LAUPAHOEHOE NATURAL AREA RESERVE

MANAGEMENT PLAN

Natural Area Reserves System

State of Hawaii

Department of Land and Natural Resources
1151 Punchbowl Street
Honolulu, Hawaii 96813

December 1989

EXECUTIVE SUMMARY

In 1970, Hawaii became one of the first states in the country to recognize the importance of its unique natural resources by establishing the State Natural Area Reserves System (NARS). Governor Waihee and the 1987 Legislature appropriated substantial new funding and legislative mandates to develop and implement management in the NARS. This plan describes the management program for the 7,894-acre Laupahoehoe Natural Area Reserve, established in 1983 by Executive Order 3168. The Reserve protects a diversity of native ecosystems, including koa (Acacia koa)/`ohi`a (Metrosideros polymorpha) forests and wet grasslands.

The Reserve, in the North Hilo District on the island of Hawaii, stretches from just above 1,600 feet to about 4,600 feet elevation and includes several stream drainages. Hakalau National Wildlife Refuge is adjacent to Laupahoehoe Reserve, and protects habitat for several endangered forest birds known to occur in Laupahoehoe as well. Five native natural communities were observed in the Laupahoehoe Reserve during the survey, including a tall-stature koa/`ohi`a forest in both montane and lowland zones, `ohi`a/hapu`u (Cibotium spp.) forest, Carex alligata wet grassland, and non-native dominated patches.

Because of the size of the Reserve, priorities for intensive management of key areas are based on the biological resources and the threats to those resources. Important biological resources in the Reserve include the koa/`ohi`a forest, which provides habitat for rare plants and birds. Management activity over the next six years will focus on protecting the forests from feral pigs, improving access for public hunting, and removing priority weed species from intact portions of natural communities. The effectiveness of management projects will be determined through long-term scientific monitoring.

A six-year implementation schedule is proposed to accomplish management objectives. The annual budget averages $69,000 over this time period. Once the pig threat is reduced, annual management costs should decrease.

Contents
Laupahoehoe Natural Area Reserve

ACKNOWLEDGEMENTS

Several organizations and individuals contributed information, guidance, and review for this management plan. Their cooperation and support is deeply appreciated. In particular, thanks to Lyman Abbott, Samuel Gon III, Joel Lau, and Steve Perlman who participated in the field survey; Barrie Fox Morgan and all the hard working professionals at the Heritage Program of the Nature Conservancy who helped prepare the plan's resource information; Division of Forestry and Wildlife staff Jeanine Branam, Charlie Wakida and the rest of the Hilo staff for their expertise and support; Deputy DLNR Chairperson Libert Landgraf; and Robert Lee and members of the Natural Area Reserves System.

Finally, sincerest thanks to Governor John Waihee, the State Legislature, and DLNR Chairperson William Paty for their desire and vision to preserve Hawaii's unique natural resources, and for their support of the Natural Area Reserves System.

Michael G. Buck
Natural Area Reserves System Coordinator

HAWAII NATURAL AREA RESERVES SYSTEM

DEPARTMENT OF LAND AND NATURAL RESOURCES

LAUPAHOEHOE NATURAL AREA RESERVE MANAGEMENT PLAN

I. INTRODUCTIONI.

In 1970, Hawaii became one of the first states in the country to recognize the importance of its unique natural resources by establishing the State Natural Area Reserves System (NARS). The NARS is legally mandated to "preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaii" (HRS 195-1). To date, there are 18 reserves on 5 islands, occupying more than 108,000 acres of the state's most biologically diverse ecosystems.

Governor Waihee and the 1987 Legislature appropriated substantial new funding and legislative mandates to develop and implement management in the NARS. Directives were given to write comprehensive management plans for each reserve, based on the most current and relevant biological information available.

This plan describes the management program at the Laupahoehoe Natural Area Reserve, established in 1983 by Executive Order 3168. The Reserve contains examples of montane `ohi`a (Metrosideros polymorpha) and koa (Acacia koa) forest communities, grasslands, and small lakes, all which provide habitat for native birds and plant species. This plan consists of five parts:

- a brief **Introduction** to acquaint the reader with the project and how the plan was prepared;
- a **Resources Summary** describing the Reserve's natural resources;
- a **Management** plan describing programs recommended to maintain the Reserve's resources with an analysis of alternative actions and impacts;
- a **Budget Summary** listing the funds necessary to carry out the management plan; and
- **Appendices** describing resource information in more detail.

Three major sources of information were used to prepare this plan. The first was The Nature Conservancy's Hawaii Heritage database on rare species and unique natural communities. The second was a field inventory conducted in November 1988, specifically designed to collect data relevant to management of the Reserve's natural resources. The third was a review of this plan by qualified managers, planners, and biologists familiar with the area and its problems.

Survey crews spent 9 field days gathering data along 9 transects, ranging from 3,935 - 7,380 feet in length, and at 1 supplemental station (Figure 1). Transects sampled the range of natural vegetation types as described by J. D. Jacobi (1985) (Appendix 1). Detailed field forms were completed at sampling stations every 165 feet, noting the presence of natural communities, rare plants, native birds, feral ungulates, and weeds (Appendix 2).

This survey was designed to gather management-oriented resource information over a large area in a short time period, and was not intended to be a comprehensive biological inventory. Sampling of small mammals, birds, and invertebrates was incidental rather than systematic. Detailed survey methods are available upon request. A list of plant species currently known from the Reserve is in Appendix 3; a list of bird species is in Appendix 4.

This plan is intended to establish long-range goals and management priorities for Laupahoehoe Natural Area Reserve, and to describe specific programs and activities to be accomplished during the 1989-1991 biennium. This plan will be updated biannually to incorporate new knowledge and refine management concepts.

II. RESOURCES SUMMARY

A. General Setting

Laupahoehoe Natural Area Reserve occupies 7,894 acres in the North Hilo District above the Big Island's Hamakua Coast. Elevations range from 1,700 - 4,700 feet, and the wet forest vegetation reflects the area's windward exposure, which receives an average of 160 inches of rain per year (Giambelluca, Nullet, and Schroeder 1986). The adjacent Hakalau National Wildlife Refuge, administered by the U.S. Fish and Wildlife Service, forms the eastern boundary of the Reserve. Blair Road provides access along the Reserve's western boundary. The state-owned Hilo Forest Reserve forms Laupahoehoe Reserve's southern and western boundary; koa used to be logged from the forest reserve, just mauka of Laupahoehoe's upper boundary. Several streams cross

INSERT FIGURE
1. Survey Area.

the Reserve, including Kilau, Haakoa, Kaiwilahilahi, and Pahale. A public right-of-way exists through Hamakua Sugar Company lands which allows access into the lower Reserve at Kilau Stream.

