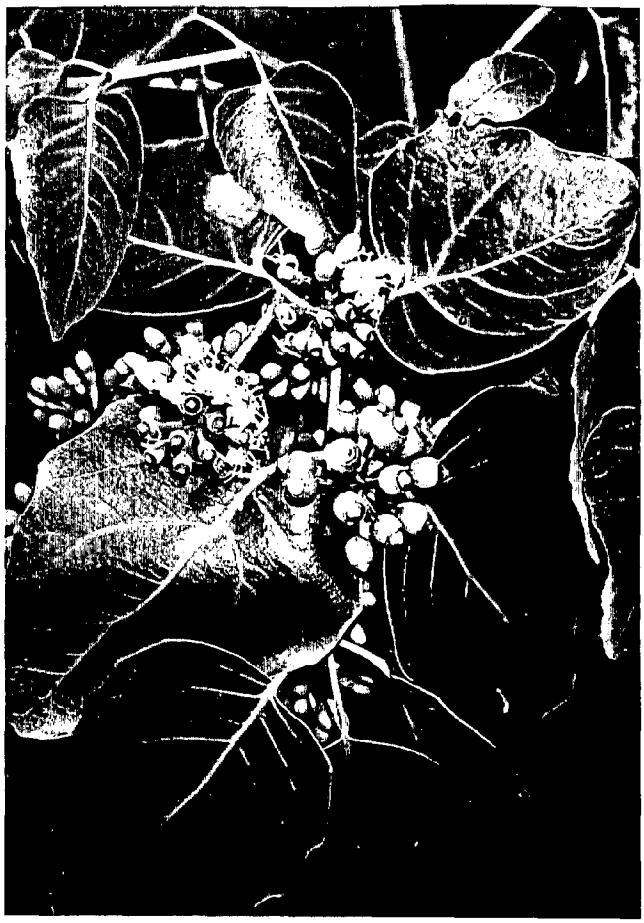


Photo. 9. Psittirostra psittacea ('O'u).
Although not found during this survey, the 'O'u has been observed in the wet 'ohi'a forests of Kahauale'a by U.S.F.W.S. survey teams. It is considered endangered.

(Photograph by S. Conant taken from painting by H. D. Pratt)

Photo. 10. Buteo solitarius ('I'o).
The 'I'o is found throughout Puna in relatively large numbers. It is considered endangered.

(Photograph by R. J. Shallenberger)

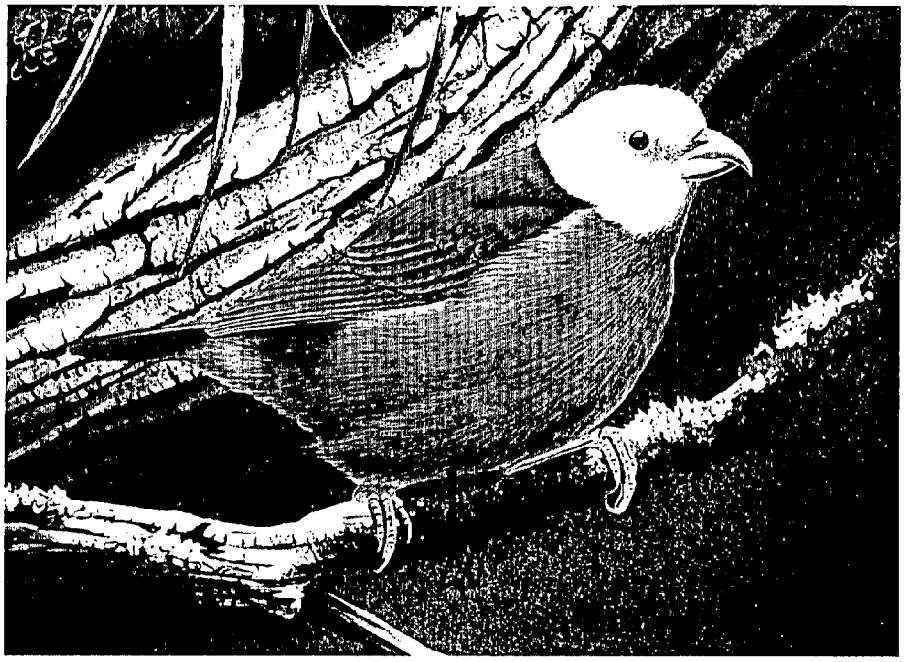


Photo. 11. Summit of Mauna Ulu, Hawaii Volcanoes National Park (HVNP). From 1969 to 1974 Mauna Ulu pumped out vast quantities of lava. A short stature 'ohi'a- grass association is seen in the foreground.

Photo. 12. Access into remote areas was made by helicopter. Landing sites were lava flows - this relatively "smooth" landing site on the 1984 Pu'u O'o flow, Kahauale'a.

