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Technical Report 110

KAʻUHAKO CRATER BOTANICAL RESOURCE AND THREAT MONITORING, KALAUPAPA NATIONAL HISTORICAL PARK, ISLAND OF MOLOKAʻI, HAWAIʻI

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Cooperative Agreement
NPS CA 8023-2-9004

December 1996

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1. EXECUTIVE SUMMARY

Botanical monitoring of the remnant dryland forest of Ka'uhako Crater on July 11 - July 14, 1995 grew out of a desire to provide baseline data on the vegetation components of the crater prior to fencing and removal of feral ungulates, primarily axis deer (Axis axis) and feral pigs (Sus scrofa). The exclusion of ungulates, identified as damaging to the crater's native flora in the Kalaupapa National Historical Park Resource Management Plan (NHPRMP) (1994), was proposed in a Draft Environmental Assessment prepared by Larry Katahira (1995) through the construction of two miles of feral animal proof fence outside the crater's rim.

Ka'uhako Crater, designated as a Special Ecological Area in the Kalaupapa NHPRMP (1994) , contains one of the finest examples of low elevation windward dryland forest remaining on the island of Moloka'i and the entire state of Hawai'i. Although previous botanical surveys have examined the flora of Ka'uhako Crater (Linney 1987; Asherman et al. 1990), none had established any permanent monitoring plots to document the inevitable changes which will follow the removal of browsing herbivores. This system of permanent monitoring was established in 1995 by utilizing the three key native trees of Ka'uhako Crater, *Wiliwili* (Erythrina), *'Ohe makai* (Reynoldsia), and *Hala pepe* (Pleomele), as the centers of circular cover plots that document every plant taxa on both the ground and in the canopy. Future monitoring and data acquisition in these plots will not only record the transitions in cover composition, but will also help identify potentially damaging alien plants that threaten the recovery of the native components. In addition, vital statistics recorded for a representative sample of each of the three key native trees will provide an overall picture of the health and status of the remnant dryland forest and will help steer management decisions necessary in implementing future restoration processes for these trees and the associated native flora.

As part of the monitoring protocol, other threats and potential problems in the preservation of the crater's native flora, from the detrimental effects of the two-spotted leafhopper (Sophonia rufofascia) on native taxa to the lack of seedling recruitment for many of the native species, have been identified, and their implications to the long term survival of the dryland ecosystem have been addressed. Furthermore, future management concerns, such as the increased threat of wildland fire associated with an accumulation in fuel biomass following exclusion of feral ungulates, are predicted to become a greater priority with the passage of time, and, depending upon the future establishment and spread of certain alien grasses, may supersede all other management considerations. Early identification of these and other problems may help managers to address the situations at a stage when response efforts are still practical and feasible.

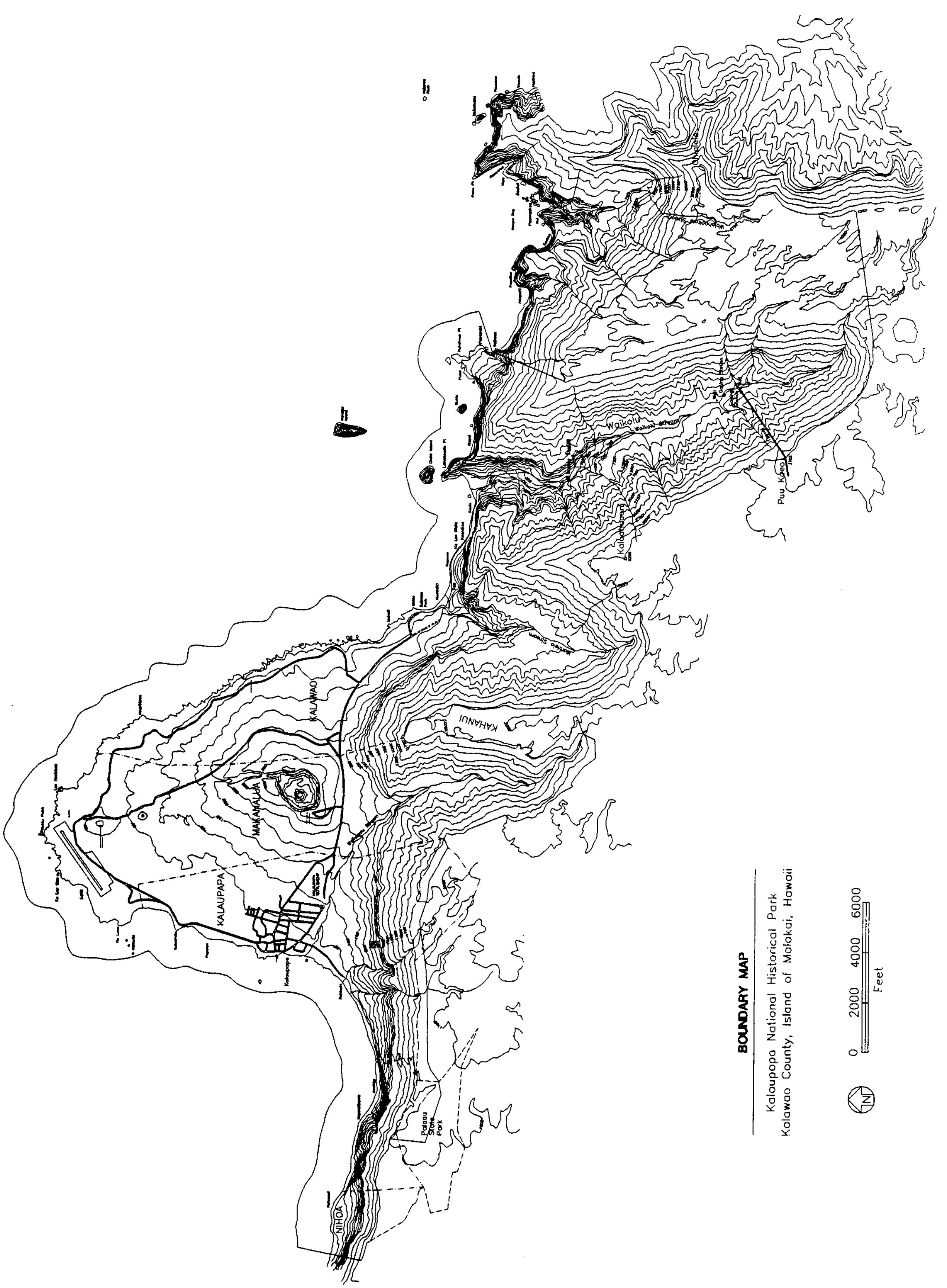


Figure 1: Kalaupapa National Historical Park

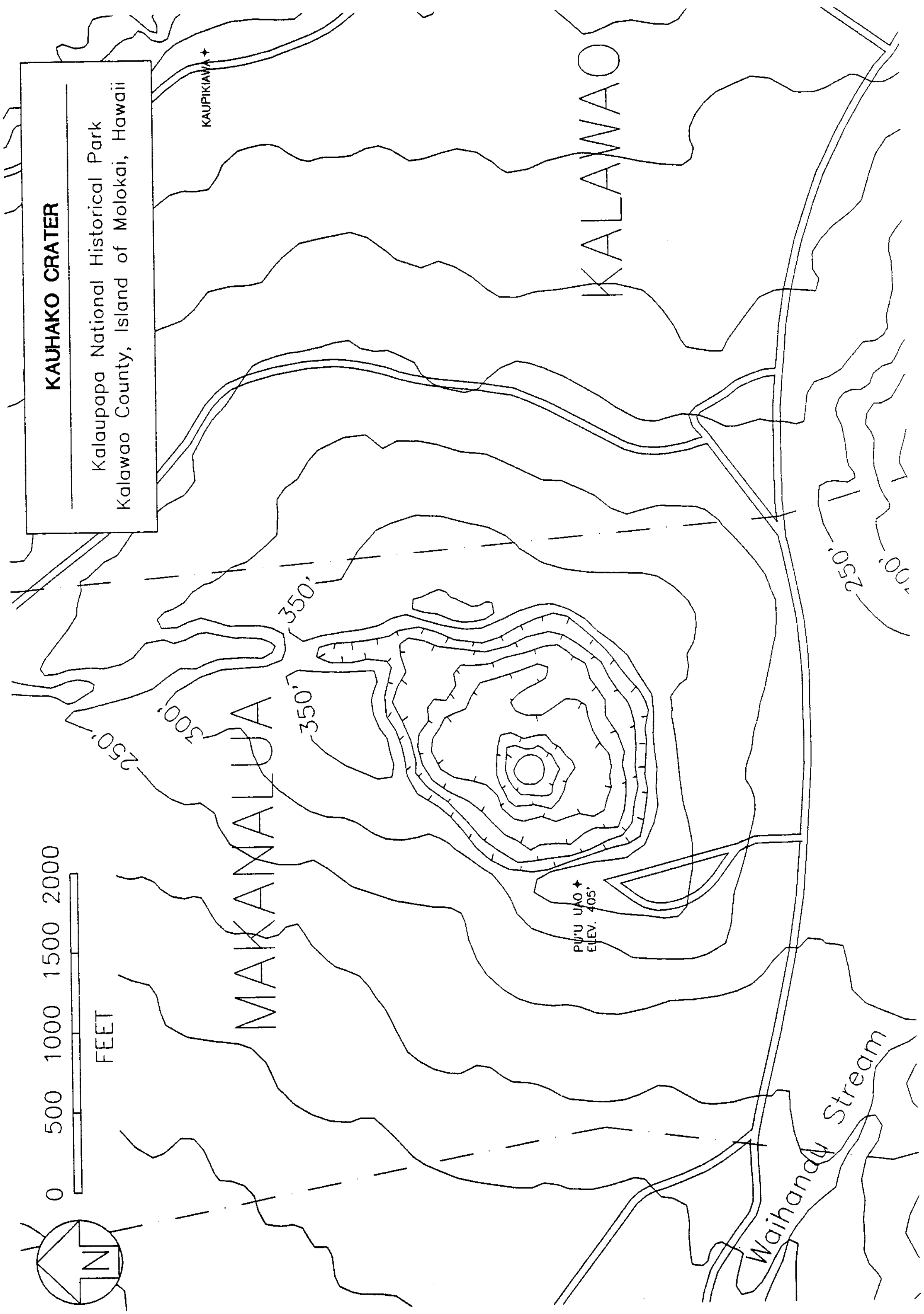


Figure 2: Close-up of Ka‘uhako Crater

2. RESOURCE ASSESSMENT

2.A. GENERAL SETTING

Ka'uhako Crater, centered at latitude 21° 13' 21" N and longitude 156° 58' 07" W, is located on Kalaupapa Peninsula, on the north shore of the island of Moloka'i (Figure 1). The crater, 123 meters (404 feet) at its highest point and 137 meters (449 feet) deep, is somewhat ovate in shape, 600 meters (1969 feet) long by 430 meters (1410 feet wide), with the long axis oriented northeast-southwest (Linney 1987). A pit crater, about 100 meters (328 feet) in diameter and 30 meters (98 feet) deep, is located in the approximate center of Ka'uhako Crater, and, being below sea level, is full of brackish water. A large, collapsed lava tube, about 30 meters (98 feet) deep in places and almost as wide, breaches Ka'uhako Crater in the northwest portion, and continues northward for another 1.7 km (1.06 miles). On the crater floor, at the start of the lava tube, is a smaller pit crater, 10 meters (33 feet) wide by no more than 30 meters (98 feet) deep, surrounded by trees and other vegetation, especially the abundant bird's nest fern or *'Ekaha* (Asplenium nidus).

Mean annual rainfall for Kalaupapa Peninsula is approximately 1000 mm per year, with the heaviest rainfall occurring from December to March and the driest periods occurring from June through December (Giambelluca et al. 1986). Although located on the windward side of Moloka'i, Kalaupapa Peninsula's mean annual rainfall is similar to that of the south slope of Haleakala on the island of Maui, a region containing many of the same dryland forest elements as those found in Ka'uhako Crater.

2.B. FLORA

2.B.1 OVERVIEW

Of greatest biological interest and significance in Ka'uhako Crater is the remnant *'Ohe makai-Hala pepe* (Reynoldsia-Pleomele) forest on the southwest inner slopes, as well as the stands of large *Wiliwili* (Erythrina) trees interspersed with additional *'Ohe makai* trees on the crater floor at the base of the aforementioned forest. Due to the large stature of many trees in this area, as well as their localized abundance, this locale represents one of the finer examples of dryland forest remaining on Moloka'i or elsewhere in the Hawai'ian Islands. As Linney (1987) states, this forest "is of such significance as to be unexcelled elsewhere in Hawai'i." For this reason, this area was chosen as the focus of a more intensive monitoring of the three dominant native tree species and their associated communities to assess and help predict the overall health of the populations. In the process, current and future potential problems to the viability of these populations were identified. In addition, the data taken will provide a baseline to document future changes following the exclusion of feral herbivores from the crater.

The most intensive monitoring of the crater's vegetation occurred, as previously stated, in the remnant southwestern *'Ohe makai-Hala pepe* forest and *Wiliwili* forest of the crater floor. A cursory survey of the remaining sections of the crater was performed and significant botanical resources and threats were identified as deemed appropriate. As the outer slopes of the crater were previously surveyed by Linney (1987), further intensive investigation of these areas was not warranted for this study.

Description of Plant Communities

The following descriptions of Ka'uhako Crater's plant communities roughly follow the designations of Linney (1987), as these communities did not appear to have changed significantly. As he states in his report, "a number of different plant communities could be distinguished, based on their major (or dominant) component species and physiognomy." However, changes in the compositions and ranges of these communities should be followed closely in the future as axis deer (Axis axis), possibly the key factor in maintaining the present status quo, and feral pigs (Sus scrofa) are excluded through fencing.

Casuarina (ironwood) Forest: Linney (1987) states that this is "only a small clump of trees, perhaps a hectare in size" and that it "is restricted to the summit area in the southwest, extending part way down the adjacent inner slope." Although the size of this community was not measured in the July 1995 survey, it appears that the area occupied has probably increased in area over the eight year period. Ironwood has not, however, extended its range appreciably beyond the southwest portion of the crater. Linney (1987) further states that "little grows beneath the trees, where the shade is quite deep, and a layer of 'needles' covers the ground to a depth of a decimeter or more. There is no real understory." Based on observations and data recorded in cover plots immediately below the ironwood stand, this litter comprises a significant portion of the ground cover and obviously plays an important role in the suppression of seedling recruitment in the understory. In effect, ironwood is displacing the upper margins of the *'Ohe makai-Hala pepe* forest.

Scaevola (*Naupaka*) Mixed Herb Prairie: This region was not thoroughly explored in July 1995, but Linney (1987) states that "this association is characteristic of the outer slope in the northwest sector" with "*Naupaka*...the most obvious component" growing in association with "an assortment of grasses, hedges, herbs, forbs, and stunted shrubs co-mixed."

Lantana Scrub With Dwarf Forest: This area on the outskirts of the crater was not explored in July 1995, but Linney (1987) describes this community as occupying the "outer slope in the northeast quadrant" with "much of the ground...covered with a lantana scrub of less than one meter height." Other components of this area include Schinus and guava trees interspersed among the lantana, with some *Wiliwili* (Erythrina) and *Alahe'e* (Psydrax) scattered throughout. Future monitoring or restoration efforts in this region are of lower priority than communities of higher native biological diversity,

Roadside Weeds: As Linney (1987) states, "this community contains a large number of weeds not found elsewhere on the site" which, although aggressive in establishing in disturbed areas, would probably be supplanted by other vegetation upon removal of the source or sources of disturbance.