B. Flora

The Laupahoehoe Reserve contains four native communities, as well as areas of non-native dominated vegetation. Koa/`ohi`a forest was observed to dominate the lowland area, and stretched up into the montane zone (above 3,000 feet elevation). `Ohi`a/hapu`u (Cibotium spp.) wet forest and Carex alligata wet grasslands were also seen in the Reserve's montane area (Figure 2). The forested communities contain rare plants and provide important forest bird habitat, though none of the communities is considered rare. Some mixed non-native tree plantings occur at the lower boundary of the Reserve and in the east corner, but do not form a significant portion of the Reserve and are not described here. Figure 2 was compiled from literature and survey information. Due to the limitations of small-scale mapping, only the general natural community pattern can be portrayed. Communities sampled along the transects are summarized in Appendix 1. Appendix 3 lists native and non-native plants known from the communities described here.

In the Laupahoehoe Reserve, Koa/`Ohi`a Montane Wet Forest was observed from the upper boundary down to about 3,000 feet elevation, where it graded into a lowland koa/`ohi`a wet forest, changing in subcanopy species composition (Figure 2). The trees in the montane area formed an open to closed canopy (about 100 feet in height) with a very well-developed subcanopy of tree ferns (Cibotium glaucum, C. chamissoi, and C. hawaiiense). Several large, emergent individuals of `ohi`a and koa were observed. Trees in the secondary tree layer included olapa (Cheirodendron trigynum ssp. trigynum), kawa`u (Ilex anomala), kolea (Myrsine lessertiana), and pilo (Coprosma rhynchocarpa and C. pubens). In the understory, native shrubs included `ohelo kau la`au (Vaccinium calycinum), `akala (Rubus hawaiensis), Cyrtandra spp., Clermontia parviflora, mamaki (Pipturus albidus), manono (Hedyotis terminalis), and saplings of `olapa, `ohi`a, pilo, and kawa`u. Ferns were often the prevalent ground cover, including Asplenium spp., Dryopteris wallichiana, akolea (Athyrium microphyllum), Ophioglossum pendulum var. falcatum, and Pleopeltis thunbergiana. Mosses were more abundant in areas with lighter pig damage, and were generally seen as epiphytes.

On the east side of the Reserve, a large patch of `Ohi`a/Hapu`u Montane Wet Forest between 3,500 and 4,500 feet elevation almost bisected the upper area of Koa/`Ohi`a Montane Wet Forest (Figure 2). A tall (approximately 80-foot) open to scattered canopy of `ohi`a with a secondary layer of native

INSERT FIGURE
2. Natural Communities.

trees such as olomea (Perrottetia sandwicensis), mehame (Antidesma platyphyllum var. platyphyllum), `olapa, and pilo grew over a variable tree fern layer composed largely of hapu`u. Under the hapu`u layer was a mix of native shrubs, such as manono, young `olapa, pilo, Cyrtandra spp., and Clermontia parviflora. Hoi`o (Athyrium sandwichianum) was the most abundant native fern, although Asplenium spp., Vandenboschia davallioides, wahine noho mauna (Adenophorus spp.), Elaphoglossum spp., and Pleopeltis thunbergiana were also present.

Much of the southeast portion of the Reserve is poorly drained, and several low-lying, very wet sections dominated by Carex alligata were observed during this survey. This community was often associated with standing water. Carex alligata often dominated the vegetation nearly to the exclusion of other species. Species from the surrounding natural communities, such as scattered `ohi`a, `olapa, and `ohelo kau la`au, were also present.

In the Reserve, the entire area below 3,000 feet was considered Koa/`Ohi`a Lowland Wet Forest. Under the 80-foot tall closed to open canopy of koa and `ohi`a, was a secondary tree

TABLE 1
NATURAL COMMUNITIESNATURAL COMMUNITIES OF LAUPAHOEHOE NATURAL AREA RESERVE

Natural Community	HHP Rank[1]	Acreage[2]
Carex alligata Montane Wet Grassland	3	+
Koa/`Ohi`a Lowland Wet Forest	3	2,921
Koa/`Ohi`a Montane Wet Forest	3	3,000
`Ohi`a/Hapu`u Montane Wet Forest	3	1,658
Non-native Dominated	E	316

[1] Key to Hawaii Heritage Program Ranks:
3 Restricted range (typically 21-100 occurrences globally)
E Exotic; non-native community

[2] Acreages are based on vegetation types mapped in Figure 2. Due to mapping and survey constraints, complex transitions between communities, or small patches of communities within others, are not accounted for.

+ Acreage too small or scattered to accurately measure

layer in which olomea, mehame, alani (Pelea clusiifolia), and kopiko (Psychotria hawaiiensis, varieties hawaiiensis and hillebrandii) were common. Other trees, such as `olapa and kawa`u were present, but not as common. Hapu`u was present, but of lower stature than in the montane koa/`ohi`a forest, and formed a discontinuous layer. Common shrubs included manono, pu`ahanui (Broussaisia arguta), `ohelo kau la`au, and saplings of kawa`u and `olapa. The vines `ie`ie (Freycinetia arborea) and maile (Alyxia oliviformis) were present, and `ie`ie was sometimes abundant. Native fern diversity was good, including wahine noho mauna, Lycopodium cernuum, Athyrium spp., Elaphoglossum spp., Odontosoria chinensis, and others.

At the lower edge of the Reserve, below 3,000 feet elevation, the understory of the Koa/`Ohi`a Lowland Wet Forest was heavily invaded by several non-native plants including strawberry guava (Psidium cattleianum), thimbleberry (Rubus rosifolius), and various grasses. One critically important weed seen in this area was Koster's curse (Clidemia hirta), which was observed at three locations along hunting trails below 2,800 feet (refer to the Management section for details on non-native plant threats to the Reserve). Forestry plantings along the lower boundary and in the east corner include non-native trees such as toon (Toona ciliata), Ficus rubiginosa, and tropical white ash (Fraxinus uhdei).