Photo 13. Wet 'ohi'a forest in Kahauale'a with lava flows of different ages. Steaming flow in background is from Pu'u O'o. Note damage to forest.

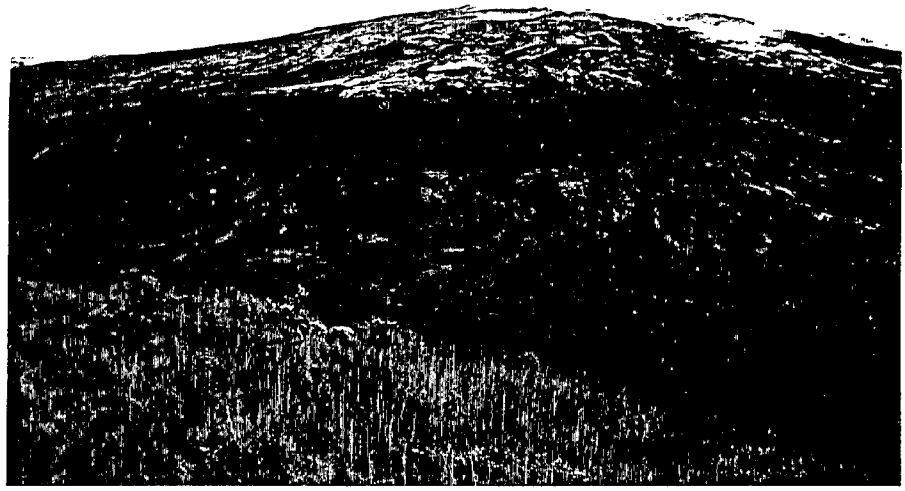
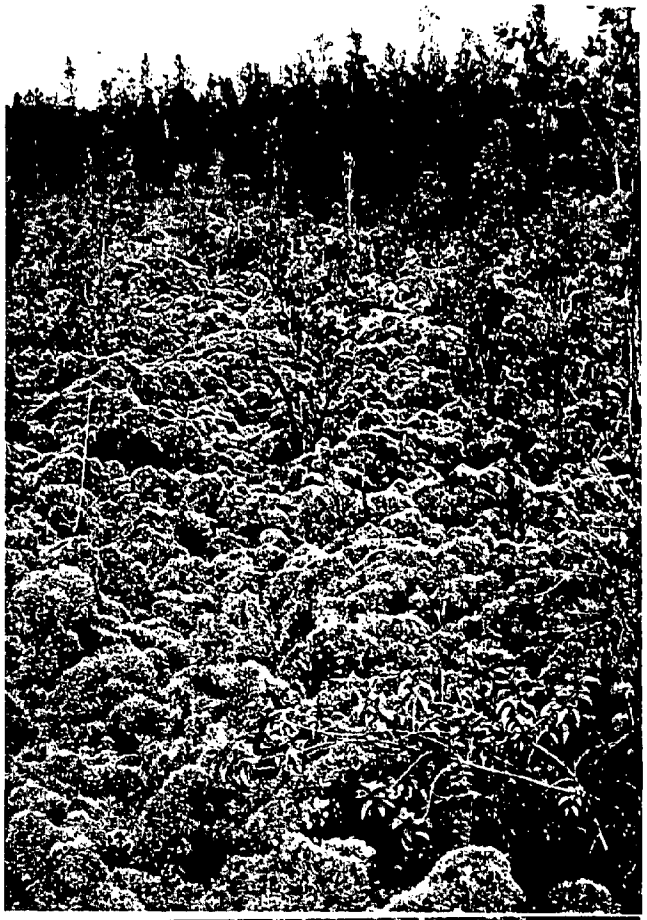


Photo. 14. Edge of 1977 lava flow, Wao Kele O Puna Natural Area Reserve. Note recovery of forest.

Photo. 15. 1955 lava flow between Keauohana and 'I'ilewa Crater, South Pahoa. 'A'a lava covered with dense carpet of lichen, Stereocaulon vulcani.

Photo. 16. 'Ohi'a woodland with uluhe fern, Puna Forest Reserve. The uluhe mat is dense, up to 3 m tall, and botanizing is difficult.

Photo. 17. 'Ohi'a-a(1) forest type, Kahauale'a. Note dense tree fern layer.