'Ohe makai-Hala pepe Remnant Forest: This open canopy forest, located on the inner slope of the southwest portion of the crater, contains the finest example of native vegetation in the immediate area. Relatively large statured *'Ohe makai* (Reynoldsia) and *Hala pepe* (Pleomele) trees occupy the scree slopes down to the crater floor where they give way to a higher canopy forest of large *Wiliwili* (Erythrina) and *'Ohe makai* trees intermixed with large Java plum (Syzygium cumini) trees. Monitoring of native tree species in this area was most intense and focused on the vigor of tagged individuals and the compositions of the surrounding communities. Other items of interest bordering this remnant forest include a few native plants conspicuous due to their absence in other areas of the crater. These include two medium statured *Lama* (Diospyros) trees, four *'Alahe'e* (Psydrax) trees and one previously undocumented shrub of *Kolomona* (Senna gaudichaudii), all of which have been tagged to document changes in their long term vigor and status.

Java plum-Schinus Forest: Linney (1987) states that "this is the only community of true forest-stature. The two dominants are mutually exclusive to a great extent, giving the forest a patchy appearance, rather than mixed in any uniform way." The areas dominated by Schinus are practically impenetrable, with dense growth reaching a height of over four meters in height. In areas where Java plum predominates, the trees form an almost unbroken canopy of up to 10 meters height, but several extremely large *Wiliwili* trees also occur throughout the crater floor. Some large *'Ohe makai* trees also spill over from the remnant native forest of the scree slopes, but are less common. Smaller statured Java plum, Schinus, and guava trees make up the predominantly non-native understory. The ground cover is mostly barren soil and rock, although small plants of lantana, Solanum seaforthianum, Senna pendula, and Ficus microcarpa are locally common with seedlings of Java plum, Schinus, *Wiliwili*, *'Ohe makai*, and guava. Axis deer scat were widespread and common throughout the crater floor region. Linney (1987) comments that "in the vicinity of the lavatube, *Kukui* is locally sub-dominant with breadfruit" and "Mauritius hemp and birdnest fern constitute the understory around the pit crater and the origin of the lavatube."

Lantana-Digitaria inularis Thicket: Linney (1987) states "on the inner slopes where there is soil, these two plants predominate in small patches. In several areas Mauritius hemp is co-mixed, and guava is occasional. Little grows beneath these plants, which themselves approach three meters in height." Due to its lack of native diversity and unpromising nature in regards to future restoration or management efforts, this area was not extensively explored in July 1995.

In summary, Ka'uhako Crater and the surrounding environs contain a total of 134 species of vascular plants including 13 species of pteridophytes and 121 species of flowering plants (Appendix 1). Over 71% of the species listed for this area, some 96 species, are introductions by man. Indigenous species account for almost 18% of all taxa; endemic species for just over 10%. Due to herbivory and seasonal aridity, there was a relative lack of pteridophyte diversity in and around the crater. This lack of diversity was also present, to a lesser degree, in the monocots of the crater. Dicots accounted for over 73% of all taxa present, with alien dicots representing 53% and native dicots (indigenous and endemic combined) accounting for just over 20% of the totals.

Table 1. Numbers of vascular plant species of Ka'uhako Crater and immediate environs in major categories.

	ALIEN	INDIGENOUS	ENDEMIC	TOTAL
PTERIDOPHYTES	6	6	1	**13**
MONOCOTS	19	2	2	**23***
DICOTS	71	16	11	**98***
TOTAL	**96**	**24**	**14**	**134***

*Two monocot and five dicot species were Polynesian introductions.

2.B.2 NATIVE PLANT SPECIES

As a result of field work conducted during this survey, native plant species were noted and, for management purposes, divided into three categories based upon their abundance in the crater and/or level of monitoring intensity focused upon them (Table 2). Group 1 taxa were those which made up the dominant components of the remnant native forest within the crater and which were the focus of the most intensive levels of monitoring conducted during the survey. These species, including Erythrina, Reynoldsia, and Pleomele, are the most conspicuous natives remaining in the last relatively intact dryland forest of Moloka'i. They, therefore, hold the greatest promise as the center of native species diversity preservation. Group 2 taxa were those species which are not necessarily rare throughout the Hawai'ian islands but which are represented by only a few individuals within Ka'uhako Crater's remnant dryland forest and were therefore tagged and monitored to follow long term changes in their vigor and status. Group 3 taxa are those individuals which may or may not be rare throughout the Hawai'ian islands, but which are extremely rare in or around the confines of Ka'uhako Crater. Due to their location away from the core dryland forest, they were noted if observed, but were not intensively monitored during the course of this survey.

Discussion of Group 1 Taxa

Wiliwili **(Erythrina sandwicensis)**

In the remnant dryland forest of Ka'uhako Crater, *Wiliwili* trees are relatively common and reach the size of large statured trees over 30 feet in height. During the course of this survey, a representative sample of 34 *Wiliwili* trees (30 living, 4 dead) were tagged in the Java plum-Schinus forest of the crater floor and were used as the centers of 100 m^2 circular cover plots. Of those trees still alive, 19 were considered healthy and 5 were considered unhealthy (Tables 5 and 6). Although Linney (1987) observed seedlings on the crater floor, no seedlings were recorded during the 1995 survey despite the presence of healthy appearing seeds on the ground. Seedlings have been easily grown in nurseries (Obata 1973a), so their lack in the

Table 2. List of native species selected for intensive monitoring or for their rarity within Ka'uhako Crater.

	STATUS IN HAWAI'I	STATUS IN CRATER
GROUP 1 TAXA:		
***Wiliwili* (Erythrina sandwicensis)**	COMMON	COMMON
***'Ohe makai* (Reynoldsia sandwicensis)**	COMMON	COMMON
***Hala pepe* (Pleomele auwahiensis)**	RARE	COMMON
GROUP 2 TAXA:		
***Lama* (Diospyros sandwicensis)**	COMMON	RARE
***Alahe'e* (Psydrax odorata)**	COMMON	RARE
***Kolomona* (Senna gaudichaudii)**	UNCOMMON	RARE
GROUP 3 TAXA:		
***'Anaunau* (Lepidium bidentatum var. o-waihiense**	RARE	EXTIRPATED?
***Nehe* (Lipochaeta rockii)**	UNCOMMON	RARE
***Kulu'i* (Nototrichium sandwicense)**	COMMON	RARE
***'Ihi* (Portulaca villosa)**	RARE	RARE
***Naupaka kuahiwi* (Scaevola gaudichaudii)**	RARE	RARE

crater may be due to several factors including herbivory by ungulates, high seasonal aridity and destruction of seeds by rodents. Changes in the understory composition following the exclusion of feral ungulates, likely resulting in the generation of a more favorable microclimate, may aid in the establishment of seedlings in the future, although competition from non-native weeds may prove to be a limiting factor. In addition to the lack of seedling recruitment, another major threat to the long term survival of the *Wiliwili* population is the presence of the invasive Chinese banyan (Ficus microcarpa) throughout the crater. These trees, which are present on both rock formations of the crater floor and growing in other trees, have invasive root systems and expanding foliar crowns that will eventually overtop and strangle the host tree. Now occurring in three of the 30 living *Wiliwili* trees tagged in this survey, Chinese banyan will accelerate the decline of these large trees, many already in a state of senescence. For this reason, Chinese banyan should be given a high priority for control or eradication in any future management strategies. Individual information on each tagged *Wiliwili* tree has been recorded in Tables 5 and 6. Data regarding the ground and canopy cover of taxa around the 34 tagged *Wiliwili* trees can be found in Tables 12, 13 and 14.

***'Ohe makai* (Reynoldsia sandwicensis)**

This tree, which is co-dominant with *Hala pepe* (Pleomele) on the western and southwestern slope inside the crater, is less common in the Schinus-dominated eastern half of the crater and Casuarina covered upper western slope. A representative sample of 40 *'Ohe makai* trees were tagged and monitored individually to assess health and vigor, and 30 of these were also used as the center of 100 m^2 circular cover plots to record understory and canopy composition. Reproduction of *'Ohe makai* appears to be occurring, as several smaller plants of various size classes were observed throughout its range, and will likely increase following the exclusion of feral ungulates from the crater confines. In addition, 38 (95 %) of the 40 tagged trees were deemed to be healthy, although the majority were in a state of seasonal defoliation at the time of monitoring. Of the eight trees with leaves still present, three were observed to have signs of two-spotted leafhopper presence (shed casts, chlorosis of leaves, immature or adult insects on leaves), a number which could be significant as this non-native insect shows its early effects on the foliage of affected plants. It is possible that the crater's native trees are only showing the early signs of infestation, and could decline at a later date, as two-spotted leafhopper related plant degeneration and death can take up to two years to manifest itself in certain species (Vince Jones, pers. comm.). Individual information on the status of tagged *'Ohe makai* trees has been recorded in Tables 7 and 8. Data regarding the ground and canopy covers of taxa around the 50 tagged *'Ohe makai* trees can be found in Tables 15, 16 and 17.

***Hala pepe* (Pleomele auwahiensis)**

Hala pepe, one of the three most common native tree species in the remnant dryland forest of Ka'uhako Crater, is co-dominant with *'Ohe makai* (Reynoldsia) on the rocky inner scree slope of the southwestern portion of the crater. Although one of the most common trees in the crater and still fairly common in the remaining dryland forests of leeward Maui, almost all individuals are mature and do not appear to be successfully reproducing by seed. Rodent predation on Pleomele seeds has been reported (C. Zimmer, Hawai'i Volcanoes National Park, pers. comm.) but is likely not the only factor in its lack of reproductive success. Although no seedlings were observed during the 1995 survey, vegetative reproduction was noted to occur. What were thought to be small saplings, upon closer inspection turned out to be broken branches that had rooted in the ground. A representative sample of 50 *Hala pepe* trees were tagged and monitored individually to assess health and vigor, and 30 of these were also used as the center of 100 m^2 circular cover plots to record understory and canopy composition. Of the 50 trees monitored, only 19 (38 %) were considered healthy. Likely factors contributing to the lack of vigor in the *Hala pepe* population are the presence of non-native two-spotted leafhoppers (Sophonia rufofascia) and whiteflies on foliage. Signs of two-spotted leafhoppers were recorded on 43 (86 %) of 50 tagged trees, and whitefly presence on 22 (44 %) of 50 tagged trees. The feeding of both insects is known to be detrimental to the health of affected individuals and could contribute to a more rapid decline of the remaining senescent trees in the crater. Individual information on the status of tagged *Hala pepe* trees has been recorded in Tables 9 and 10. Data regarding the ground and canopy covers of taxa around the 50 tagged *Hala pepe* trees can be found in Tables 18, 19 and 20.

Discussion of Group 2 Taxa

***Lama* (Diospyros sandwicensis)**

During the course of the 1995 survey, two *Lama* trees were discovered on the inner southwestern slopes of the crater, on the fringes of the remnant *'Ohe makai-Hala pepe* forest. *Lama* was not recorded as present in the crater by Linney (1987) or Asherman et al. (1990), although they did record its presence in the areas from Kalawao to Waikolu Valleys. This tree, although rare in the crater is, as Rock (1913) stated, still "common on all the islands of the group, but especially so in the dry districts, where it forms almost pure stands." Both trees, which were sterile at the time of the survey, appeared to be extremely healthy, and were tagged to follow their long term vigor and status. No seedlings were observed under or in the vicinity of either tree, however. Individual information on the status of these tagged *Lama* trees has been recorded in Table 11.

***Alahe'e* (Psydrax odorata)**

Although only one *Alahe'e* plant was observed by Linney (1987) on the crater's northeastern inner slope, and one plant by Asherman et al. (1990), four plants were discovered and tagged on the inner southwestern slope during the course of the 1995 survey. This plant is more common on the eastern outer slope, where Linney (1987) states it is a "sub-dominant component of the dwarf *Wiliwili*-Christmasberry forest". Hillebrand (1888) stated of *'Alahe'e*: "All islands, on dry open slopes of mean elevation". Although all tagged plants appeared to be healthy, no seedlings were observed in the understory. Medeiros et al. (1986), found abundant fruit production but relative lack of seedling establishment on the south slopes of Haleakala, whereas Williams (1980) recorded good seedling establishment in the lowlands of Hawai'i Volcanoes National Park. In addition, Obata (1973b) reported good seed germination in the greenhouse. Information on the status of individually tagged *'Alahe'e* trees has been recorded in Table 11.

***Kolomona* (Senna gaudichaudii)**

This indigenous shrub was not recorded by Linney (1987) or Asherman et al. (1990) on either of their surveys of Ka'uhako Crater, but a single plant was discovered on the inner western slope by Art Medeiros in June 1995. Although *Kolomona* was once relatively common at lower elevations on all of the main islands (Hillebrand 1888; Mann 1868) it has since become scarce in its former range (Fosberg and Herbst 1975; Lamb 1981). The one plant, growing on the edges of the remnant *'Ohe makai-Hala pepe* forest, appeared healthy and was fruiting as of July 1995. No seedlings were observed, but this plant is apparently easy to grow from seed (Medeiros et al. 1986). Nothing appears to be immediately threatening the survival of this individual, although the encroachment of Mauritius hemp (Furcraea foetida) from below and ironwood (Casuarina equisetifolia) from above could pose problems in the future. For data on the vitality of the single *Kolomona*, refer to Table 11.

Discussion of Group 3 Taxa

'Anaunau (Lepidium bidentatum var. o-waihiense)

Asherman et al. (1990) found *'Anaunau* "between the mouths of Waile'ia and Waikolu, along the coast at Keanakua, on the cliffs 3-5 m above the boulder beach. 3 plants seen; 5-10 cm tall; sterile." Although no living specimens were recorded during the 1995 survey, Art Medeiros found the desiccated skeleton of a plant on the cliff face of the lava tube which extends from the northern portion of the crater that he tentatively identified as a Lepidium. It may be possible to locate living *'Anaunau* seedlings in this area following the wet season. *'Anaunau*, which is widespread in the Pacific (Wagner et al. 1990), has no current federal status but is proposed as a Category 2 candidate for listing.

Nehe (Lipochaeta rockii)

Gardner (1979) lists the range of L. rockii as western Moloka'i, south and central Maui and Kaho'olawe at 30 to 500 m, and Wagner et al. (1990) mention a single collection from Hawai'i. Asherman et al. (1990) found a single *Nehe* on the rim of Ka'uhako Crater, but this plant was not observed during the 1995 survey. The rim of the crater should be more thoroughly explored to check on the status of the one known plant and to look for any additional undiscovered individuals.

Kului (Nototrichium sandwicense)

Nototrichium sandwicense is found on all of the main islands where it is not uncommon in open dry forest, exposed ridges and lava fields (Wagner et al. 1990). *Kului* was not recorded in the crater by Linney (1987) or Asherman et al. (1990) in either of their surveys, but a single large shrub was pointed out by archaeologist Earl Neller in the northern half of the crater floor, on an upper bench, and to the west of the small pit crater. This plant was growing on the fringes of a Christmasberry stand, but otherwise appears to be healthy and in no immediate danger. Medeiros et al. (1986) state that "goats and cattle seem to preferentially browse Nototrichium", so the now excluded axis deer also presumably exerted grazing pressure and could have prevented seedling establishment. However, *Kului* is apparently grown easily from cuttings (Rene Sylva, pers. comm.).