A total of 12 rare plant taxa have been reported from the Laupahoehoe Reserve. For the purposes of this management plan, a species is considered rare if it is known from 20 or fewer locations worldwide, or fewer than 3,000 individuals, or if it is listed as endangered. Due to changes in taxonomy, some taxa currently listed as candidate species in the most recent Federal Register may no longer be considered rare by the Hawaii Heritage Program, and their federal status is being reevaluated (Herbst pers. com.). Because many native plants lack unique Hawaiian or common names, scientific names are used throughout this section. Hawaiian names, where available, are provided in Table 2.

Of the 12 rare plant taxa seen within the Reserve, all were seen recently (since 1972), and 6 were observed during this November 1988 survey (Table 2). Two species of mint were observed during the survey. In Koa/`Ohi`a Montane Wet Forest, Stenogyne macrantha was seen between Kaiwilahilahi Stream and the Reserve's western boundary (Figure 3). This population is known from previous surveys to extend from 4,200 feet elevation down to 2,600 feet. This vine bears yellowish-green flowers in clusters, and is found in wet forests throughout the Big Island (Wagner et al. in press). The vines seen during the survey were not in flower or fruit.

The other mint taxon, Stenogyne scrophularioides, was seen

TABLE 2
RARE PLANTSRARE PLANTSRARE PLANTS OF LAUPAHOEHOE NATURAL AREA RESERVE

Scientific Name[1] **Former Name[2] (Common Name)**	**Current (Historic) Occurrences[3]**	**Federal Status[4]**	**HHP Rank[5]**
*Cyanea tritomantha (`oha, haha, `ohawai)	2(0)	C1	2
*Cyrtandra giffardii (ha`iwale, kanawao ke`oke`o)	1(0)	C2	1
Cyrtandra tintinnabula (ha`iwale, kanawao ke`oke`o)	2(0)	-	1
*Gardenia remyi (nanu, na`u)	1(0)	-	2
Huperzia mannii Lycopodium mannii (-)	1(0)	- C1	1
Joinvillea ascendens ssp. ascendens (`ohe)	1(0)	-	1
Phyllostegia floribunda P. floribunda var. forbesii (-)	3(0) C1	-	1
Phyllostegia longipes P. brevidens var. longipes (-)	2(0)	- C1	1
Phyllostegia vestita (-)	1(0)	-	2
*Platydesma remyi (-)	2(0)	C1	1
*Stenogyne macrantha (-)	1(0)	C1	2
*Stenogyne scrophularioides (-)	3(0)	C2	?

* Observed during 1988 survey.

[1] Wagner and Wagner (1987), Wagner et al. (in press)

[2] Following taxonomy used in 1985 Federal Register (USFWS)

[3] Current occurrences reported since 1972

[4] Key to Federal Status (USFWS 1985, 1987):
- C1 Candidate for endangered or threatened status
- C2 Candidate for endangered or threatened status, more data needed
- \- No federal status; described as rare by Hawaiian botanists and confirmed by Heritage data

[5] Key to Hawaii Heritage Program Ranks:
- 1 Critically imperilled globally (typically 1-5 occurrences)
- 2 Imperilled globally (typically 6-20 occurrences)
- ? No more than 100 occurrences globally; rank not yet determined by HHP

in two locations during the survey. The first population of 50-100 plants was observed near Kilau Stream in `Ohi`a/Hapu`u Montane Wet Forest. The second population was seen in Kaiwilahilahi Gulch in Koa/`Ohi`a Lowland Wet Forest, and consisted of several small patches of the vining mint bearing yellowish-green flowers in clusters. This taxon was previously known from only Mauna Loa and Mauna Kea (Wagner et al. in press).

Cyrtandra giffardii was observed during the survey near Kilau Stream in Koa/`Ohi`a Lowland Wet Forest. An estimated 30-80 individuals of this tree were seen along transects 1 and 2, some with small white flowers and some with white berries (Figure 3). This population is known to be very large from previous surveys, extending beyond the northwest boundary of the Reserve and south up to 3,800 feet. This is the only population known in the Laupahoehoe area; two other populations are known in the Kulani area of the Big Island (Wagner et al. in press).

Cyanea tritomantha was seen along Kaiwilahilahi Stream in Koa/`Ohi`a Lowland Wet Forest, and covering a large area along Kilau Stream (Figure 3). Two saplings of this palm-like tree with prickly leaves were seen, and some mature individuals bore clusters of purple or white flowers up to 3 inches long. This taxon is found on windward Mauna Kea and Mauna Loa and in Waipio Valley on the Big Island (Wagner et al. in press).

One Gardenia remyi tree of poor vigor was seen in Pahale Gulch in Koa/`Ohi`a Lowland Wet Forest (Figure 3). This tree generally bears fragrant white flowers, and is found on Kauai, Molokai, and Maui as well as the Hilo and Puna districts of the Big Island (Wagner et al. in press).

Two populations of Platydesma remyi were observed during the survey. One was near Kaiwilahilahi Stream and the other near Pahale Stream, both in Koa/`Ohi`a Lowland Wet Forest (Figure 3). The Pahale Stream population consisted of only one plant, while the other population is known from previous surveys to extend from 2,400 to 3,400 feet elevation. Neither population was flowering or fruiting at the time of the survey. This shrub bears small inconspicuous flowers, and is found throughout the Hamakua-Kohala area of the Big Island (Wagner et al. in press).

Six taxa within the Reserve were not seen during the survey: Cyrtandra tintinnabula, Huperzia mannii, Joinvillea ascendens ssp. ascendens, and three mint taxa: Phyllostegia floribunda, P. longipes, and P. vestita. All of these taxa were seen since 1977, and is it most likely that they still occur within the Reserve. Asplenium schizophyllum was seen outside the southwest boundary of the Reserve in 1937, and could be discovered in the Reserve during future surveys.

insert Figure
3. Rare Plants and Birds.

C. Fauna

Forest birds make up the native vertebrates known from Laupahoehoe Reserve. Common native forest birds were observed during the survey in all of the Reserve's vegetation types, but were most prevalent in closed-canopy forests of koa and `ohi`a. (Taxonomy used in this section follows the Checklist of the Birds of Hawaii by Pyle, 1988.) A complete list of bird species known from the Reserve area is in Appendix 4.