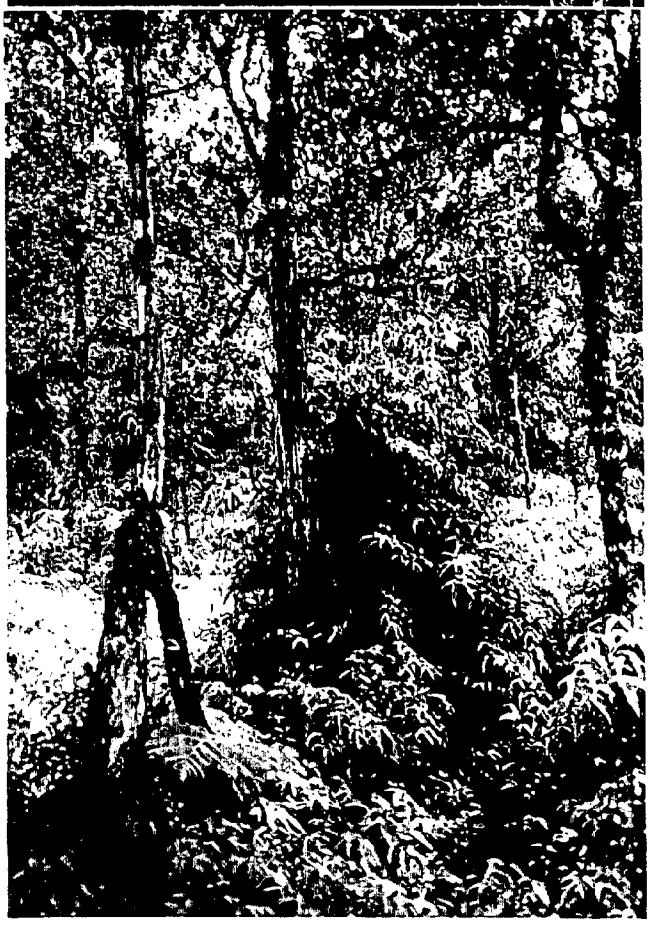


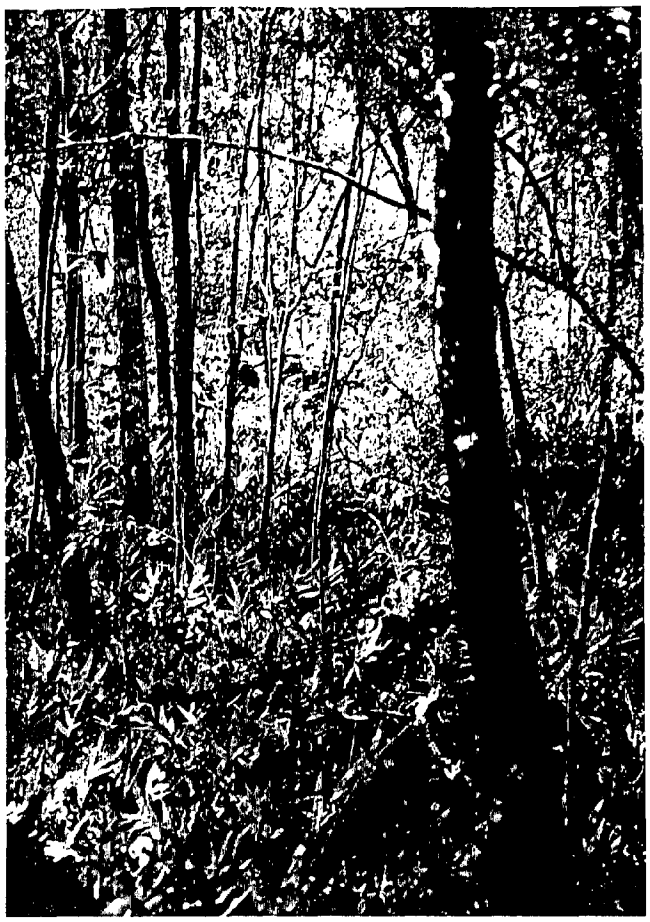
Photo. 18. 'Ohi'a woodland with uluhe and large amounts of 'uki (Machaerina angustifolia), Napau Crater, HVNP. Pu'u O'o in background.

Photo. 19. Dry forest at Royal Gardens subdivision, Kalapana. Dry scrub community and dry grassland in background.

Photo. 20. One of several large, steaming areas on Heiheiahulu, Wao Kele O Puna Natural Area Reserve. The ground is hot underfoot and much of the vegetation has been killed.