'Ihi (Portulaca villosa)

Portulaca villosa, a Category 2 candidate for listing as an endangered species, is found on Nihoa, Ka'ula and all of the main islands except Ni'ihau and Kaua'i (Wagner et al. 1990). A population of six plants was discovered by Asherman et al. (1990) on the southwestern rim of the Ka'uhako Crater to the east of the cross and just below the crater rim. At least three more plants were discovered in 1995 just inside the northern crater rim and to the west of the lava tube and were fruiting at the time. This *'Ihi* closely resembles the non-native Portulaca pilosa, also found in the area, and can practically be distinguished only by the color of the seeds. The seeds of *'Ihi* are reddish brown, whereas the seeds of P. pilosa are dark blue with a metallic luster (Wagner et al. 1990).

***Naupaka kuahiwi* (Scaevola gaudichaudii)**
A population of 20 plants was recorded by Asherman et al. (1990) just below the southwestern rim on the inside of Ka'uhako Crater, and still appears to be healthy as of 1995. This yellow-flowered Scaevola, once common on all of the main islands except Ni'ihau and Kaho'olawe (Wagner et al. 1990) has in recent times become greatly depleted (Medeiros et al. 1986).

2.B.3 INVASIVE ALIEN PLANT SPECIES

The majority of the alien plants present in and around the crater, over 71% of all plant taxa present, were introduced by Europeans after the late 1700s. Most of these plants pose little threat to the health and well being of the crater's native flora and are only the by-product of disturbance caused by grazing of feral ungulates, particularly axis deer. Nevertheless, a few of these plants are different in that they are aggressively invasive and harmful to native plants, either through competition for habitat, or in the case of Chinese banyan, by directly harming the host plant through overtopping and strangulation. Weeds such as these require some form of management to check their spread and to prevent their domination in parts of the crater. Within Ka'uhako Crater, the alien plant species listed in Table 3 are currently or potentially invasive and will likely require some form of management efforts.

Table 3. List of nine alien plant species selected as aggressive and primary threats to native vegetation, Ka'uhako Crater

Broomsedge (Andropogon virginicus)
Spanish needle (Bidens pilosa)
Common ironwood (Casuarina equisetifolia)
Chinese banyan (Ficus microcarpa)
Mauritius hemp (Furcraea foetida)
Lantana (Lantana camara)
Molassesgrass (Melinis minutiflora)
Christmasberry (Schinus terebinthifolius)
Java plum (Syzygium cumini)

Weed species	Status in crater	Degree of threat to native vegetation	Difficulty of management
Andropogon virginicus	rare	medium	medium
Bidens pilosa	rare	medium	high
Casuarina equisetifolia	locally dominant	high	high
Ficus microcarpa	uncommon	high	high
Furcraea foetida	locally dominant	medium	high
Lantana camara	common	medium	high
Melinis minutiflora	uncommon	medium	medium
Schinus terebinthifolius	widespread	high	high
Syzygium cumini	widespread	medium	high

Broomsedge (Andropogon virginicus)
Broomsedge (Poaceae), native to eastern North America, is an invasive alien grass with the potential to form dense, monotypic ground cover that excludes native vegetation and carries fire (Anderson et al. 1992; Smith and Tunison 1992). Although only a few tussocks were discovered on the upper western wall of the crater below a stand of ironwood trees, broomsedge spreads readily by wind-borne seeds and could dramatically increase its cover in the crater following the exclusion of feral ungulates. Three tussocks of A. virginicus seen in July 1995 were uprooted, but a more thorough survey for this weed should be conducted and any individuals encountered should be immediately eliminated before control becomes impractical or impossible.

Spanish needle (Bidens pilosa)
Spanish needle (Asteraceae), native to tropical North America, is an annual herb that can grow to over three feet tall and has been known to seasonally dominate the understories of dryland forests on Maui and interfere with native seedling establishment (Medeiros et al. 1993). Even though Spanish needle accounted for an insignificant portion of the ground cover in the monitoring plots, its cover could increase due to changes in the forest understory with the removal of grazing animals. For these reasons, any future monitoring should pay particular attention to the status of weeds such as Spanish needle so that control strategies can be implemented when and if necessary.

Common ironwood (Casuarina equisetifolia)
Common ironwood (Casuarinaceae), native to Australia, is an aggressive tree with a root system that uses up most of the soil's available nutrients and with a dense accumulation of fallen branchlets underneath each tree (Neal 1965). Both of these factors contribute to ironwood's ability to prevent other plants from growing under or near it. This proved true in the almost monotypic ironwood stand on the upper inner slopes in the southwestern portion of Ka'uhako Crater, where practically nothing else will grow. Although Linney (1987) felt that this species could pose a problem for native vegetation, they were generally not very concerned with its invasiveness. Nevertheless, in vegetation monitoring conducted during the 1995 survey, Casuarina litter made up a very significant portion of the ground cover and larger trees occupied a consistently high percentage of the canopy cover in circular plots centered around the native Reynoldsia and Pleomele trees of the remnant dryland forest (Tables 15 and 18). Whether or not Casuarina is spreading rapidly remains to be determined, but there is no doubt that existing stands prevent the establishment of any native species in the areas they now occupy. Furthermore, fallen litter from these trees appears to be a significant factor in the prevention of native seedling recruitment in the remnant dryland forest which borders the ironwood stands. For these reasons, some form of mechanical or chemical control should be implemented to check ironwood's further spread while minimizing the disturbance to the native vegetation below, a difficult task considering the size of the trees in question.

Chinese banyan (Ficus microcarpa)
Chinese banyan (Moraceae), native throughout Asia from China to Australia, is an often epiphytic shrub to spreading evergreen tree (Wagner et al. 1990). Because of its invasive, strangling root network and its tendency to overtop and shade out host trees, Chinese banyan has the serious potential to hasten the demise of many senescent native trees growing in the crater, especially the large *Wiliwili* trees of the crater floor. Linney (1987) ranks Ficus microcarpa as the second most serious weed threat in Ka'uhako Crater. In the monitoring of individual trees conducted during the 1995 survey, three of 30 (10%) tagged *Wiliwili* trees had Ficus plants growing upon them. In one instance, the Chinese banyan's roots were penetrating the trunk of the host *Wiliwili* and were obviously contributing to and possibly hastening the trunk rot observed in that tree (Table 6). Only one Chinese banyan was recorded growing on 50 tagged *Hala pepe* trees, and none were recorded on the 40 tagged *'Ohe makai* trees (Tables 8 and 10). Nevertheless, several smaller individuals were observed growing upon other trees and rock formations of Ka'uhako Crater, and larger fruiting trees are located along the inner northeastern slopes as well as beyond the crater's environs. As the syconia (fruits) of this Ficus are readily bird dispersed (Wagner et al. 1990), and as the wasp pollinator, Euprestina verticillata, has been present in Hawai'i since 1938 (information from Hawai'i State Department of Agriculture, G. Funasaki pers. comm. in Wagner et al. 1990), allowing for fertile fruit and seed set, Chinese banyans will only increase in size and abundance unless some form of control is initiated. Larger fruiting trees should be cut down and treated with an appropriate herbicide to prevent regrowth, while smaller individuals should be pulled up if possible, or also cut and treated with an herbicide such as Garlon 3A or Garlon 4. For Ficus that cannot be reached due to their location high in the boughs of other trees, but which have their roots wrapped around the host and extending to the ground, it may be possible to inject an herbicide into the root network to kill the parent Ficus with minimal disturbance to the host tree.

Mauritius hemp (Furcraea foetida)
Mauritius hemp (Agavaceae) is a large acaulescent plant with long, densely crowded lanceolate leaves native to northern South America. Although it does not produce seed, it is spread rapidly by bulbils (Wagner et al. 1990), and is a prominent feature of the crater's inner flora where large plants crowd out other vegetation. Linney (1987) ranks Mauritius hemp as the third most threatening weed of the crater. In monitoring plots centered around Reynoldsia and Pleomele trees during the 1995 survey, Mauritius hemp made up the largest percentage of alien plant ground cover and was one of the top five aliens present in the canopies of these plots (Tables 15 and 18). Although the average percentage cover for Mauritius hemp in the plots was rather low, this number is misleading as plots were centered around native trees with relatively open understories. In certain areas of the crater where Mauritius hemp dominates, cover is almost 100% with nothing else growing under the mass of large foliage. Mauritius hemp clearly demonstrates the ability to take over an ecosystem, especially one as open as the remnant *'Ohe makai-Hala pepe* forest of the inner southwest quadrant, and should therefore be selectively removed when threatening native vegetation.

Lantana (Lantana camara)

Lantana (Verbenaceae) is a prickly malodorous shrub possibly native to the West Indies but now found throughout the world's tropics and subtropics (Wagner et al. 1990). Introduced to Hawai'i as an ornamental in 1858 (Hillebrand 1888) and widespread in drier, lower areas by 1902 (Perkins and Swezey 1924), Lantana has long been recognized as one of the world's more troublesome and invasive weeds. Nevertheless, Lantana is only mentioned here since it occupies a fairly large proportion of the entire crater, but will not likely spread into any new habitat. This is because, as Linney (1987) states "lantana is already predominant in favorable areas, and effectively excluded from unfavorable areas." With the fencing of Ka'uhako Crater and the subsequent removal of feral pigs and axis deer, habitat disturbance which could favor the spread of lantana will be minimized and further contain its spread. It should therefore only be necessary to remove lantana from areas in which it will impede other more important restoration efforts.

Molassesgrass (Melinis minutiflora)

Molassesgrass (Poaceae), native to Africa, is a robust mat-forming grass with foliage containing sticky, aromatic and highly flammable resins. After the exclusion of feral goats from the lower elevations of Hawai'i Volcanoes National Park and Haleakala National Park, molassesgrass populations exploded and suppressed the reproduction of *Koa* and other native species (Loope et al. 1992; Scowcroft and Hobdy 1986). Furthermore, molassesgrass burns readily and recovers quickly after fire, thus increasing its own spread and the loss of native species diversity (Hughes, Vitousek and Tunison 1991). Although it was not recorded in any of the 1995 vegetation monitoring plots and is not yet dominant in any areas, it is possible that, following the exclusion of axis deer from the crater, molassesgrass will increase in cover and abundance and pose the same management problems as it has in other natural areas. Its presence should therefore be noted when encountered and its status monitored to head off any imminent population increases. If feasible, populations should be eliminated with the appropriate foliar applied herbicide, especially when growing near vulnerable native species.

Christmasberry (Schinus terebinthifolius)

Christmasberry (Anacardiaceae), native to Brazil, is a shrub to small tree that can reach a height of up to 25 feet. Linney (1987) ranked Christmasberry as the greatest alien plant threat within Ka'uhako Crater due to its ability to produce large numbers of fruits which are eaten and spread by birds, as well as its tendency to produce dense thickets that do not enable anything else to grow beneath them. This is the case in the eastern half of the crater, where Schinus forms almost solid stands in spots and makes much of this area impenetrable. In the circular cover plots centered around Erythrina, Reynoldsia, and Pleomele trees, Christmasberry consistently comprised some of the higher percentages of ground and canopy covers for alien plants, but had its highest average cover value in the Erythrina plots which border the dense Christmasberry stands (Tables 12, 15 and 18). Although Christmasberry is a serious weed that does warrant major concern, its ubiquitous presence in the crater makes any immediate large scale management impractical and possibly even detrimental to the natives growing within. Selective removal of Christmasberry from some of the more intact areas of native vegetation should provide a short term solution to the problem, but any long range management plans will have to include the containment of encroaching Schinus as one of the goals in preserving the remnant dryland forests of Ka'uhako Crater.

Java plum (Syzygium cumini)
Java plum (Myrtaceae), native to India, Ceylon and Malesia, is the dominant alien tree in the western half of the crater where it reaches a height of up to 33 feet. Although it is an undesirable part of intact native ecosystems, Linney (1987) suggested that it may be restricting the spread of Schinus, an even less desirable alien, into its half of the crater. Java plum may also be creating a more favorable microclimate for seed germination on the crater floor and might even provide a relatively open understory that does not mutually exclude all other vegetation. Although Java plum made up the dominant canopy cover around both Erythrina and Reynoldsia circular cover plots, it still allowed a relative abundance of understory plants, mostly alien, to grow on the crater floor (Tables 16 and 19). On the other hand, it has been known to form dense carpets of seedlings in other areas and is considered a major threat by many land managers (Tanimoto and Char 1992). If any restoration of native vegetation is planned in the future, it may only be necessary to selectively remove Java plum from areas where it might interfere with these efforts while allowing it to remain at other low management priority sites. Nevertheless, the population should be periodically monitored in order to detect and prevent any imminent increases.

The remainder of the alien plants occurring in and around Ka'uhako Crater have been recorded in Appendix 1, with observations made on pertinent species. Although certain taxa, such as common guava (Psidium guajava) and strawberry guava (P. cattleianum) have a reputation as being invasive in wetter ecosystems, it is unlikely that they will thrive in the drier climate of Ka'uhako Crater. Other plants, such as swordfern (Nephrolepis multiflora), *Koa haole* (Leucaena leucocephala), bloodwood (Haematoxylum campechianum), yellow alder (Turnera ulmifolia) and others, although conspicuous due to their almost ubiquitous occurrence in and around the crater, are not major habitat disrupters and currently do not warrant the focus of intense management efforts.

2.C. FAUNA

2.C.1 UNGULATES

The detrimental effects of introduced ungulates on Hawai'i's unique flora has been well documented (Yocum 1967; Kjargaard 1984; Aplet et al. 1991; Anderson and Stone 1993; Tomich 1986). Damage to archaeological features and the native vegetation of Ka'uhako Crater, listed as a Special Ecological Area (SEA), has also been noted and has prompted the fencing and exclusion of feral ungulates from its boundaries (Kalaupapa NHPRMP 1994; Katahira 1995). Although impacts by feral ungulates were not specifically focused upon during the 1995 survey, the presence of droppings was recorded in monitoring plots to help quantify the extent of their presence in the remnant dryland forest. Vegetative composition and cover is also expected to change dramatically with the removal of feral ungulates, and the pre-existing monitoring plots will be valuable in documenting this transition.

Axis deer (Axis axis)
Axis deer were first introduced from their native range in India and Ceylon to the Hawai'ian Islands on Moloka'i in 1868 (Tomich 1986). Since that time the axis deer population has increased substantially and as Tomich states "in about 30 years became a pest in its relatively protected status on private lands." Katahira (1995) mentions that "between 350 to 500 deer" roam the peninsula "during a single evening" and that their "constant browsing prevents regeneration of certain native plants." In the July 1995 survey, prior to construction of the ungulate proof fence and the removal of ungulates contained therein, what were presumed to be axis deer droppings were recorded in 34 out of 34 (100%) circular plots centered around *Wiliwili* trees on the western half of the crater floor (Table 5). This number of plots containing droppings fell to 15 of 40 (37.5%) plots around *'Ohe makai* trees and only two of 50 (4%) plots centered around *Hala pepe* trees (Tables 7 and 9). Axis deer probably had their greatest effect on the crater floor, where all of the tagged *Wiliwili* trees were located, and were less damaging on the scree slopes of the *'Ohe makai-Hala pepe* forest possibly due to the instability of the ground. With the removal and exclusion of axis deer from the confines of the crater, changes in the components of the understory vegetation are expected as more palatable species are released from browsing pressure and allowed to grow. Existing plots can be utilized to document these changes and to predict which plants will likely become management problems as well as to record the recruitment of any native seedlings which, prior to fencing, has been non-existent.