Most of the more common forest birds known from the Reserve area were seen during the survey. `Amakihi (Hemignathus virens virens), `Apapane (Himatione sanguinea sanguinea), `I`iwi (Vestiaria coccinea), `Oma`o (Myadestes obscurus), and `Elepaio (Chasiempis sandwichensis sandwichensis, recognized by Scott et al., 1986, as Chasiempis sandwichensis ridgwayi) were heard frequently in the Reserve's higher elevations and more intact forests. As has been observed before, `I`iwi, `Apapane and `Amakihi were seen feeding on flowers of the non-native banana poka (Passiflora mollissima). Mosquitos were abundant in the lower Reserve and ranged up to 3,300 feet elevation. Only the `Oma`o, `Elepaio, and occasional `Apapane were observed in the upper portion of the mosquito range.

Four native bird species, all listed endangered by the U.S. Fish and Wildlife Service, have been reported from the Reserve area (Table 3). Two of these, the Hawaiian Duck or Koloa maoli (Anas wyvilliana), and the Hawaiian Hawk or `Io (Buteo solitarius), were seen in the Reserve during this November 1988 survey on several transects, but no nests were observed. The two other species, Hawaii Creeper or `Alauahio (Oreomystis mana), and `Akiapola`au (Hemignathus munroi) were not observed during the survey, but have been sighted in or near the Reserve during the Hawaii Forest Bird Survey (Figure 3) (USFWS N.D. a, b). It is important to note that Hakalau Forest National Wildlife Refuge is adjacent to the southern tip of the Reserve where these species are seen regularly along with many other native species. The rare `Akepa (Loxops coccineus coccineus) is known from Hakalau, but has not been reported from the Reserve area.

During this November 1988 survey, off Transect 2, a Koloa was sighted flying from a pond east of Blair Road (Figure 3). Koloa have also been observed in 1983 and in 1981 breeding in stock ponds west of the Reserve near Keanakolu (DOFAW 1983). Koloa numbers declined dramatically early in this century and by 1949 were considered only visitors in the Big Island. Captive propagation and release have been successful and the Koloa has been reestablished in an area of at least 100 square miles from Hawi to Paauilo (USFWS 1978). All releases were in the Kohala Mountains until December 1980, when the Division of Forestry and Wildlife released 58 Koloa near the Wailuku River in the Hilo

watershed. Much of the Hilo Forest Reserve (which includes Laupahoehoe Reserve) has habitat suitable for Koloa (Paton 1981).

The `Io breeds only on the Big Island and is widely distributed. It is locally common on the slopes of Mauna Loa, on both the windward and Kona coasts, and to a lesser extent on Mauna Kea (USFWS 1984). Sightings of `Io were noted on both the northern and southern boundaries of the Reserve during the 1977 U.S. Fish and Wildlife Service Hawaii Forest Bird Survey, and observations also occurred numerous times adjacent to the Reserve (USFWS N.D. a, b). A nest with a young chick was observed in 1971 and 1979 in the vicinity of Keanakolu forestry cabin, several miles west of the Reserve (Griffin 1985). While `Io were seen during the November 1988 survey, no nests were observed.

TABLE 3
RARE BIRDSRARE BIRDSRARE BIRDS OF LAUPAHOEHOE NATURAL AREA RESERVE

Scientific Name (Common Name)	Population Estimate (Island of Hawaii)[1]	Federal Status[2]	HHP Rank[3]
*Anas wyvilliana (Koloa maoli, Hawaiian Duck)	NA	LE	1
*Buteo solitarius (`Io, Hawaiian Hawk)	1,400 - 2,500	LE	2
Hemignathus munroi (`Akiapola`au)	1,500 ± 400	LE	2
Oreomystis mana (`Alauahio, Hawaii Creeper)	12,500 ± 2,000	LE	3

---

* Observed during 1988 survey

[1] No recent count for Anas available; Buteo estimate is from USFWS 1984; Hemignathus and Oreomystis estimates birds/km^2 with a 95% confidence interval (Scott et al. 1986).

[2] Key to Federal Status (USFWS 1987):
LE Endangered

[3] Key to Hawaii Heritage Program Ranks:
1 Critically imperilled globally (fewer than 1,000 individuals)
2 Imperilled globally (typically 1,000-3000 individuals)

3 Restricted range (typically 3,000-10,000 individuals)

The Hawaii Creeper, or `Alauahio (Oreomystis mana), is known from the Big Island's Kona, Kau, and windward areas. One of Hawaii's more abundant endangered forest birds, it was observed in and around the Reserve several times during the 1977 USFWS Forest Bird Survey (USFWS N.D. a, b). Only in Kau and the windward areas are Hawaii Creepers found below 3,600 feet elevation; they tend to be most common above 4,921 feet (Scott et al. 1986).

The `Akiapola`au (Hemignathus munroi) exists only on the Big Island with its largest population on the windward side between 4,265 - 6,234 feet elevation (Scott et al. 1986). This species was seen during the USFWS Forest Bird Survey less than half a mile from the southern tip of the Reserve. It was also observed several miles west and south of the Reserve, and has been seen regularly in Hakalau Forest National Wildlife Refuge, adjacent to the Reserve's southern boundary (USFWS N.D. a, Scott et al. 1986).

Non-native birds observed during the survey included Hwamei (Garrulax canorus), Japanese White-eye (Zosterops japonicus), Red-billed Leiothrix (Leiothrix lutea), Northern Cardinal (Cardinalis cardinalis), Wild Turkey (Meleagris gallopavo), and Kalij Pheasant (Lophura leucomelana). The Hwamei, White-eye, and Leiothrix were distributed throughout the Reserve and noticed in all vegetation types, while the Kalij Pheasant and the Wild Turkey were noticed near Blair Road on the edge of koa/`ohi`a forest above 2,500 feet.

Spoor, scat and feeding damage of feral pigs were encountered on every transect, and several pigs were seen (Figure 4). No recent evidence of cattle was seen in the Reserve. A summary of damage and threats posed by these non-native mammals is discussed in the Ungulate Control program.

Native invertebrates, including several guilds of insects, spiders, and snails were observed in the Laupahoehoe Reserve during this survey. Where native vegetated communities were intact and most diverse, there was an observable parallel in invertebrate diversity. The potential for invertebrate research in the Reserve is great, and it is likely that undescribed species await discovery and description.

Non-native invertebrates were also observed in the Reserve. These were somewhat distributed by elevation and proximity to adjacent, non-native vegetation. Lower elevation portions of the Reserve (below about 3,000 feet elevation) were mosquito-infested. There was an apparent dearth of forest birds in the mosquito zone, despite closed-canopy koa/`ohi`a forest.

INSERT FIGURE
4. Threats Map.