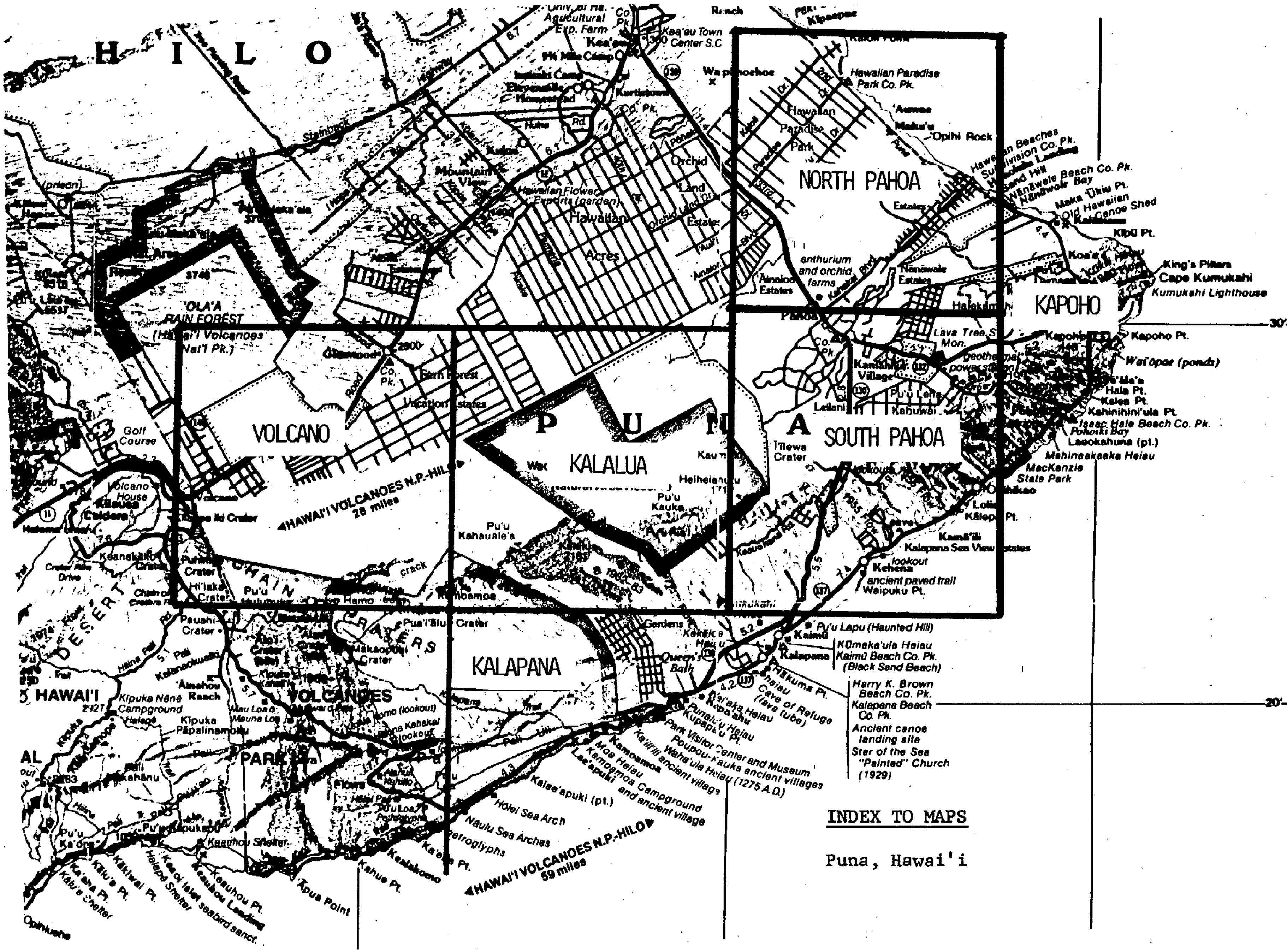
Photo. 21. Dry forest, Royal Gardens subdivision, Kalapana. Lama trees are common; shrubs include alahe'e (Canthium odoratum) and 'akia (Wikstroemia sp.) Lau'ae fern (Phymatosorus scolopendria) is a common ground cover.

Photo. 22. Mixed lowland forest, Malama-Ki Forest Reserve. The trees consist of 'ohi'a and lama (Diospyros ferrea ssp. sandwicensis). Kopiko (Psychotria hawaiiensis) is a common subcanopy tree and shrub. Abundant swordfern (Nephrolepis multiflora) covers the ground. Note 'ie'ie (Freycinetia arborea) climbing up trunk of tree (center of photo).



APPENDIX B

(Vegetation Maps)



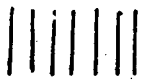
INDEX TO MAPS

Puna, Hawai'i

MAP SYMBOLS

project boundary

transect route



Pu'u O'o flows 1983-1984

lava	lava flows with pioneer vegetation
ohia-uluhe	'ohi'a woodland with uluhe
ohia-gr	'ohi'a woodland with grass
ohia-a(1)	wet 'ohi'a with native species, i. e., native subcanopy trees, tree ferns and native shrubs
ohia-a(2)	wet 'ohi'a forest with native species and exotic shrubs
ohia-a(3)	'ohi'a-kukui forest with mixed native and exotic shrubs
ohia-a(4)	moderately moist 'ohi'a forest
ohia-b	'ohi'a forest with largely exotic subcanopy and shrub layers
dry for	dry forest
dry scr	dry scrub community
dry gr	dry grassland
ml for	mixed lowland forest
scr	scrub
ag	agricultural land