Feral pigs (Sus scrofa)
Feral pigs found in the Hawai'ian Islands today are the ancestors of Eurasian stock (Warner 1959; Nichols 1962) released on the islands beginning with Cook's first voyage in 1778 (Cook, 1785). Known to cause damage to forests throughout the Islands (Tomich 1986), feral pigs have also been implicated in destroying native plants, encouraging weed establishment, and damaging archaeological sites in Ka'uhako Crater through their incessant rooting in the forest understory (Kalaupapa NHPRMP 1994). Their exclusion will therefore also benefit the regeneration of vegetation in the sub-canopy and understory, so changes should be documented utilizing existing plots from this survey.

Feral goats (Capra hircus)
Feral goats have also been implicated with causing damage to Ka'uhako Crater's native flora and archeological sites (Kalaupapa NHPRMP 1994; Katahira 1995). However, no goats were seen or heard in the crater during the course of the 1995 survey. Although feral goats probably wandered into the crater on occasion, it is presumed that the majority of ungulate damage observed was caused by axis deer and feral pigs and that impacts attributed to goats were rather minor in comparison. Nevertheless, exclusion of all feral ungulates, including goats, will likely benefit the crater's native vegetation and help preserve the integrity of the archeological sites found within.

2.C.2 RODENTS

According to the Kalaupapa NHPRMP (1994), the distribution, abundance and breeding status of three Rattus species, and presumably also the house mouse (Mus musculus) in the

Special Ecological Areas of the park, including Ka'uhako Crater, is currently unknown and needs to be studied to document damage to native birds, plants and insects. As the native ecosystems of the Hawai'ian Islands evolved without rodents, the native flora has no coevolved defenses to cope with the destruction of fruits and seeds by these rodents. Destruction of seeds of *'Ohe makai* (Reynoldsia) by rats and rodent-gnawed seed casings of *Hala pepe* (Pleomele) has been observed in Maui in the Kanaio district of the south slope (Medeiros et al. 1986; Medeiros et al. 1993). Similar damage to the seeds of native trees in Ka'uhako Crater could also be one of the factors contributing to a lack of native seedling recruitment. The impacts of rodents therefore needs to be further studied to help devise any future management or restoration strategies that may be used to counter this damage.

2.C.3 INVERTEBRATES

A thorough sampling of Ka'uhako Crater's invertebrate fauna was not conducted during the 1995 survey. However, one insect present in the crater and throughout the Hawai'ian Islands, the two-spotted leafhopper (Sophonia rufofascia), has recently earned a reputation as one of the worst potential threats to the long term health and well being of the Islands' native flora. The leafhopper, first discovered on O'ahu in 1987, has since been recorded on at least 309 host plants, many of them native (Vince Jones, pers. comm.). Probably spread throughout the islands by movement of plant materials infested with barely detectable eggs, the adult leafhopper uses its piercing-sucking mouthparts to feed on plants and females oviposit within leaf vascular tissue (Jones et al. 1994). Feeding and ovipositing result in damage that Jones (pers. comm.) states manifests itself through "yellowing between leaf veins", leaf collapse, appearance of brown or black patches, leaf distortion, stunting of the plant, and sometimes death. In Ka'uhako Crater, tagged native trees were checked for presence or sign of the two-spotted leafhopper by inspecting the undersides of leaves for the adult insect itself or the cast skins of the insect's immature stages. Presence of leafhopper was highest for *Hala pepe* (Pleomele) trees, with 43 of 50 (86%) tagged trees exhibiting some sign of the insect (Table 9). Of the eight *'Ohe makai* (Reynoldsia) trees with leaves still present, three (37.5%) showed signs of leafhopper presence (Table 7). In contrast, no *Wiliwili* trees had leafhoppers observed upon them, but a thorough inspection of many of the trees was not possible due to the inaccessibility of most of the foliage (Table 5). The only effects of leafhopper activity to date appear to be the yellowing or chlorosis of infected leaves, a trait which manifested itself most dramatically on *Hala pepe* trees. Yet, none of the damaged trees appeared to be in a serious state of decline due solely to leafhopper damage. Nevertheless, it may take up to two years before the ultimate effects of the two-spotted leafhopper are fully expressed (Vince Jones, pers. comm.), and infested trees may only be exhibiting the earliest stages of decline. Therefore, until some form of biocontrol or remedy to this problem is produced, it is deemed important to document changes in the health and vitality of native trees. These records will assist in determining if the two-spotted leafhopper is the main agent in any decline, or just one of several detrimental factors.

2.D. NON-DIRECT IMPACTS ON THE NATIVE BIOTA

Aside from the threats to the crater's native flora previously mentioned, one factor of great concern is the lack of reproduction of many of the native species. No true seedlings were observed for many of the key or rare native trees of the crater, including *Wiliwili* (Erythrina), *'Ohe makai* (Reynoldsia), *Hala pepe* (Pleomele), *Lama* (Diospyros), *Alahe'e* (Psydrax), or *Kolomona* (Senna). The definitive reason for the lack of reproduction in any of these species is unknown, but could be due to one or many factors. One of the most obvious obstacles to the production of seedlings is the browsing and trampling of feral ungulates, especially axis deer, which should no longer be a problem upon completion of the crater fence and removal of the remaining animals. Nevertheless, animal browsing is not likely the only element contributing to a lack of native seedling establishment, so their elimination addresses only a single concern. In a survey of the Kanaio Natural Area Reserve, Medeiros et al. (1993) found native seedling establishment of similar dryland tree species to be lacking, and attributed this to any one of the following reasons which could also be applied to the native flora of Ka'uhako Crater:

1) lack of outcrossing pollination in native plants due to the loss or reduction of coevolved native bird and insect fauna, and the low numbers of certain native plants.
2) loss of dispersal and scarification by extinct or reduced populations of native birds.
3) predation of seeds by introduced rodents (see section C.2).
4) production of hotter and drier understory microclimates as a result of continuous browsing by feral ungulates.
5) competition with aggressive alien weeds following the removal of feral ungulates.
6) modification of nutrient cycling due to the two previous problems and compounded by a loss or reduction of symbiotic mycorrhizae and rhizobia.
7) negative impacts by introduced invertebrates or pathogens, such as the two-spotted leafhopper (Sophonia rufofascia) (see section C.3).

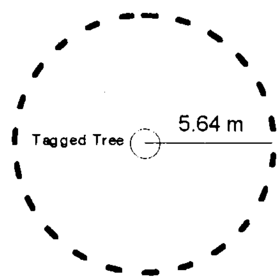
3. MONITORING

To follow the long term status of the dominant native tree species present in Ka'uhako Crater, and to document changes in the vegetative cover following the exclusion of axis deer (Axis axis) and other feral ungulates, individuals of the three dominant native tree species, *Wiliwili* (Erythrina sandwicensis), *'Ohe makai* (Reynoldsia sandwicensis) and *Hala pepe* (Pleomele auwahiensis), were tagged and analyzed for a number of vital statistics. This information gives a general picture of the relative health and vigor of the particular species being analyzed. Subsets of these tagged trees were also used as the centers of circular plots to estimate ground and canopy covers of each plant taxa present within a specified radius from the tree in question. The data acquired from these plots can be utilized as a baseline for future comparisons following the inevitable changes in the vegetation once browsing effects have been eliminated.

During the week of July 11 through 14, 1995, 34 *Wiliwili* trees (Erythrina sandwicensis), 40 *'Ohe makai* trees (Reynoldsia sandwicensis), 50 *Hala pepe* trees (Pleomele auwahiensis), two *Lama* trees (Diospyros sandwicensis), four *Alahe'e* trees (Psydrax odorata) and one *Kolomona* shrub (Senna gaudichaudii) were tagged and assessed to follow changes in their long term status, vigor and overall health. An aluminum tag, imprinted with a sequential number, was loosely affixed to the tree being monitored, using a piece of aluminum wire wrapped either around the trunk itself or on a prominent branch. In each case, enough room was left so as not to restrict any future growth in the tagged individual. In addition, to aid in the relocation of the tagged individuals, a piece of arctic grade blue flagging tape was wrapped around each tree, and was labeled with the tree number and the monitoring date.

Table 4 contains the data categories collected for all of the native tree species being monitored, as well as descriptions of each category. Raw monitoring data for these tagged individuals can be found in tables 6, 8, 10 and 11. A synopsis of this data can be located in tables 5, 7 and 9.

For 34 *Wiliwili* trees (#'s 1-34), 30 *'Ohe makai* trees (#'s 1-30), and 30 *Hala pepe* trees (#1-30), a modified Braun-Blanquet classification was utilized to visually estimate percent covers of all plant taxa, bare ground and *Casuarina* litter within a 5.64 m radius (100 m^2 circular plot) of each tagged individual, both on the ground and in the canopy. Taxa under one meter height were categorized in ground cover, and any taxon over 1 meter height was classified as canopy cover.



The following categories were used to estimate the ground and canopy covers within the designated circular plots:

Braun-Blanquet Category	Estimated Cover (%)
1	less than 1
2	1 to 5
3	5 to 25
4	25 to 50
5	50 to 75
6	75-100

The results for the ground and canopy cover estimates have been recorded in tables 13, 14, 16, 17, 19 and 20. A more concise summary of this data, with the data ranked according to decreasing cover, can be found in tables 12, 15 and 18.

Table 4: KEY TO NATIVE TREE MONITORING DATA CATEGORIES, KA`UHAKO CRATER

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	# of Ramettes	Ficus Presence	Sophonia Presence	Whitefly Presence

DATA CATEGORIES:

Plant #: Refers to the imprinted number on the aluminum tag attached to the designated tree species monitored. For this study, 34 Erythrina sandwicensis trees (#'s 1-34), 40 Reynoldsia sandwicensis trees (#'s 1-40), 50 Pleomele auwahiensis trees (#'s 1-50), two Diospyros sandwicensis trees (#'s 390, 391), four Psydrax odoratum trees (#'s 392-395) and one Senna gaudichaudii tree (# 396) were tagged.

Diam: Refers to the diameter of the tree, measured in centimeters, recorded above the basal swell and any root buttresses that might be present. In several instances, the basal diameters for trees of Pleomele auwahiensis were recorded as the combined totals of several smaller trunks remaining after the central trunk had rotted.

Phen: Refers to the phenology, or the periodically changing form, of the tree species monitored, as this affects its relationship with the environment. The phenology categories assigned to the tree species monitored are as follows:

- **0** = No leaves present. Certain dryland tree species, including Erythrina sandwicensis and Reynoldsia sandwicensis, lose their leaves seasonally as a result of climatic conditions.
- **1** = Leaves present.
- **FL** = Flowers present.
- **FR** = Fruits present (immature or mature).
- **FF** = Flowers and fruits present.

Vigor Categories:

The following vigor categories have been assigned to each tree species monitored to assess an individual's overall health and to help predict the status of trees in the future. This is a subjective rating of tree health and is not a progressive scale.

Vigor:dead:
"False" indicates that the tree is NOT dead. "True" indicates that the tree is dead.

Vigor: healthy:
"True" indicates that the tree has an overall general appearance of health and vitality. "False" does not necessarily indicate that the tree is unhealthy, but only that its general appearance does not warrant a healthy status.

Vigor: trunk rot:
"True" indicates that some rotting of the trunk is present, as a result of disease, senescence or other factors.

Vigor: broken branch:
"True" indicates the presence of large size broken branches of a diameter greater than 15 cm (6 inches).

Vigor: sap flux:
"True" indicates the presence of tree sap oozing from openings in a tree's trunk. This phenomenon is most common in Reynoldsia sandwicensis.

Vigor: unhealthy:
"True" indicates that the tree has an overall general unhealthy appearance and may be in a state of decline, possibly resulting in death. "False" does not

necessarily indicate that the tree is healthy, but only that its general appearance does not warrant an unhealthy status.

Droppings Presence:

"True" indicates that fresh ungulate droppings were observed within a 5.64 meter radius (100 m^2 circular plot) of the tree being monitored.

# of Ramettes:

This category was recorded for Pleomele auwahiensis trees only and is a count of the number of leaf bearing branches (ramettes) present on a tree.

Ficus Presence:

During the course of the study, many seedlings, saplings and larger individuals of the Chinese Banyan, Ficus microcarpa, were observed in the crater and on certain tree individuals. A scale was developed to quantify the presence of this alien growing on native trees to follow its effects on the survival of affected individuals. Because of its invasive root system (capable of penetrating a host tree's trunk) and competition for light and other resources, this invasive species could pose a serious threat to the long term survival of native trees in the crater. The categories of "Ficus Presence" are as follows:

- **0** = No Ficus present.
- **1** = Mild invasiveness. This rating indicates the presence of a small Ficus seedling or sapling growing on a tree which has not reached the point of competing with the host tree for resources.
- **2** = Moderate invasiveness. This rating indicates the presence of a larger Ficus sapling growing on the tree, with greater root system development and a larger foliar crown present.
- **3** = Severe invasiveness. This rating indicates the presence of a large Ficus plant growing on the tree, with a well developed root system wrapped around a host tree's trunk and possibly penetrating it at certain points, and /or with a well developed foliar crown competing with the host tree for sunlight.

Sophonia Presence:

"True" indicates the presence of the two-spotted leafhopper (Sophonia rufofascia) on the tree being monitored, as evidenced by presence of shed casts (skins) on leaf undersurfaces, signs of feeding or oviposition (yellowing or chlorosis of leaves in spots), or observations of the adult insect itself on the leaf undersurface. This introduced insect has been observed on many native and alien plants, and is responsible for the deaths of many individuals as a result of feeding damage. Sophonia could play an important adverse role in the long term survival of the crater's native species.

Whitefly Presence:

"True" indicates the presence of whiteflies on monitored trees, as evidenced by the presence of a small powdery white ring on affected leaves. Whitefly feeding can cause serious damage to leaves of trees and could contribute to a decline in a tree's health and vigor.

TABLE 5: Data Analysis For 30 Erythrina sandwicensis Trees, Ka'uhako Crater, Kalaupapa National Historical Park

Data Category	Percentage of Individuals With Characteristics "True"	Percentage of Individuals With Characteristics "False"
Phen: 0 = No leaves	3.33%	96.67%
Phen: 1 = Leaves present	96.67%	3.33%
Vigor: dead (n = 34)	11.80%	88.20%
Vigor: healthy	63.30%	36.70%
Vigor: trunk rot	10.00%	90.00%
Vigor: broken branch	46.70%	53.30%
Vigor: sap flux	3.33%	96.67%
Vigor: unhealthy	16.70%	83.30%
Droppings Presence	100.00%	0.00%
Ficus Presence		
0 = No Ficus present	90.00%	10.00%
1 = Mild invasiveness	3.33%	96.67%
2 = Moderate invasiveness	3.33%	96.67%
3 = Severe invasiveness	3.33%	96.67%
Sophonia Presence	0.00%	100.00%
Whitefly Presence	0.00%	100.00%

For each of the above categories, n = 30 Erythrina sandwicensis trees with the exception of Vigor: dead in which n = 34.