Other non-native species were more widespread in the Reserve. Large flies associated with mammals (pigs and cattle) were observed at several locations in the Reserve, especially where pig damage was fresh and heavy. The predatory yellow-jacket wasp (Vespula sp.) was present, and along at least two of the lower altitude transects, very large numbers of foraging Vespula were encountered by the survey team. This aggressive predator poses a severe threat to native terrestrial invertebrates and may disrupt native insect pollinators, to the detriment of native plants. Other non-native threats to the Reserve are discussed in the Management section.

III. MANAGEMENT

The overall management goal is to protect and maintain the Reserve's native ecosystems. The following key considerations were included in the management programs developed to achieve this goal:

A. Key Management Considerations

1) At this time, it is not economically realistic to intensively manage the entire Reserve. Intensive management of key areas is proposed and priorities are based on the area's biological resources, the extent of current disturbance, the nature of other biological threats within and near the areas, and the feasibility of management (e.g. topography and access). Although a large reserve, Laupahoehoe is relatively accessible with an all-weather, four-wheel drive road on its western boundary, three hiking access routes into the lower reserve, and a road within a mile of the upper reserve.

2) Feral pig control is the number one management priority. Pigs are devastating the forest floor of the Reserve, dispersing weed seeds, and creating favorable conditions for weed establishment. They also are creating breeding conditions for mosquitos, which negatively affect native forest birds. Fluted roots on trees and soil pedestals are common with surface erosion occurring on sloping grounds throughout the Reserve. Many areas are down to bare rock with no plant growth at all. Plants such as Astelia and Lobeliads, favored by pigs, are only found as epiphytes or on steep slopes inaccessible to pigs.

3) Aggressive weeds are established within the Reserve and are spreading. Many of these weeds have become naturalized in Hawaii, and their total removal from the Reserve is not feasible. The best control strategy is maintenance of intact native forests through limitation of disturbance.

While feral pig control will assist this strategy, many weeds are spread by birds and people.

Manual and chemical weed control methods are costly and priorities for their use will be set by the nature of the weed, the value of the area it is invading, and the effectiveness of the control measure. Biocontrol is an important potential tool in the management of widespread priority weed species, and the NARS should support ongoing interagency biocontrol projects.

B. Management Unit Descriptions

The Reserve has been divided into three management units (Figure 5). Descriptions of each unit follow, with an outline of problems, key program features, and management priorities:

Upper Unit - This 2,763 acre unit, between 3,600 and 4,600 feet elevation, is dominated by large stature Koa/`Ohi`a Montane Wet Forest. It contains excellent forest bird habitat with rare plants found in the steep gullies. There is heavy pig disturbance in the forest understory, and banana poka is well established and spreading. Accessibility is limited to the western side via Blair Road. The unit has the highest priority for feral pig control.

Middle Unit - This 2,684 acre unit, between 2,800 and 3,600 feet elevation, has excellent koa/`ohi`a and `ohi`a forest communities. Good forest bird habitat exists in the unit's upper portions. Pig disturbance is heavy, and banana poka and strawberry guava are spreading from the upper and lower portions of the unit. Other weed invasion is light. Rare plants are found in steep gullies undisturbed by pigs. This unit has a high priority for feral pig control.

Lower Unit - This 2,447 acre unit, between 2,100 and 2,800 feet elevation, has a good koa/`ohi`a forest on the upper end of the unit. Native bird habitat seems marginal as a result of mosquitos. Non-native trees such as Ficus, strawberry guava, and tropical ash are well established and spreading in the lower portions of the unit. This unit is an important buffer zone for the rest of the Reserve, and public hunting is recommended for controlling pigs. The Reserve's northeast extension contains an old forestry planting area, and is excluded from management.

C. Management Programs

The following four management programs outline the long-term goals for the Reserve. A six-year implementation schedule is proposed. Although the programs are listed by priority, they fit together to form an integrated management package.

INSERT FIGURE
5. Management Units.

Priority #1: Ungulate ControlUngulate ControlUngulate Control Program (LAU-RM-01)

GOAL: Reduce the impact of ungulates to a level that prevents further degradation of the Reserve's native ecosystems, and allows the greatest possible recovery of the Reserve's native species.

Statement of the Problem: Heavy pig disturbance is occurring throughout the Reserve, and an aggressive control program is essential to maintain and enhance the Reserve's native ecosystems. Successful establishment of guava and banana poka in the Reserve has created additional food sources, increasing the carrying capacity for feral pigs. Public hunting success in the Reserve is excellent, thus negating the need for hunters to hike far from existing roads and trails. Hunting pressure in the lower reserve and upper adjoining forest lands has encouraged pigs to move into portions of the Reserve with minimal hunting pressure. This is resulting in increased distribution and establishment of noxious weeds in the Reserve.

Pig control fencing is feasible but would be expensive due to the Reserve's steep gulches and uneven terrain. There are three major streams in the Reserve, but they do not provide effective topographic barriers to pig movement. This is unfortunate as the Reserve is surrounded by forest lands from which pigs move freely into the Reserve from adjacent forest lands.

Alternative Actions and Probable Impacts:

1) No action. Accept the continuing deterioration of Laupahoehoe's forest watershed and native resources. Without control, pigs degrade native communities, which lowers biological diversity and increases non-native plant invasion.

2) Control pigs through increased hunting. Increase hunting pressure through better access and encouragement of public hunting, supplemented by staff hunting.

3) Control feral pigs with fences. Cost and maintenance of fencing will be high, due to the terrain and numerous streams which cross the Reserve.

4) Control ungulates with the aid of snares. Snaring has been proven to be an effective and inexpensive technique in similar control programs in Hawaii. Cost of equipment is relatively low compared to fencing.

Recommended Action: Alternatives #2 and #4 are recommended.

Because of the high population levels of pigs currently in the Reserve, pig control activities will focus on the reduction of the current population to remnant levels over the next six years. Fencing is not recommended during this time period as it would be expensive and its cost effectiveness uncertain, due to the Reserve's large size and lack of effective natural barriers. Funds would be better spent on an aggressive hunting and snaring program to reduce the pig population to remnant levels in key portions of the Reserve.

Snaring should be used in the Reserve's remote sections and more widely after hunting decreases pig populations. Fencing at a later date may be required to maintain a low number of pigs. Monitoring native vegetation recovery, spread of priority weeds, and movement of pigs into the Reserve from adjacent forest lands will be an essential component of the pig control program.