TABLE 6: Erythrina sandwicensis Monitoring Data, Ka'uhako Crater, Kalaupapa National Historical Park

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	Ficus Presence	Sophonia Presence	Whitefly Presence
1	80	1	False	False	False	False	False	False	True	0	False	False
2	62	1	False	True	False	True	False	False	True	0	False	False
3	55	1	False	True	False	False	False	False	True	0	False	False
4	44	1	False	True	False	True	False	False	True	0	False	False
5	55	1	False	True	False	False	False	False	True	0	False	False
6	56	0	False	False	True	True	False	False	True	3	False	False
7	64	1	False	True	False	False	False	False	True	0	False	False
8	73	1	False	True	False	False	False	False	True	1	False	False
9	66	1	False	False	False	True	False	True	True	0	False	False
10	29	1	False	True	False	False	True	False	True	0	False	False
11	55	0	True	False	False	False	False	False	True	0	False	False
12	79	1	False	False	False	True	False	True	True	2	False	False
13	35	0	True	False	False	False	False	True	True	0	False	False
14	47	0	True	False	False	False	False	False	True	0	False	False
15	26	1	False	True	False	False	False	False	True	0	False	False
16	48	1	False	False	False	True	False	True	True	0	False	False
17	64	1	False	True	False	False	False	False	True	0	False	False
18	60	1	False	True	False	False	False	False	True	0	False	False
19	55	1	False	False	False	True	False	True	True	0	False	False
20	25	1	False	True	False	False	False	False	True	0	False	False
21	36	0	True	False	False	False	False	False	True	0	False	False
22	84	1	False	True	False	True	False	False	True	0	False	False
23	90	1	False	False	True	True	False	False	True	0	False	False
24	26	1	False	True	False	False	False	False	True	0	False	False
25	64	1	False	False	False	True	False	False	True	0	False	False
26	47	1	False	True	False	False	False	False	True	0	False	False
27	74	1	False	True	False	True	False	False	True	0	False	False
28	73	1	False	False	False	True	False	False	True	0	False	False
29	71	1	False	True	False	True	False	False	True	0	False	False
30	65	1	False	True	False	False	False	False	True	0	False	False
31	28	1	False	False	False	False	False	True	True	0	False	False
32	44	1	False	True	False	False	False	False	True	0	False	False
33	26	1	False	False	False	True	False	False	True	0	False	False
34	69	1	False	True	True	False	False	False	True	0	False	False

TABLE 7: Data Analysis For 40 Reynoldsia sandwicensis Trees, Ka'uhako Crater, Kalaupapa National Historical Park

Data Category	Percentage of Individuals With Characteristics "True"	Percentage of Individuals With Characteristics "False"
Phen: 0 = No leaves	80.00%	20.00%
Phen: 1 = Leaves present	20.00%	80.00%
Vigor: dead	0.00%	100.00%
Vigor: healthy	95.00%	5.00%
Vigor: trunk rot	5.00%	95.00%
Vigor: broken branch	17.50%	82.50%
Vigor: sap flux	5.00%	95.00%
Vigor: unhealthy	0.00%	100.00%
Droppings Presence	37.50%	62.50%
Ficus Presence		
0 = No Ficus present	100.00%	0.00%
Sophonia Presence	10.00%	90.00%
*Soph. Presence (n = 8)	37.50%	62.50%
Whitefly Presence	0.00%	100.00%

*Soph, Presence (n = 8) refers to the eight Reynoldsia sandwicensis trees with leaves present, 3 (37.5%) of which had Sophonia presence. This designation is important as Sophonia shows its early effects (chlorosis of leaves) and presence on the foliage of trees, which would not be observable on trees which have lost their leaves.

TABLE 8: Reynoldsia sandwicensis Monitoring Data, Ka`uhako Crater, Kalaupapa National Historical Park

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	Ficus Presence	Sophonia Presence	Whitefly Presence
1	17	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
2	19	0	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
3	29	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
4	22	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
5	17	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
6	29	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
7	19	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
8	7	0	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	0	FALSE	FALSE
9	18	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
10	19	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
11	25	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	TRUE	FALSE
12	6	0	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	0	FALSE	FALSE
13	8	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
14	3	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
15	13	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
16	28	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
17	10	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
18	7	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
19	20	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
20	24	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
21	9	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
22	7	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
23	2	0	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	0	FALSE	FALSE
24	20	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
25	30	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
26	8	0	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	0	FALSE	FALSE
27	40	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	TRUE	FALSE
28	23	1	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE	0	FALSE	FALSE
29	57	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
30	21	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
31	38	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	TRUE	FALSE
32	4	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
33	4	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	0	FALSE	FALSE
34	3	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE

TABLE 8: Reynoldsia sandwicensis Monitoring Data, Ka`uhako Crater, Kalaupapa National Historical Park (*Continued*)

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	Ficus Presence	Sophonia Presence	Whitefly Presence
35	22	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	TRUE	FALSE
36	43	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	TRUE	0	FALSE	FALSE
37	6	0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
38	5	0	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	0	FALSE	FALSE
39	21	0	FALSE	TRUE	FALSE	TRUE	TRUE	FALSE	TRUE	0	FALSE	FALSE
40	21	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE

TABLE 9: Data Analysis For 50 *Pleomele auwahiensis* Trees, Ka`uhako Crater, Kalaupapa National Historical Park

Data Category	Percentage of Individuals With Characteristics "True"	Percentage of Individuals With Characteristics "False"
Phen: 0 = No leaves	0	100
Phen: 1 = Leaves present.	100	0
Phen: FR = Fruiting	6	94
Vigor: dead	0	100
Vigor: healthy	38	62
Vigor: trunk rot	64	36
Vigor: broken branch	72	28
Vigor: sap flux	0	100
Vigor: unhealthy	44	56
Droppings Presence	4	96
Ficus Presence		
0 = No Ficus present.	98	2
1 = Mild invasiveness	2	98
Sophonia Presence	86	14
Whitefly Presence	44	56

TABLE 10: *Pleomele auwahiensis* Monitoring Data, Ka`uhako Crater, Kalaupapa National Historical Park

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	# of Ramettes	Ficus Presence	Sophonia Presence	Whitefly Presence
1	10	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	5	0	FALSE	FALSE
2	8	1	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	1	0	TRUE	FALSE
3	30	1	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	11	0	TRUE	FALSE
4	33	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	24	0	TRUE	TRUE
5	2	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	1	0	TRUE	FALSE
6	30	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	10	0	TRUE	TRUE
7	22	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	9	0	TRUE	FALSE
8	34	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	10	0	TRUE	FALSE
9	18	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	12	0	TRUE	TRUE
10	13	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	4	0	TRUE	TRUE
11	2	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	2	0	TRUE	FALSE
12	31	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	35	0	TRUE	TRUE
13	19	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	8	0	TRUE	FALSE
14	40	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	48	0	TRUE	TRUE
15	31	1	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	39	0	TRUE	TRUE
16	14	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	8	0	TRUE	TRUE
17	24	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	14	0	TRUE	FALSE
18	8	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	1	0	TRUE	TRUE
19	21	FR	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	5	1	TRUE	FALSE
20	6	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	3	0	TRUE	TRUE
21	3	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	2	0	TRUE	TRUE
22	11	1	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	3	0	TRUE	TRUE
23	59	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	29	0	TRUE	FALSE
24	7	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	4	0	TRUE	FALSE
25	19	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	3	0	TRUE	FALSE
26	11	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	5	0	TRUE	FALSE
27	16	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	4	0	FALSE	FALSE
28	11	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	12	0	TRUE	TRUE
29	4	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	3	0	TRUE	FALSE
30	38	FR	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	20	0	FALSE	TRUE
31	2	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	1	0	FALSE	FALSE
32	2	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	1	0	FALSE	FALSE
33	10	1	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	8	0	FALSE	TRUE
34	63	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	TRUE	8	0	TRUE	TRUE
35	58	1	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	29	0	TRUE	FALSE

TABLE 10: *Pleomele auwahiensis* Monitoring Data, Ka`uhako Crater, Kalaupapa National Historical Park (*continued*)

Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	# of Ramettes	Ficus Presence	Sophonia Presence	Whitefly Presence
36	8	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	5	0	TRUE	FALSE
37	29	FR	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	16	0	TRUE	TRUE
38	32	1	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	73	0	TRUE	TRUE
39	58	1	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	30	0	TRUE	FALSE
40	11	1	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	15	0	TRUE	TRUE
41	7	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	7	0	TRUE	FALSE
42	6	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	6	0	TRUE	TRUE
43	19	1	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	32	0	FALSE	TRUE
44	8	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	3	0	TRUE	FALSE
45	10	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	3	0	TRUE	FALSE
46	8	1	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	5	0	TRUE	FALSE
47	3	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	2	0	TRUE	FALSE
48	5	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	4	0	TRUE	FALSE
49	2	1	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	2	0	TRUE	TRUE
50	9	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	2	0	TRUE	FALSE

TABLE 11: Uncommon or Rare Native Woody Species Monitoring Data, Ka`uhako Crater, Kalaupapa National Historical Park

Genus	Species	Plant #	Diam.	Phen.	Vigor: dead	Vigor: healthy	Vigor: trunk rot	Vigor: broken branch	Vigor: sap flux	Vigor: unhealthy	Droppings Presence	Ficus Presence	Sophonia Presence	Whitefly Presence
Diospyros	*sandwicensis*	390	15	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	TRUE
Diospyros	*sandwicensis*	391	10	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
Psydrax	*odoratum*	392	6	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
Psydrax	*odoratum*	393	5	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
Psydrax	*odoratum*	394	7	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
Psydrax	*odoratum*	395	9	1	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE
Senna	*gaudichaudii*	396	3	FR	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	0	FALSE	FALSE

TABLE 12: Most common (percentage cover) native and alien plant species, ground and canopy, *Erythrina sandwicensis* plots, Ka`uhako Crater, July 1995

Native Plants, Ground	
Taxa	**% Cover**
Erythrina sandwicensis	0.40
Asplenium nidus	0.09
Reynoldsia sandwicensis	0.04
No other natives present	

Alien Plants, Ground	
Taxa	**% Cover**
Syzygium cumini	1.21
Schinus terebinthifolius	0.62
Psidium guajava	0.32
Lantana camara	0.26
Solanum seaforthianum	0.25

Bare Ground	**87.50**

Native Plants, Canopy	
Taxa	**% Cover**
Erythrina sandwicensis	1.35
Reynoldsia sandwicensis	0.24
Asplenium nidus	0.00
No other natives present	

Alien Plants, Canopy	
Taxa	**% Cover**
Syzygium cumini	55.75
Schinus terebinthifolius	26.43
Ficus microcarpa	3.87
Senna pendula	0.60
Psidium guajava	0.41

TABLE 13: Percent ground cover for all plant species in thirty-four 100 sq. meter circular plots around *Erythrina sandwicensis* trees, Ka`uhako Crater, July 1995

Taxa	Average of % Cov, grnd
Bare ground	87.50
Syzygium cumini	1.21
Schinus terebinthifolius	0.62
Erythrina sandwicensis	0.40
Psidium guajava	0.32
Lantana camara	0.26
Solanum seaforthianum	0.25
Senna pendula	0.18
Ficus microcarpa	0.12
Asplenium nidus	0.09
Ipomoea sp.	0.09
Turnera ulmifolia	0.09
Cyperus gracilis	0.07
Leucaena leucocephala	0.04
Reynoldsia sandwicensis	0.04
Oxalis corniculata	0.03
Psidium cattleianum	0.01
Passiflora subpeltata	0.00

TABLE 14: Percent canopy cover for all plant species in thirty-four 100 sq. meter circular plots around Erythrina sandwicensis trees, Ka`uhako Crater, July 1995

Taxa	Average of % Cov, can
Syzygium cumini	55.75
Schinus terebinthifolius	26.43
Ficus microcarpa	3.87
Erythrina sandwicensis	1.35
Senna pendula	0.60
Psidium guajava	0.41
Reynoldsia sandwicensis	0.24
Psidium cattleianum	0.07
Asplenium nidus	0.00
Bare ground	0.00
Cyperus gracilis	0.00
Ipomoea sp.	0.00
Lantana camara	0.00
Leucaena leucocephala	0.00
Oxalis corniculata	0.00
Passiflora subpeltata	0.00
Solanum seaforthianum	0.00
Turnera ulmifolia	0.00

TABLE 15: Most common (percentage cover) native and alien plant species, ground and canopy, *Reynoldsia sandwicensis* plots, Ka`uhako Crater, July 1995

Native Plants, Ground	
Taxa	**% Cover**
Peperomia leptostachya	0.42
Doryopteris decipiens	0.35
Cocculus trilobus	0.34
Reynoldsia sandwicensis	0.30
Pleomele auwahiensis	0.25

Alien Plants, Ground	
Taxa	**% Cover**
Furcraea foetida	2.62
Nephrolepis multiflora	1.10
Syzygium cumini	0.83
Lantana camara	0.57
Schinus terebinthifolius	0.53

Bare Ground	**61.18**
Casuarina litter	**23.05**

Native Plants, Canopy	
Taxa	**% Cover**
Reynoldsia sandwicensis	0.90
Pleomele auwahiensis	0.85
Erythrina sandwicensis	0.58
Wikstroemia uva-ursi	0.08
Diospyros sandwicensis	0.08

Alien Plants, Canopy	
Taxa	**% Cover**
Syzygium cumini	17.43
Casuarina equisetifolia	14.00
Schinus terebinthifolius	4.12
Furcraea foetida	0.58
Psidium guajava	0.50

TABLE 16: Percent ground cover for all plant species in thirty 100 sq. meter circular plots around *Reynoldsia sandwicensis* trees, Ka`uhako Crater, July 1995

Taxa	Average of % Cov, grnd
Bare ground	61.18
Casuarina litter	23.05
Furcraea foetida	2.62
Nephrolepis multiflora	1.10
Syzygium cumini	0.83
Lantana camara	0.57
Schinus terebinthifolius	0.53
Casuarina equisetifolia	0.43
Peperomia leptostachya	0.42
Doryopteris decipiens	0.35
Cocculus trilobus	0.34
Reynoldsia sandwicensis	0.30
Phymatosorus scolopendria	0.28
Pleomele auwahiensis	0.25
Asplenium nidus	0.23
Nephrolepis exaltata	0.20
Plectranthus parviflorus	0.20
Haematoxylum campechianum	0.17
Leucaena leucocephala	0.17
Stachytarpheta urticifolia	0.13
Wikstroemia uva-ursi	0.13
Psilotum nudum	0.10
Solanum seaforthianum	0.08
Turnera ulmifolia	0.08
Chamaesyce celastroides	0.08
Sida fallax	0.07
Senna pendula	0.05
Ficus microcarpa	0.05
Erythrina sandwicensis	0.03
Passiflora sp.	0.03
Peperomia tetraphylla	0.03
Pleopeltis thunbergiana	0.03
Psidium guajava	0.03
Cassytha filiformis	0.03
Bidens pilosa	0.02
Osteomeles anthyllidifolia	0.02
Unidentified mint	0.02
Cyperus gracilis	0.02
Digitaria insularis	0.02
Diospyros sandwicensis	0.00
Morinda citrifolia	0.00

TABLE 17: Canopy cover for all plant species in thirty 100 sq. meter *circular plots around Reynoldsia sandwicensis* trees, Ka`uhako Crater, July 1995

Taxa	Average of % Cov, can
Syzygium cumini	17.43
Casuarina equisetifolia	14.00
Schinus terebinthifolius	4.12
Reynoldsia sandwicensis	0.90
Pleomele auwahiensis	0.85
Erythrina sandwicensis	0.58
Furcraea foetida	0.58
Psidium guajava	0.50
Wikstroemia uva-ursi	0.08
Diospyros sandwicensis	0.08
Cassytha filiformis	0.03
Morinda citrifolia	0.02
Senna pendula	0.02
Asplenium nidus	0.00
Bare ground	0.00
Bidens pilosa	0.00
Casuarina litter	0.00
Chamaesyce celastroides	0.00
Cocculus trilobus	0.00
Cyperus gracilis	0.00
Digitaria ciliaris	0.00
Digitaria insularis	0.00
Doryopteris decipiens	0.00
Ficus microcarpa	0.00
Haematoxylum campechianum	0.00
Lantana camara	0.00
Leucaena leucocephala	0.00
Nephrolepis exaltata	0.00
Nephrolepis multiflora	0.00
Osteomeles anthyllidifolia	0.00
Passiflora sp.	0.00
Peperomia leptostachya	0.00
Peperomia tetraphylla	0.00
Phymatosorus scolopendria	0.00
Plectranthus parviflorus	0.00
Pleopeltis thunbergiana	0.00
Psilotum nudum	0.00
Sida fallax	0.00
Solanum seaforthianum	0.00
Stachytarpheta urticifolia	0.00
Turnera ulmifolia	0.00
Unidentified mint	0.00

TABLE 18: Most common (percentage cover) native and alien plant species, ground and canopy, *Pleomele auwahiensis* plots, Ka`uhako Crater, July 1995

Native Plants, Ground	
Taxa	**% Cover**
Doryopteris decipiens	0.48
Peperomia leptostachya	0.48
Asplenium nidus	0.47
Cocculus trilobus	0.35
Pleomele auwahiensis	0.27

Alien Plants, Ground	
Taxa	**% Cover**
Furcraea foetida	4.05
Syzygium cumini	1.48
Nephrolepis multiflora	0.83
Schinus terebinthifolius	0.58
Phymatosorus scolopendria	0.38

Bare Ground	**71.42**
Casuarina litter	**10.57**

Native Plants, Canopy	
Taxa	**% Cover**
Pleomele auwahiensis	0.87
Reynoldsia sandwicensis	0.63
Cassytha filiformis	0.12
Chamaesyce celastroides	0.02
Asplenium nidus	0.00

Alien Plants, Canopy	
Taxa	**% Cover**
Syzygium cumini	26.20
Schinus terebinthifolius	12.55
Casuarina equisetifolia	4.83
Furcraea foetida	0.80
**Morinda citrifolia*	0.03

TABLE 19: Percent ground cover for all plants in thirty 100 sq. meter circular plots around *Pleomele auwahiensis* trees. Ka`uhako Crater, July 1995

Taxa	Average of % Cov, grnd
Bare ground	71.42
Casuarina litter	10.57
Furcraea foetida	4.05
Syzygium cumini	1.48
Nephrolepis multiflora	0.83
Schinus terebinthifolius	0.58
Doryopteris decipiens	0.48
Peperomia leptostachya	0.48
Asplenium nidus	0.47
Phymatosorus scolopendria	0.38
Cocculus trilobus	0.35
Lantana camara	0.27
Pleomele auwahiensis	0.27
Plectranthus parviflorus	0.23
Reynoldsia sandwicensis	0.22
Stachytarpheta urticifolia	0.22
Casuarina equisetifolia	0.18
Psilotum nudum	0.17
Ficus microcarpa	0.15
Chamaesyce celastroides	0.12
Cassytha filiformis	0.10
Conyza bonariensis	0.10
Leucaena leucocephala	0.10
Digitaria ciliaris	0.08
Peperomia tetraphylla	0.07
Psidium cattleianum	0.07
Haematoxylum campechianum	0.05
Morinda citrifolia	0.05
Nephrolepis exaltata	0.05
Pluchea symphytifolia	0.05
Turnera ulmifolia	0.05
Digitaria setigera	0.03
Musa x paradisiaca	0.03
Osteomeles anthyllidifolia	0.03
Pleopeltis thunbergiana	0.03
Solanum seaforthianum	0.03
Bidens pilosa	0.02
Cordyline fruticosa	0.02
Digitaria insularis	0.02
Emilia fosbergii	0.02
Psidium guajava	0.02

Table 20: Percent canopy cover for all plant species in thirty 100 sq. meter circular plots around *Pleomele auwahiensis* trees, Ka`uhako Crater, July 1995

Taxa	Average of % Cov, can
Syzygium cumini	26.20
Schinus terebinthifolius	12.55
Casuarina equisetifolia	4.83
Pleomele auwahiensis	0.87
Furcraea foetida	0.80
Reynoldsia sandwicensis	0.63
Cassytha filiformis	0.12
Morinda citrifolia	0.03
Chamaesyce celastroides	0.02
Cordyline fruticosa	0.02
Asplenium nidus	0.00
Bare ground	0.00
Bidens pilosa	0.00
Casuarina litter	0.00
Cocculus trilobus	0.00
Conyza bonariensis	0.00
Digitaria ciliaris	0.00
Digitaria insularis	0.00
Digitaria setigera	0.00
Doryopteris decipiens	0.00
Emilia fosbergii	0.00
Ficus microcarpa	0.00
Haematoxylum campechianum	0.00
Lantana camara	0.00
Leucaena leucocephala	0.00
Musa x paradisiaca	0.00
Nephrolepis exaltata	0.00
Nephrolepis multiflora	0.00
Osteomeles anthyllidifolia	0.00
Peperomia leptostachya	0.00
Peperomia tetraphylla	0.00
Phymatosorus scolopendria	0.00
Plectranthus parviflorus	0.00
Pleopeltis thunbergiana	0.00
Pluchea symphytifolia	0.00
Psidium cattleianum	0.00
Psidium guajava	0.00
Psilotum nudum	0.00
Solanum seaforthianum	0.00
Stachytarpheta urticifolia	0.00
Turnera ulmifolia	0.00

4. MANAGEMENT RECOMMENDATIONS

Preserving and perpetuating the native components of the remnant dryland forest in Ka'uhako Crater, along with documenting and protecting its archeological features, should be the chief long term management goals in any future plans. With the construction of the fence and the exclusion and removal of feral ungulates, the greatest immediate threats to the survival of the remaining native flora are competition from invading alien weed species, wildland fires and lack of seedling production in the rare and key native elements of the forest. The following is a discussion of these threats along with their management implications and recommendations to address each problem.

4.A. ALIEN PLANT CONTROL

The previous distribution and abundance of alien weed species within and around Ka'uhako Crater was largely a by-product of the frequency and intensity of browsing by feral ungulates. With their exclusion from these environs, appreciable changes in the vegetative understory are likely to occur very rapidly and with noticeable effect. Some species which have been kept in check by this browsing will flush and become more conspicuous, while other low-growing species may be crowded out by more aggressive components. Grasses which are currently relatively sparse in the crater, such as broomsedge (Andropogon), molassesgrass (Melinis) and possibly Natal redtop (Rhynchelytrum repens), have the potential to greatly increase as they are released from browsing pressure.

The nine alien plant species previously mentioned in section B.3 will likely require future control or management efforts due to their prevalence in the crater now or because of their potential to rapidly increase and come to dominate in areas relatively free of their presence. Of these nine species, however, three (Christmasberry, Java plum and lantana) are currently so abundant that any short term solution is unlikely. They should be dealt with only in areas where they interfere with other restoration efforts or until other more immediate management concerns are addressed.

Broomsedge occurs at very low levels in the crater and should be actively sought out and removed whenever encountered. With its ability to form dense groundcover and carry fire, it is important that it not be allowed to reach levels that make manual or selective herbicidal control impractical.

Spanish needle currently occurs at very low levels in the crater but has demonstrated its ability to dominate the understories of other dryland areas (Medeiros et al. 1993). Although the elimination of Spanish needle would be desirable, it is unlikely that all plants could be located. Therefore, it is important to monitor Spanish needle abundance in areas where it could have the greatest detrimental effect, namely under native trees where potential seedlings need every competitive advantage, and selectively eliminate it in these areas. Furthermore, workers should regularly check clothing for the barbed awns of this weed and remove them whenever found to avoid inadvertently transporting it to other areas of the crater.

Common ironwood poses a management problem due to the large sizes of the individuals on the inner slopes of the crater. If some method of removing large ironwood trees could be developed that would minimize disturbance to the native plants below, selective removal of trees on the periphery of native stands could, at least, prevent any further encroachment on the natives' current range. Any small ironwood saplings or seedlings encountered within the native stands should be uprooted if feasible, or cut and treated with the appropriate herbicide to prevent regrowth.

Chinese banyan, with its strangling roots and spreading canopy high atop host trees, could seriously hasten the decline of senescent native trees or contribute to the deterioration of otherwise healthy individuals. At present, most Chinese banyans in the crater are smaller sized and could be easily cut and treated with an herbicide such as Garlon 3A or Garlon 4 to deter regrowth. It may also be possible to treat individuals growing high up in other trees with some herbicide injected into their root system, either by drilling a hole in their roots and squirting in an herbicide such as Garlon 3A, or by utilizing one of the new injection devices, such as the EZ-Ject Lance, currently available.

Mauritius hemp currently dominates certain areas of the crater and has the potential to occupy more area, especially on the scree slopes of the *'Ohe makai-Hala pepe* forest. Although this is not likely to occur rapidly, without management, Mauritius hemp could come to take over these relatively open areas. Therefore, any smaller individuals should be uprooted if possible or cut and treated with an appropiate herbicide. Larger individuals currently bordering upon more intact stands of native trees should also be cut and treated with an herbicide, especially in areas where they interfere with native growth and reproduction.

Asherman et al. (1990) recorded the presence of molassesgrass in their survey of Ka'uhako Crater, but this mat-forming grass was not present in the 1995 monitoring plots. The full extent of molassesgrass is currently unknown, but following the exclusion of feral ungulates, its cover is expected to increase. Therefore, due to its ability to crowd out other vegetation and, as Smith and Tunison (1992) state, produce a "many-fold increase in biomass and a fuel bed capable of supporting fire", any incipient populations of this grass should be mapped, monitored and when possible, sprayed with a foliar herbicide such as Roundup. Priority should be given to areas where this grass threatens native plants, although, ideally, all populations should be eliminated.

4.B. FIRE SUPPRESSION

In many areas of the world, fire is a natural and integral part of a healthy ecosystem, with certain fire-adapted species dependent on burning for stimulation and normal growth. This is not the case in the Hawai'ian Islands, however, where native species had only infrequently encountered fire set by lava flows or the uncommon lightning strike. For this reason, native species did not adapt to a regime of intense wildland fires and are, therefore, very slow to recover following such an episode of fire (Mueller-Dombois 1981). In contrast, those introduced species, especially the alien grasses, that have evolved with fire are capable of quick regrowth afterwards and can come to dominate a previously native ecosystem following a few such events (Vogl 1975, Christensen 1985). What this leads to is, as Hughes et al. (1991) state "a grass/fire cycle whereby invading grasses promote fire, which in turn favors alien grasses over native species." In Ka'uhako Crater, alien grasses and other species which could add to the fuel biomass and promote fire have, up to this point, been kept in check by the continuous browsing and grazing of feral ungulates, especially axis deer. However, with the exclusion of feral ungulates through fencing, certain species, especially alien grasses such as broomsedge and molassesgrass, are expected to increase in cover and abundance unless some control strategy is implemented. Therefore, it is strongly recommended that fire tolerant grasses and other weeds be eliminated or at least kept out of predominantly native stands of vegetation until the understory recovers to such a point as to exclude them or keep them in check.

4.C PROPAGATION OF NATIVE SPECIES

Due to the lack of reproduction in many native species in the crater as a possible result of various factors touched upon in section 2.D., it would be desirable to implement a propagation and planting program following prescribed guidelines in the hope of reestablishing and augmenting stands of native vegetation. Some good candidates for such a replanting program should include the more common dryland tree species such as *'Ohe makai, Hala pepe,* and *Wiliwili* as well as uncommon ones such as *Alahe'e, Lama, Kulu'i* and *Kolomona*. It is important that certain conditions and guidelines be adhered to in a well-conceived planting program.

a. A written plan highlighting the objectives and methods of a replanting program should be produced and reviewed by the appropriate authorities or members of the scientific community.
b. Only plants produced by seeds or cuttings from plants in and around Ka'uhako Crater should be replanted in the crater.
c. If possible, a voucher specimen and accurate records of the seed source and date of planting should be kept, and published or made available to the public.
d. Special care should be taken to prevent the introduction of alien invertebrates (slugs and snails), weeds, or insects into the crater either in the potting media or in the new plants themselves.

ACKNOWLEDGMENTS

The authors wish to thank Earl "Buddy" Neller, Dean Alexander, and Rick Potts for providing logistical support for this survey. The field assistance of Paul Krushelnycky and Paul O'Coner, and the technical computer assistance of Philip Thomas was also greatly appreciated.

5. LITERATURE CITED

Anderson, S.J. and C.P. Stone. 1993. Snaring to control feral pigs Sus scrofa in a remote Hawai'ian rainforest. Biological Conservation 63: 195-201.

Anderson, S.J., C.P. Stone, and P.K. Higashino. 1992. Distribution and spread of alien plants in Kipahulu Valley, Haleakala National Park, above 2300 ft elevation, p.300-338. In C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien plant invasions in native ecosystems of Hawai'i: management and research. Univ. Hawai'i Press for Cooperative National Park Resources Studies Unit. Honolulu, Hawai'i.

Aplet, G.H., S.J. Anderson, and C.P. Stone. 1991. Association between feral pig disturbance and the composition of some alien plant assemblages in Hawai'i Volcanoes National Park. Vegetation 95: 55-62.

Asherman, K., J.M. Crummer, and J.Q.C. Lau. 1990. A botanical reconnaissance of Kalaupapa National Historical Park, November 27-December 5, 1989. The Nature Conservancy of Hawai'i. 41 p.

Christensen, N.L. 1985. Shrubland fire regimes and their evolutionary consequences, p.85-101. In S.T.A. Pickett and P.S. White (eds.), The ecology of natural disturbance and patch dynamics. Academic Press, New York, New York.

Cook, J. 1785. A voyage to the Pacific Ocean. 2nd Ed. Vol. 2: 190-252. Hughes, London.

Fosberg, F.R., and D. Herbst. 1975. Rare and endangered species of Hawai'ian vascular plants. Allertonia 1: 1-72.

Gardner, R.C. 1979. Revision of Lipochaeta (Compositae: Heliantheae) of the Hawai'ian Islands. Rhodora 81: 291-343.

Giambelluca, T.W., M.A. Nullet, and T.A. Schroeder. 1986. Rainfall atlas of Hawai'i. State of Hawai'i, Department of Land and Natural Resources, Division of Water and Land Development. Honolulu, Hawai'i. Report R76: 267 p.

Hillebrand, W. 1888. Flora of the Hawai'ian Islands. 3rd. Ed. (1981). Lubrecht and Cramer, Monticello, NY. 673 p.

Hughes, F., P.M. Vitousek, and T. Tunison. 1991. Alien grass invasion and fire in the seasonal submontane zone of Hawai'i. Ecology 72(2): 743-746.

Jones, V.P., D.E. Ullman, J.S. Hu, W.B. Borth, R. Messing, V.M. Tanimoto, J. Ishiki, M.T. Fukada. 1994. Role of twospotted leafhoppers in disorders in uluhe and ohia in Hawai'ian forests. GACC Semi-Annual Progress Report. GACC Contract No. GACC 93-6. 4 p.

Kalaupapa National Historical Park. 1994. Resource management plan, Kalaupapa National Historical Park, Kalaupapa, Hawai'i. National Park Service. 150 p.

Katahira, L. 1995. Draft environmental assessment. Construct feral animal proof fence at Ka'uhako Crater, Kalaupapa National Historical Park, Moloka'i. 5 p.

Kjargaard, J.I. 1984. Some aspects of feral goat distribution in Haleakala National Park. Coop. N.P. Resources Studies Unit, Department of Botany, University of Hawai'i, Tech. Rept. 52: 1-19.