Public hunting will be encouraged in the Lower Unit. Existing access trails will be improved and maintained. New trails will be built. The upper two units, which are little used by the public at present, will be posted and a deputy hunting system using public hunters will be employed. The deputy hunters will receive training, logistical support, and other incentives to assist staff in conducting an intensive pig control program using snaring and hunting. A management trail system will be established and maintained to allow easy access into remote portions of the Reserve (Figure 6). A helipad and management shelter are recommended for the Upper management unit.

Cost/Workload: The following resources will be needed to conduct the improved access and shelter construction project:

Improved Access: Approximately 24 miles of trails will be established and/or maintained. These trails will not be developed as recreational hiking trails but flagged and cleared as management trails to aid hunters and management staff within the Reserve. The proposed helipad and management shelter will be built to aid management staff in emergency and overnight work in the remote south corner of the Upper management unit.

Year 1 -	Establish Public Access Trail(2.0 mi.)	$4,000
	Establish Pahale Trail (5.5 mi.)	8,250
	Establish Helipad	3,000
	Total	**$15,250**
Year 2 -	Build Management Shelter	$15,000
	Establish Upper Contour Trail (2.2 mi.)	4,400
	Establish Kilau Trail (3.6 mi.)	5,400
	Maintenance	1,000
	Total	**$25,800**

Insert Figure
6. Trails and Shelters. . Trails and Shelters

Year 3 -	Establish Kaiwilahilahi Trail (4.0 mi.)		6,000
	Establish Middle Contour Trail(2.2 mi.)		4,400
	Maintenance		2,000
		Total	**$12,400**
Year 4 -	Establish Lower Contour Trail (2.8 mi.)		5,600
	Maintenance		2,500
		Total	**$ 8,100**
Year 5-6	Maintenance	**Total**	**$ 3,000**

Costs are based $2,000 per mile for contour trail establishment and $1,500 per mile for other trail establishment, $100 per mile per year for trail maintenance, $3,000 for helipad establishment and $200 per helipad per year for maintenance, and $15,000 for shelter establishment and $400 per year per shelter for maintenance. The majority of this work can be done on contract supplemented with the use of volunteers.

Cost/Workload: The following resources will be needed for the pig control project:

Pig Control: Pig removal activities in year 1 will consist of 20 days of staff hunting (2-person crew), 20 days of special hunts for the general public (2-person crew), and 50 days of deputy hunting (2-person crew). Years 2 - 6 will be similar to year 1, with an additional 500 acres set with snares each year.

Year 1:	Personnel - Res. Manager 20 Person Days (PD)		1,700
	Technician 60 PD		4,200
	Supplies and Support		7,000
		Total	**$12,900**
Year 2:	Personnel - Res. Manager 20 PD		1,700
	Technician 78 PD		5,460
	Supplies and Support		8,200
		Total	**$15,360**
Year 3:	Personnel - Res. Manager 20 PD		1,700
	Technician 96 PD		6,720
	Supplies and Support		9,400
		Total	**$17,820**
Year 4:	Personnel - Res. Manager 20 PD		1,700
	Technician 114 PD		7,980
	Supplies and Support		10,600
		Total	**$20,280**

Year 5:	Personnel - Res. Manager 20 PD		1,700
	Technician 132 PD		9,240
	Supplies and Support		11,800
		Total	**$22,740**
Year 6:	Personnel - Res. Manager 20 PD		1,700
	Technician 150 PD		10,500
	Supplies and Support		13,000
		Total	**$25,200**

Costs are based on a two-person crew able to establish 50 snares per day or check 200 snares per day. Snares ($6 each) will be replaced every year and inspected five times a year. Snaring densities will be approximately 100 snares for every 250 acres within the management units. Supplies and support for a two-person crew for staff and deputy hunting (dogs, ammunition, etc.) are estimated at $100 per day. Salaries are $85 per day for a reserve manager and $70 per day for technicians.

Priority #2: Non-native Plant ControlNon-native Plant ControlNon-native Plant Control Program (LAU-RM-02)

GOAL: To limit the spread and, where feasible, eradicate non-native plant species that are or may become invasive weeds in the Reserve.

Statement of the Problem: Weeds that are known to be invasive and disruptive to the Reserve's native ecosystems are considered priority weeds for management. Several of these weeds are too abundant to attempt reserve-wide manual or chemical control. Biocontrol may be the only hope for controlling or eradicating banana poka (Passiflora mollissima), Melastoma candidum, guava (Psidium guajava) and strawberry guava (Psidium cattleianum), and various grasses.

The spread of non-native plants in the Reserve has been accelerated by seed dispersal and forest floor disturbance by feral pigs. Even when pig populations are reduced, the spread of weeds will continue by birds, rats, and people. Banana poka is well established in the koa logging area and has spread into the Reserve down to 3,600 feet elevation. Strawberry guava is well established in the lower Reserve and extends up to 3,100 feet elevation. Ficus trees are also spreading in the lower Reserve, especially in windthrow areas. Hilo grass (Paspalum conjugatum) has taken over the understory in many parts of the lower Reserve. Other noxious weeds such as Himalayan golden raspberry (Rubus ellipticus var. obcordatus), blackberry (R. argutus), and palm grass (Setaria palmifolia) were found along Blair Road. Two patches of Koster's curse, an extremely invasive weed, were found along hunting trails in the lower Reserve and subsequently removed.

All of these weed species have demonstrated the capability to displace native vegetation over large areas in other forest areas in the state. Without biological control, the complete removal of many of these weeds is not feasible. The resiliency and vigor of the native trees and tree fern canopy is currently saving the Reserve from an even larger spread of noxious weeds. The windthrow areas in the lower Reserve demonstrate how quickly the forest can become invaded by weeds once major canopy openings occur.

Alternative Actions and Probable Impacts:

1) Do not control spread of non-native plants. Native communities will become deteriorated as weeds invade and choke out native plants. Pigs, birds, and people will continue to disperse weed seeds.

2) Control pigs, but do not attempt to control any priority weeds. This will reduce the spread of many ungulate-dispersed plant species, but will allow continued spread of plants by birds and people. Decreased rooting and disturbance to the forest floor by pigs will slow down establishment of many non-native plants, but already established plants may continue to spread unchecked. A few especially aggressive weeds could overwhelm large areas.

3) Control certain priority weeds before they become widely established. Set up monitoring transects to locate other incipient populations of priority weed species. Management measures would include selective use of approved herbicides and manual removal with hand tools.

Recommended Action: Alternative #3 is recommended. Once pig control activities have begun, the rate and spread of the well-established priority weeds (banana poka, strawberry guava, Hilo grass) will be monitored. Interagency biological control programs will be supported by providing research sites and lobbying when appropriate.

Incipient populations of certain priority weeds, such as Himalayan raspberry, blackberry, Tibouchina, and Clidemia will be removed when found in the Reserve. Monitoring staff will be trained to identify other priority weeds known to be in and adjacent to the Reserve. Large Ficus trees will be girdled. All management trails and access routes into the Reserve will be regularly checked for these species. Signs at trail heads will be posted informing the public of these threats. Strict sanitary procedures will be established to avoid weed seeds spread by management staff on their equipment and vehicles.

Cost/Workload:

Year 1 - Personnel	- Res. Manager 10 PD		$ 850
	Technician 60 PD		4,200
Supplies and support			$ 8,000
		Total	**$13,050**
Year 2-6 same as Year 1		**Total**	**$13,050**

Salaries are $85 a day for Reserve manager and $70 a day for technicians. Supplies and support include hand tools, herbicides, and logistical support for volunteer labor.

Priority #3 - MonitoringMonitoringMonitoring Program (LAU-RM-03)

GOAL: Monitor the effectiveness of management projects and track significant ecological changes through long-term scientific monitoring.

Statement of the Problem: Management activities may not always achieve desirable results, and management efficiency needs to be judged. Monitoring changes in non-native and native plant distribution and animal species abundance entails recording specific data at permanent points and transects in the Reserve. Monitoring also documents progress and facilitates refinement of management techniques employed in the Reserve.

Alternative Actions and Probable Impacts:

1) No monitoring program. This could lead to inefficient management resulting from poor understanding of the area's biological needs.

2) Conduct ad hoc monitoring whenever possible. This is likely to be considerably less effective in the long run than a systematic approach.

3) Establish systematic monitoring programs for ungulate damage, non-native weed invasion, native vegetation recovery, and status of rare species. Increase monitoring intensity for select problems and areas as needed.

Recommended Action: Alternative #3 is recommended. Develop monitoring programs to evaluate effects of management activities and identify future management needs. Many transects will require a two-person crew for safety. Two-person monitoring crews may be dropped off by helicopter in remote areas, take data at established monitoring points, and hike out. Specific goals of the program are to determine: 1) the effectiveness of staff and public hunting in reducing ungulate damage; 2) the success of

priority weed species control; 3) the location of incipient populations of other priority weeds; and 4) the status of known rare species. Some monitoring activities will be done in conjunction with fence inspection.

Cost/Workload: The following resources will be needed to conduct the monitoring project:

Year 1 - Personnel	- Res. Manager 20 PD		$ 1,700
	Technician 20 PD		1,400
	Helicopter (2 trips and reconnaissance)		1,100
	Supplies and support		$ 6,000
		Total	**$10,200**
Year 2-6 same as Year 1		**Total**	**$10,200**

Salaries are $85 a day for Reserve manager and $70 a day for technicians. Supplies and support include film and development, software development, and office supplies.

Priority #4 - Public Education and Volunteer SupportPublic Education and Volunteer SupportPublic Education and Volunteer Support Program (LAU-RM-04)

GOAL: To build public understanding and support for the Reserve and the NARS in the local community. Educational opportunities will be provided for interested groups. Volunteer labor to help staff in management activities will be procured.

Statement of the Problem: The population of the Big Island is increasing. In light of this development, there is strong public sentiment to conserve what is left of the native Hawaiian heritage, but also an increased consumptive demand to utilize natural resources. Many Big Island residents are unaware of Hawaii's natural heritage and the Laupahoehoe Reserve. Even fewer realize that native resources and the benefits they provide are being threatened. Management of this Reserve will be a long-term effort, and public support and involvement is necessary.

Feral ungulate control is an emotional issue on the Big Island, especially after the Mauna Kea Palila/feral sheep controversy. The pig control program for Laupahoehoe Reserve, through its deputy hunters, is designed to directly involve public hunters in Reserve management activities and represents an important opportunity for public education and cooperation.

Other volunteer groups have proven successful in certain natural area management activities, especially in labor-intensive efforts such as fence construction, weed control, and trail

maintenance. These groups tend to be extremely motivated, representing a valuable resource for the reserve manager.

Alternative Actions and Probable Impacts:

1) Do not attempt to inform the general public about resources protected in the Reserve or explain reasons for specific management actions. Do not use volunteer groups in relevant management activities. The results of this alternative could include less public and legislative support for the NARS, misunderstanding among certain groups resulting in vandalism of capital improvements, and increased costs for overall NARS management, especially in plant control work.

2) Maintain community outreach program to give public presentations, provide informational material, and utilize concerned volunteer groups. This could result in cooperation with the general public in feral pig and non-native plant control programs and result in less expensive yet more effective management results. It could also provide a local constituency that would support Reserve management activities.

Recommended Action: Alternative #2 is recommended. Inform the general public about resources within the Reserve and management activities through television, newspaper, and other local media outlets. Present slide shows and talks to community groups.

Utilize deputy hunters for pig control and other volunteer groups for trail maintenance and weed control activities in the Reserve. Reserve staff hours will be adjusted so personnel are available to supervise volunteer work groups, especially on weekends. Eventually, leaders from volunteer groups can be trained to supervise volunteer crews.

Cost/Workload:

Year 1 -	Personnel -	Res. Manager 20 PD	$ 1,700
		Technician 20 PD	1,400
	Supplies and support		$ 1,000
		Total	**$ 4,100**
Year 2 -	Personnel -	Res. Manager 10 PD	$ 850
		Technician 20 PD	1,400
	Supplies and support		$ 1,000
		Total	**$ 3,250**
Year 3-6	Same as year 2	**Total**	**$ 3,250**

D. Boundary Administration and Special UsesD. Boundary Administration and Special UsesD. Boundary Administration and Special Uses

Participation and cooperation among all adjacent landowners is an important factor for effective management of the Laupahoehoe Reserve. Ingress of feral pigs and priority weeds from adjacent forest lands is a management concern. A cooperative management program to reduce feral pig densities should be established with the U.S. Fish and Wildlife Service's Hakalau Refuge, which is the Reserve's neighbor to the east. Any management activity in the Hilo Forest Reserve that reduces feral pig populations and spread of priority weeds should be supported.