Lamb, S.H. 1981. Native trees and shrubs of the Hawai'ian Islands. The Sunstone Press, Santa Fe, New Mexico. 159 p.

Linney, G. 1987. Botanical survey of Ka'uhako Crater, Kalaupapa National Historical Park, Moloka'i. National Park Service Kalaupapa files. 21 p.

Loope, L.L., R.J. Nagata, and A.C. Medeiros. 1992. Alien plants in Haleakala National Park, p.551-576. In C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien plant invasions in native ecosystems of Hawai'i: management and research. Univ. Hawai'i Press for Cooperative National Park Resources Studies Unit. Honolulu, Hawai'i.

Mann, H. 1868-1871. Flora of the Hawai'ian Islands. Part IV. Proceedings of the Essex Institute. Salem, Mass.

Medeiros, A.C., L.L. Loope, and C.G. Chimera. 1993. Kanaio Natural Area Reserve biological inventory and management recommendations. Natural Area Reserve System. State of Hawai'i. 90 p.

Medeiros, A.C., L.L. Loope, and R.A. Holt. 1986. Status of native flowering plant species on the south slope of Haleakala, East Maui, Hawai'i. Cooperative National Park Resources Studies Unit, Department of Botany, University of Hawai'i, Tech. Rept. 59: 1-230.

Mueller-Dombois, D. 1981. Fire in tropical systems. In H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (eds.), Fire regimes and ecosystem properties; proceedings of the conference. United States Department of Agriculture General Technical Report WO-26.

Neal, M.C. 1965. In gardens of Hawai'i. B.P. Bishop Museum Press, Honolulu. 924 p.

Nichols, L. Jr. 1962. Ecology of the wild pig. State of Hawai'i, Div. Fish and Game, Honolulu, Project W-5-R-13. 20 p.

Obata, J. 1973a. Propagating native Hawai'ian plants (continued). Newsletter of the Hawai'ian Botanical Society, Vol. XII: No. 1.

Obata, J. 1973b. Propagating native Hawai'ian plants (continued). Newsletter of the Hawai'ian Botanical Society, Vol. XII: No. 2.

Perkins, R.C.L. and O.H. Swezey. 1924. The introduction into Hawai'i of insects that attack Lantana. Entomological Series Bull. of the Expt. Sta. of the Hawai'i Sugar Planters Association. No. 16.

Rock, J.F. 1913. The indigenous trees of the Hawai'ian Islands. Reprinted in 1974 by Charles E. Tuttle Co., Tokyo, Japan. 548 p.

Scowcroft, P.G. and R. Hobdy. 1986. Recovery of montane *Koa* parkland vegetation protected from feral goats. Biotropica 19: 208-215.

Smith, C.W. and J.T. Tunison. 1992. Fire and plants in Hawai'i: research and management implications for native ecosystems, p.394-408. In C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien plant invasions in native ecosystems of Hawai'i: management and research. Univ. Hawai'i Press for Cooperative National Park Resources Studies Unit. Honolulu, Hawai'i.

Tanimoto, V.M., and W.P. Char. 1992. Alien plant control on state lands including natural areas, p.536-550. In C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien plant invasions in native ecosystems of Hawai'i: management and research. Univ. Hawai'i Press for Cooperative National Park Resources Studies Unit. Honolulu, Hawai'i.

Tomich, P.Q. 1986. Mammals in Hawai'i. A synopsis and notational bibliography. 2nd Ed. Bishop Museum Press, Honolulu. 375 p.

Vogl, R.J. 1975. Fire: a destructive menace or a natural process? p.261-289. In J. Cairns, Jr., K.L. Dickson, and E.E. Herricks (eds.), Recovery and restoration of damaged ecosystems. University Press of Virginia, Charlottesville, Virginia.

Wagner, W.L., D.R. Herbst, and S.H. Sohmer. 1990. Manual of the flowering plants of Hawai'i. B.P. Bishop Museum and University of Hawai'i Press, Honolulu. 1854 p.

Warner, R.E. 1959. Ecological investigations on the Hawai'ian pig. State of Hawai'i, Div. Fish and Game, Honolulu, Project W-5-R-10. 5 p.

Williams, J. 1980. Native vs. exotic woody vegetation recovery following goat removal in the eastern coastal lowlands of Hawai'i Volcanoes National Park, p. 373-382. Proc. 3rd Conf. in Natural Sciences, Hawai'i Volcanoes N.P., Cooperative National Park Resources Studies Unit, Department of Botany, University of Hawai'i.

Yocom, C.F. 1967. Ecology of feral goats in Haleakala National Park, Maui, Hawai'i. American Midland Naturalist 77: 418451.

APPENDIX 1

Annotated checklist of native and non-native vascular plants, Ka'uhako Crater, Kalaupapa National Historical Park

An annotated checklist of the crater's vegetation is necessary to document the current status of the area's flora and to follow the inevitable changes in both native and alien species following the removal and exclusion of feral ungulates. The systematics and distributions for flowering plants, as well as the use of Hawaiian plant names, follows Wagner, Herbst, and Sohmer (1990). The sytematics and distributions for pteridophytes largely follows the Hawaiian pteridophyte work of Warren H. Wagner Jr. (University of Michigan).

The following terms have been used to designate the range of species:

NATIVE: naturally occurring in an area without human intervention. In the Hawaiian Islands, the term is generally used to describe species that are either endemic or indigenous.

NON-NATIVE: introduced either directly or indirectly as a consequence of human intervention.

ENDEMIC: naturally occurring only in a specific region or locality. For example, Lobelia dunbarii subsp. paniculata grows only on cliffs in wet forests of Moloka'i and is therefore endemic to that area. In this report, when endemic is used without specifying an area, it is assumed that the species is endemic to the Hawaiian Islands.

INDIGENOUS: growing and living naturally in a particular locality. In the Hawaiian Islands, the term is most often used to describe species which are native but not endemic. For instance, the *moa* or whisk fern (Psilotum nudum) is an indigenous species as it occurs naturally in the Hawaiian Islands as well as the continental U.S., Asia, Africa and other Pacific islands.

Families, genera and species are listed alphabetically within the classes of pteridophytes, monocotyledons and dicotyledons.

The final line of each species description is a code which refers to the plant survey referenced in this document. The letter refers to the codes below, and the number refers to the page of the particular reference. The lack of a letter and number indicates that the plant was found in the 1995 survey only.

Plant surveys referenced in this document

ACL = Asherman, K., J.M. Crummer and J.Q.C. Lau. 1990. A Botanical Reconnaissance of Kalaupapa National Historical Park, November 27-December 5, 1989. The Nature Conservancy of Hawai'i. 41 p.

LF = Linney, G. 1987. Botanical Survey of Ka'uhako Crater, Kalaupapa National Historical Park, Moloka'i. National Park Service Kalaupapa files. 21 p.

PTERIDOPHYTES
(FERNS AND FERN ALLIES)

ASPLENIACEAE — **ASPLENIUM FAMILY**

Asplenium nidus L. — **BIRD'S NEST FERN, *'EKAHA***
Native: indigenous to Hawaii and the tropics of the eastern hemisphere.
ACL12, LF11

BLECHNACEAE — **BLECHNUM FAMILY**

Blechnum occidentale L.
Non-native: native to tropical America.
ACL12

DRYOPTERIDACEAE

Cyrtomium falcatum (L.fils) Presl — **JAPANESE HOLLY-FERN**
A small population of this fern was found growing on the crater rim, near the lava tube rift.

Non-native: native to the Old World tropics and subtropics.

Nephrolepis cordifolia (L.) Presl
Native: indigenous from pantropical Japan to New Zealand, including the main Hawaiian Islands.
ACL12

Nephrolepis exaltata (L.) Schott — ***'OKUPUKUPU***
Native: pantropical, including the main Hawaiian Islands.
ACL12

Nephrolepis multiflora (Roxb.) Jarret ex Morton — **SWORDFERN, *'OKUPUKUPU***
[= N. hirsutula (Forssk.) Presl sensu ACL12]
Non-native: native of Old World tropics, now widely naturalized in tropical America.
LF11

POLYPODIACEAE — **POLYPODY FAMILY**

Phlebodium aureum (L.) J. Sm. — *LAUA'E-HAOLE*
Non-native: native to tropical America.
LF11

Phymatosorus scolopendria (N.L. Burm.) Pichi. Serm. — *LAUA'E, LAUWA'E*
[= Microsorium scolopendrium (Burm.) Copel. sensu ACL13]
Non-native: native to Old World tropics and Pacific islands.
ACL13, LF11

Pleopeltis thunbergiana Kaulf. — *PAKAHAKAHA, 'EKAHA-'AKOLEA*
Native: indigenous to the Hawaiian Islands as well as China, Japan and Korea (Jones 1987).
ACL13, LF11

PSILOTACEAE — **PSILOTUM FAMILY**

Psilotum nudum (L.) Beauv. — *MOA*
Native: indigenous and broadly distributed in the tropics and subtropics.
ACL14, LF11

PTERIDACEAE

Doryopteris decipiens (Sm.) Hook — *'IWA'IWA, KUMUNUI*
Native: endemic to the Hawaiian Islands.
ACL12, LF11

THELYPTERIDACEAE

Thelypteris parasitica (L.) Fosberg — **DOWNY WOOD FERN**
[= Christella parasitica (L.) Leveille sensu ACL14]
Non-native: native from Southeast Asia to East Asia and Pacific islands.
ACL14

Thelypteris interrupta (Willd.) Iwats. — *NEKE*
[= Cyclsorus interruptus (Willd.) H. Ito Neke sensu ACL14]
Native: indigenous to pantropics, including the main Hawaiian Islands.
ACL14

ANGIOSPERMS
MONOCOTYLEDONS

AGAVACEAE — AGAVE FAMILY

Cordyline fruticosa (L.) A. Chev. — ***TI, KI***

[= Cordyline terminalis (L.) Kunth. sensu LF16]
Non-native: Polynesian introduction probably native to Asia, Malesia, and northern Australia.
ACL14, LF16

Furcraea foetida (L.) Haw. — **MAURITIUS HEMP**

Non-native: native to northern South America.
ACL15, LF16

Pleomele auwahiensis St. John — ***HALA PEPE***

[= Dracaena aurea Mann sensu LF16]
Hala pepe comprises one of the three most common native tree species in the remnant dryland forest of Ka'uhako Crater. Linney (1987) states that it is "a co-dominant with *'Ohe* (Reynoldsia) in a remnant forest on scree on the inner slope of the southwestern quadrant. Regeneration appears to be occurring." No seedlings were recorded in the July 1995 survey, although what were thought to be small trees, upon closer examination, turned out to be broken branches that had rooted in the soil. The non-native two-spotted leafhopper (Sophonia rufofascia) was responsible for a chlorotic appearance to foliage on a majority of trees monitored and could pose a serious threat to the long term survival and viability of the crater's *Hala pepe* population.

Native: endemic to Moloka'i and Maui.
ACL15, LF16

ARECACEAE — PALM FAMILY

Phoenix dactylifera L. — **DATE PALM**

[= Phoenix sp. sensu LF18]
Although no trees were located in the crater during the July 1995 survey, Linney (1987) states that "two trees were seen inside the crater. It has little potential for becoming a major pest." Trees outside the crater were identified as date palms, and it is assumed that those mentioned by Linney were the same species.

Non-native: native to Arabia and North Africa (Graf 1992).
ACL15, LF18

COMMELINACEAE **SPIDERWORT FAMILY**

Commelina diffusa N. L. Burm. *HONOHONO*
Potentially invasive only in wet areas. Found along the road where the water seeps (Linney 1987).

Non-native: native to the Old World tropics.
LF12

CYPERACEAE **SEDGE FAMILY**

Cyperus gracilis R. Br. **MCCOY GRASS**
Non-native: native to Australia and New Caledonia.
ACL16

Eleocharis sp. **SPIKERUSH**
Not found in the July 1995 survey. In the survey attributed to Linney (1987), he states that this sedge is "found only in the floor of the crater. Its significance cannot be evaluated."

Non-native?
LF13

Fimbristylis cymosa R. Br.
[= Fimbristylis pycnocephala Hbd sensu LF13]
Native: indigenous to coastal areas of Australia, western Malesia, Pacific islands, the Neotropics and the Hawaiian Islands.
ACL16, LF13

Mariscus phleoides ssp. **phleoides** Nees ex Kunth
Not observed in this current survey. Reported as present in Kauhako Crater in November-December 1989 (Asherman et al. 1990).

Native: endemic to Kaua'i, Moloka'i, Lana'i, Maui and Hawai'i.
ACL16

MUSACEAE **BANANA FAMILY**

Musa x **paradisiaca** L. ***MAI'A*, BANANA**
Linney (1987) states that "a few plants were found in the vicinity of the pit crater at the beginning of the lava tube" but were not observed at this location during the course of the current survey.

Non-native: Polynesian introduction. Most edible bananas are sterile triploids that probably originated in Malesia and Southeast Asia.
ACL17, LF17

POACEAE — **GRASS FAMILY**

Andropogon virginicus L. — **BROOMSEDGE, YELLOW BLUESTEM**
A few tussocks of this invasive, alien grass were found on the upper western wall of the crater next to some ironwood trees. Due to its ability to form dense, monotypic groundcover which can exclude native species and carry fire (Anderson et al. 1992) , this grass should be eliminated whenever encountered and before becoming more firmly established.

Non-native: native to eastern North America and now extending into Central America.
ACL17

Botriochloa pertusa (L.) A. Camus — **PITTED BEARDGRASS**
Non-native: native to the Paleotropics.
ACL17, LF14

Cenchrus echinatus L. — **COMMON SANDBUR, *'UME'ALU***
Non-native: native to the Neotropics.
ACL17, LF14

Chloris barbata (L.) Sw. — **SWOLLEN FINGERGRASS, *MAU'U LEI***
Non-native: native to Central America, the West Indies and South America.
LF14

Cynodon dactylon (L.) Pers. — ***MANIENIE***
Non-native: possibly native to tropical Africa.
ACL17, LF14

Digitaria ciliaris (Retz.) Koeler — **HENRY'S CRABGRASS, *KUKAEPUA'A***
Non-native: native to China, Indo-China, Samoa and the Philippines.
ACL17

Digitaria insularis (L.) Mez ex Ekman — **SOURGRASS**
Non-native: native to Neotropics.
ACL18, LF15

Digitaria setigera Roth — **ITCHY CRABGRASS, *KUKAEPUA'A***
Native?: native to tropical Asia from India to Sri Lanka, and Pacific Islands; in Hawai'i, possibly indigenous or a very early introduction.
ACL18

Eleusine indica (L.) Gaertn. **WIREGRASS, *MANIENIE ALI'I***
Non-native: native to the Old World.
LF15

Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult. **LOVEGRASS**
Non-native: native to the Paleotropics.
LF15

Melinis minutiflora P. Beauv. **MOLASSESGRASS**
Although not recorded in any monitoring plots during the course of the July 1995 survey of the crater's flora, Asherman et al. (1990) reported the presence of this grass in the crater during their 1989 survey. As it is considered a serious pest in dry to mesic areas and can crowd out native vegetation (Wagner et al. 1990), as well as carry fire, the presence of this grass should be documented when encountered and any incipient infestations eliminated.