The northeastern corner (approximately 100 acres) of the Reserve is dominated by non-native tree species as a result of planting initiatives by the State Division of Forestry and Wildlife (DOFAW). The trees are now harvestable size. It is recommended that DOFAW continue to manage this area as a forest plantation. The area is small, on the Reserve boundary, and is not important to the Reserve's management objectives. Reserve management could benefit from improved access through this area.

The Na Ala Hele program offers an excellent vehicle to formalize certain key access routes, and NARS staff should work closely with this trails and access program.

IV. BUDGET SUMMARY

When this plan was prepared, the long-term funding and organizational structure of the NARS had not been settled. Coordination and implementation of priority projects among the 18 reserves may be affected by future organizational and funding decisions. This may require some revision in the priority projects described here.

A six-year implementation schedule is presented to accomplish management goals as efficiently as possible. Four management programs are proposed to achieve this. Although listed by priority, they build upon each other to form an integrated strategy.

The budget summary is based on a NARS integrated within the Division of Forestry and Wildlife. The budget summary shown is for the management of the Laupahoehoe Reserve only. It does not include all the administrative, clerical, and facility support needed to run a state-wide NARS or to manage the other seven Natural Area Reserves on the island of Hawaii. These infrastructure costs for the NARS will be identified and

documented separately.

Expenses for purchase, operation and maintenance of one 4-wheel drive vehicles with a mobile radio and two portable radios are included in program LAU-OP-01. Starting with year 3, an 1 percent inflation increase is incorporated into each yearly total.

BUDGET SUMMARY
LAUPAHOEHOE NATURAL AREA RESERVE

PROGRAM	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6
LAU-RM-01	28,200	41,200	30,200	28,400	25,700	28,200
LAU-RM-02	13,100	13,100	13,100	13,100	13,100	13,100
LAU-RM-03	10,200	10,200	10,200	10,200	10,200	10,200
LAU-RM-04	4,100	3,250	3,250	3,250	3,250	3,250
LAU-OP-01	40,000	5,000	5,000	5,000	5,000	5,000
TOTAL ($)	**95,600**	**72,800**	**62,400**	**61,100**	**59,000**	**62,100**

MANAGEMENT PROGRAMS
LAU-RM-01 - Ungulate Control (Priority 1)
LAU-RM-02 - Non-native Plant Control (Priority 2)
LAU-RM-03 - Monitoring (Priority 3)
LAU-RM-04 - Public Education and Volunteer Support(Priority 4)
LAU-OP-01 - Infrastructure Expenses

PERSONNEL (PD = person days)

YR 1 - Reserve manager	70 PD	YR 4 - Reserve manager	60 PD
Technician	160 PD	Technician	214 PD
YR 2 - Reserve manager	60 PD	YR 5 - Reserve manager	60 PD
Technician	178 PD	Technician	232 PD
YR 3 - Reserve manager	60 PD	YR 6 - Reserve manager	60 PD
Technician	196 PD	Technician	250 PD

V. SOURCES

Cuddihy, L. W., J. A. Davis, and S. J. Anderson. 1982. A Botanical Survey of the Proposed Laupahoehoe Natural Area Reserve, Hawaii. Endangered Plant Species Program. Division of Forestry and Wildlife, Department of Land and Natural Resources, Hilo, Hawaii.

Division of Forestry and Wildlife. N.D. Endangered Plant Species Program. Department of Land and Natural Resources, Hilo, Hawaii.

Division of Forestry and Wildlife. 1983. (1) Abundance and Distribution of Koloa on Island of Hawaii. (2) Movements, Survival, Reproductive Success and Habitat of Koloa on the Island of Hawaii. Project # W-18-R-8. Job # R-III-H. July 1, 1981 to July 31, 1983.

Giambelluca, T. W., M. A. Nullet, and T. A. Schroeder. 1986. Rainfall Atlas of Hawaii. Water Resources Research Center/Department of Meteorology, University of Hawaii at Manoa. State of Hawaii, DLNR, Division of Water and Land Development, Report R76. Honolulu, Hawaii.

Griffin, C. R. 1985. Biology of the Hawaiian Hawk Buteo solitarius. Thesis. University of Missouri-Columbia.

Herbst, D. V. Personal Communications, June 1988. Endangered Species Botanist, Office of Environmental Services. U.S. Fish and Wildlife Service, 300 Ala Moana Blvd., #6307, Honolulu, Hawaii 96850.

Jacobi, J. D. 1985. Vegetation Maps of the Upland Plant Communities on the Islands of Hawaii, Maui, Molokai, and Lanai. U.S. Fish and Wildlife Service. Mauna Loa Field Station. Volcano, Hawaii.

Paton, P. W. C. 1981. The Koloa (Hawaiian Duck) on the Island of Hawaii. `Elepaio 41(12):131-133.

Pyle, R. L. 1988. Checklist of the Birds of Hawaii--1988, in: `Elepaio 48 (11): 95-106.

Scott, M. J., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest Bird Communities of the Hawaiian Islands: Their Dynamics, Ecology, and Conservation. Studies in Avian Biology No. 9, Cooper Ornithological Society. Allen Press, Lawrence, Kansas.

State of Hawaii. Hawaii Revised Statutes, Chapter 195-1.

U.S. Fish and Wildlife Service. N.D.a. Computerized Data from USFWS Forest Bird Surveys.

U.S. Fish and Wildlife Service. N.D.b. USFWS Incidental Sightings, Hamakua, Hawaii.

U.S. Fish and Wildlife Service. 1978. Hawaiian Waterbirds Recovery Plan. USFWS, Portland, Oregon.

U.S. Fish and Wildlife Service. 1984. Hawaiian Hawk Recovery Plan. Prepared under contract with C. R. Griffin. USFWS, Portland, Oregon.

U.S. Fish and Wildlife Service. 1985. Endangered and Threatened Wildlife and Plants; Review of Plant Taxa for Listing as Endangered or Threatened Species; Notice of Review. Federal Register. 50 CFR Part 17. Vol. 50, No. 188. Department of the Interior. U.S. Government Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 1987. Endangered and Threatened Wildlife and Plants. 50 CFR 17.11 & 17.12. U.S. Government Printing Office, Washington, D.C.

Wagner, W. H. Jr. and F. S. Wagner. 1987. Revised Checklist and Key to Hawaiian Pteridophytes. Unpublished.

Wagner, W. L., D. R. Herbst and S. H. Sohmer. In Press. Manual of the Flowering Plants of Hawaii. Bishop Museum Press, Honolulu, Hawaii.