Non-native: native to Africa.
ACL18

Rhynchelytrum repens (Willd.) Hubb. **NATAL REDTOP, NATAL GRASS**
Non-native: native to Africa.
ACL18, LF15

Sporobolus indicus (L.) R. Br. **WEST INDIAN DROPSEED, SMUTGRASS**
[= Sporobolus sp. sensu LF15]
Non-native: native to the Neotropics.
ACL18, LF15

ANGIOSPERMS
DICOTYLEDONS

ACANTHACEAE — ACANTHUS FAMILY

Thunbergia sp.
Not observed in this survey but recorded as present by Asherman et al. (1990).

Non-native
ACL19

AMARANTHACEAE **AMARANTH FAMILY**

Amaranthus spinosus L. **SPINY AMARANTH, *PAKAI KUKU***
Linney (1987) states that this plant is "occasional along the road and potentially invasive on disturbed soil". Not recorded during monitoring in the July 1995 survey.

Non-native: widespread in warmer regions worldwide, perhaps of American origin.
LF11

Nototrichium sandwicense (A. Gray) Hillebr. ***KULU'I***
One large shrub was discovered in the northern half of the crater floor, on an upper bench, and to the west of the small pit crater. This plant was growing on the fringes of a christmas berry stand, but otherwise appears to be healthy and in no immediate danger.

Native: endemic to all of the main Hawaiian Islands.

ANACARDIACEAE **MANGO FAMILY**

Mangifera indica L. **MANGO, *MANAKO***
Non-native: native to Asia.
ACL19

Schinus terebinthifolius Raddi **CHRISTMAS BERRY, WILELAIKI**
This tree is an extremely aggressive plant which forms dense stands on the floor of the crater and the eastern outer slope (Linney 1987). It is one of the most common ground and canopy cover species in the native tree monitoring plots, and prevents the growth of other species in areas where it dominates. In addition, its sap can induce skin irritation and rashes in sensitive individuals.

Non-native: native to Brazil.
ACL19, LF12

APIACEAE **PARSLEY FAMILY**

Centella asiatica (L.) Urb. **ASIATIC PENNYWORT**
Linney (1987) states that this is an "insignificant weed of the roadsides, becoming important only in wet areas". Not recorded during monitoring in the July 1995 survey.

Non-native: native to Asia.
LF20

ARALIACEAE **GINSENG FAMILY**

Reynoldsia sandwicensis A. Gray *'OHE, 'OHE MAKAI*

This tree is still common on the western slope inside the crater, but is uncommon to rare in other locations, especially in the Schinus dominated eastern half and the Casuarina covered upper western slope. Of the 40 tagged trees, the large majority were deemed healthy, but most were in a state of defoliation and could not be accurately monitored for the presence of the two-spotted leafhopper (Sophonia rufofascia). This insect could play a major role in any propagation plans for Reynoldsia and could contribute to an overall decline in the crater population.

Native: endemic to Ni'ihau, O'ahu, Moloka'i, Lana'i, Maui and Hawai'i.
LF12

ASCLEPIADACEAE **MILKWEED FAMILY**

Asclepias curassavica L. **BUTTERFLY WEED,** ***LAULELE***
Non-native: native from Florida to South America and the West Indies.
ACL20

ASTERACEAE **SUNFLOWER FAMILY**

Ageratina riparia (Regel) R. King & H. Robinson *HAMAKUA PAMAKANI*
Non-native: native to Mexico and the West Indies.
ACL20

Ageratum conyzoides L. **AGERATUM,** ***MAILE HOHONO***
Non-native: native to Central and South America.
ACL20, LF12

Bidens pilosa L. **SPANISH NEEDLE,** ***KI NEHE***

Spanish needle accounted for an insignificant percentage of the ground cover in monitoring plots around native trees. Nevertheless, it has been known to seasonally dominate the understories of many native trees and possibly interfere with seedling recruitment in other dryland forest environments (Medeiros et al. 1993). For these reasons, any future monitoring protocol should closely follow changes in the range or increased abundance of weeds such as Spanish needle to identify problems before they become unmanageable.

Non-native: native to tropical America.
ACL20, LF12

Cirsium vulgare (Savi) Ten. **BULL THISTLE**
[= Cirsium arvense L. sensu LF12]
Non-native: native to Eurasia.
LF12

Conyza bonariensis (L.) Cronq. **HAIRY HORSEWEED**
Non-native: perhaps native to South America but now cosmopolitan in distribution.
ACL20, LF13

Emilia fosbergii Nicolson **FLORA'S PAINTBRUSH**
Non-native: native range unknown, perhaps a hybrid from Central or East Africa.
ACL20, LF13

Erechtites hieracifolia (L.) Raf. ex DC **FIREWEED**
Non-native: native from southern Canada to northern Argentina.
LF13

Hypochoeris radicata L. **HAIRY CAT'S EAR, GOSMORE**
Non-native: native to Eurasia.
ACL21, LF13

Lipochaeta rockii Sherff ***NEHE***
A single plant was observed on the rim of Ka'uhako Crater (Asherman et al. 1990).

Native: endemic to Moloka'i, Maui, Kaho'olawe and Hawai'i.
ACL21

Pluchea symphytifolia (Mill.) Gillis **SOURBUSH**
Linney (1987) states that Pluchea "has the potential of forming dense scrub on disturbed soil" which, during their survey, formed "a minor element of the scrub on the outer slopes in the southeastern sector."

Non-native: native to Mexico, the West Indies and northern South America.
LF13

Sonchus oleraceus L. **SOWTHISTLE, *PUALELE***
Non-native: native to Europe.
ACL21, LF13

Synedrella nodiflora (L.) Gaertn. **NODEWEED**
Non-native: native to the American tropics.
LF13

Taraxacum officinale W. W. Weber — **COMMON DANDELION**
Non-native: native to Eurasia.
LF13

Tridax procumbens L. — **COAT BUTTONS**
Non-native: native from Mexico, Central America, Venezuela, and Colombia to Peru and Bolivia.
ACL21, LF13

Vernonia cinerea (L.) Less. — **LITTLE IRONWEED**
Non-native: native to tropical Asia.
ACL21

Xanthium strumarium L. — **COCKLEBUR, *KIKANIA***
Non-native: probably native to the New World.
LF13

BORAGINACEAE — BORAGE FAMILY

Heliotropium ampexicaule Vahl — **HELIOTROPE**
Linney (1987) states that this is "a vigorous weed found along the road. Probably of no significance due to its small stature."

Non-native: native to Argentina and Uruguay.
LF12

BRASSICACEAE — MUSTARD FAMILY

Lepidium bidentatum Montin var. **o-waihiense** (Cham. & Schlechtend.) Fosb. — ***'ANAUNAU***
Asherman et al. (1990) found three sterile plants between the mouths of Waile'ia and Waikolu along the coast at Keanakua, on the cliffs, 3 to 5 meters above the boulder beach.
On the 1995 survey, Art Medeiros found the desiccated skeleton of a plant on the cliff face at the beginning of the lava tube as it extends from the northwest portion of the crater, which he identified as a Lepidium. This area should be further explored for what may be *'Anaunau* progeny following the wet season, when vegetation will be green and more readily identifiable. *'Anaunau*, which is widespread in the Pacific (Wagner et al. 1990), currently has no federal status but is proposed as a Category 2 candidate for listing.

Native: Variety endemic to Kaua'i, O'ahu, Moloka'i, Lana'i, Maui and Hawai'i.
ACL22

CARICACEAE **PAPAYA FAMILY**

Carica papaya L. **PAPAYA, *MIKANA***
Linney (1987) states papaya is "a straggler not likely to persist unless cultivated. It was seen only twice in the crater." One tree was observed during this survey.

Non-native: native to the Neotropics.
ACL23, LF12

CASUARINACEAE **SHE-OAK FAMILY**

Casuarina equisetifolia L. **COMMON IRONWOOD, *PAINA***
Linney (1987) states that ironwood "stands on the inner slopes of the western half of the crater bear watching, as they border good remnant native vegetation." In this survey's vegetation monitoring, Casuarina litter made up a significant portion of the ground cover, while larger trees comprised a consistently high percentage of the canopy cover within the 5.64 m radius plots around Pleomele and Reynoldsia trees. The encroachment of ironwood not only prevents the establishment of native species under its dense stands, but also will likely pose a threat to the stands of native trees located on the slopes below. Some form of mechanical or chemical control should be attempted to stem its further spread.

Non-native: native to Australia.
ACL23, LF12

CONVOLVULACEAE **MORNING GLORY FAMILY**

Ipomoea indica (J. Burm.) Merr. **MORNING GLORY, *KOALI'AWA***
Widespread but not abundant throughout the floor of the crater (Linney 1987.)

Native: indigenous in low elevations of all the main islands and pantropical.
ACL24, LF13

Ipomoea cf. **violacea** L.
Non-native: pantropical.
ACL24

CRASSULACEAE **ORPINE FAMILY**

Kalanchoe pinnata (Lam.) Pers. **AIR PLANT, LIFE PLANT**
Linney (1987) found this plant only along the road but states that "because it has the potential to spread with great rapidity, excluding other understory plants, and resists removal, its presence should not be tolerated at any time." It was not observed to make up a significant portion of the crater vegetation during the course of this survey.

Non-native: native range unknown, now widely established in many tropical and subtropical areas.
ACL24, LF13

EBENACEAE **EBONY FAMILY**

Diospyros sandwicensis (A. DC) Fosb. ***LAMA, ELAMA***
Two medium-statured trees, not recorded as present in the crater during the surveys of Linney (1987) or Asherman et al. (1990), were located on the inner northeastern slope during the 1995 summer survey. These individuals, which appeared to be healthy, were tagged and vital statistics were recorded to monitor their long term vigor and status (Table 11).

Native: Endemic to all of the main Hawaiian islands except Ni'ihau and Kaho'olawe.

EUPHORBIACEAE **SPURGE FAMILY**

Aleurites moluccana (L.) Willd. **CANDLENUT TREE, *KUKUI***
Confined to the inner slopes of the northeastern quadrant and dominant around and above a small pit crater at the opening of the lava tube (Linney 1987).

Non-native: Polynesian introduction native to Malesia.
LF14, ACL25

Chamaesyce celastroides (Boiss.) Croizat & Degener ***'AKOKO***
var. **amplectans** (Sherff) Degener & I. Degener
Linney (1987) states '*Akoko* is "common at the summit and upper portions of the inner slope of the northwestern quadrant. Specimens of about two meters height may be found in the '*Ohe-Hala pepe* remnant forest." Still fairly common in 1995.

Native: endemic to Nihoa and all of the main islands.
ACL25, LF14

Chamaesyce hirta (L.) Millsp. **HAIRY SPURGE**
Non-native: native from southern United States to Argentina, the West Indies, and the Paleotropics.
ACL25, LF14

Chamaesyce prostrata (Aiton) Small **PROSTRATE SPURGE**
Prostrate and hairy spurge are insignificant and are uncommon along roads and tracks (Linney 1987).

Non-native: native from southern United States to South America, the West Indies, and the Paleotropics.
LF14

Phyllanthus debilis Klein ex Willd. **NIRURI**
Insignificant in disturbed soil (Linney 1987).

Non-native: probably native to southern India and Sri Lanka.
ACL25, LF14

Ricinus communis L. **CASTOR BEAN, *PA'AILA***
Linney (1987) only observed two plants in the crater and states that "it is unlikely to increase and become a threat to the ecosystem." Not found in any of the 1995 monitoring plots and not a significant component of the vegetation.

Non-native: native to Africa and perhaps India.
ACL25, LF14

FABACEAE PEA FAMILY

Caesalpinia bonduc (L.) Millsp. ***KAKALAIOA*, GRAY NICKERS**
[= Caesalpinia major (Medik.) Dandy & Exell sensu LF15]
Occasional at the base of Ka'uhako Crater (Asherman et al. 1990.) Linney (1987) describe this plant as "a most undesirable vine due to its savage thorns. Its presence can render an area impenetrable. Plants were occasional on the floor of the crater in the crowns of smaller trees, but more common on the lower inner slopes of the northeastern quadrant, where it formed thickets." This plant has the potential to increase substantially following the exclusion and removal of feral ungulates from the crater, and may need to be actively managed in order to prevent it from dominating regions and making them impassable.

Native: either an early introduction or indigenous to Ni'ihau, Kaua'i, O'ahu, Moloka'i, East Maui and Hawai'i, and pantropical.
ACL26

Chamaecrista nictitans (L.) Meonch ssp. **patellaria** (DC ex Collad.) H. Irwin & Barneby var. **glabrata** (Vogel) H. Irwin & Barneby — **PARTRIDGE PEA, *LAUKI***

Non-native: native to the Neotropics.
ACL26, LF15

Crotolaria sp. — **RATTLEPOD**
Non-native.
LF15

Desmodium incanum DC — **SPANISH CLOVER, *KA'IMI***
Non-native: native to tropical and subtropical America.
ACL26, LF16

Desmodium triflorum (L.) DC
Non-native: native to the Old World tropics and subtropics.
ACL26

Erythrina sandwicensis Degener — ***WILIWILI***
According to Linney (1987), there are two populations of *Wiliwili* trees, one on the outer slope of the eastern quadrant, and the other on the crater floor. Christmas berry can be a serious competitor to these trees and excludes practically all other plants from the eastern half of the crater. However, in areas where the canopy inhibited christmas berry dominance, Linney did note that seeds germinated on the crater floor. This phenomenon was not observed during the 1995 survey. Of the 30 tagged individuals monitored in the 1995 survey, 19 were considered healthy, and 5 were considered unhealthy. Aside from the general lack of seedling recruitment throughout the crater floor, a definite threat to the long term survival of the population comes from the presence of Chinese banyan (Ficus microcarpa) on some trees. With their invasive root systems and expanding foliar crown, Chinese banyans are expected to accelerate the decline of the larger *Wiliwili* trees, many of which are already in a stage of senescence. As of July 1995, 3 of the 30 tagged trees had Chinese banyan growing on them. A strategy of selective removal of Chinese banyans should be implemented to check their spread while the invasion is still in its incipient stages.

Native: endemic on leeward slopes of all the main islands.
ACL26, LF16

Haematoxylum campechianum L. — **LOGWOOD, BLOODWOOD**
An uncommon element of the liliputian forest, roadside scrub and scree just below the ironwoods (Linney 1987).

Non-native: native in the Neotropics.
LF16

Indigofera suffruticosa Mill. **INDIGO, *'INIKO***

Non-native: pantropical, but presumably of Neotropical origin.
ACL26, LF16

Leucaena leucocephala (Lam.) de Wit ***KOA HAOLE***

Linney (1987) states this tree is "occasional to common throughout the area, especially along roads and tracks of the outer slope, southwest quadrant. Heavily infested with psyllids, they are not a community dominant in any part of the crater. One or two stressful seasons could reduce this to a minor component". *Koa haole* was not a major cover component in any of the 1995 monitoring plots.

Non-native: native to the Neotropics.
ACL26, LF16

Macroptilium lathyroides (L.) Urb. **WILD BEAN, COW PEA**

Non-native: native to the Neotropics.
ACL26, LF16

Mimosa pudica L. **SENSITIVE PLANT**

This plant has the potential for becoming a pest due to its prickles, and can form thickets on disturbed soil (Linney 1987).

Non-native: a pantropical weed, probably native to South America.
LF16

Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth ***KIAWE,* MESQUITE**

Non-native: native to Peru, Colombia and Ecuador.
ACL27

Senna gaudichaudii (Hook. & Arnott) H. Irwin & Barneby ***KOLOMONA***

A single, small shrub was found by Art Medeiros in June 1995, growing on the northwest slope inside the crater, approximately seven meters from tagged Reynoldsia sandwicensis #27. This individual, tag #396, is healthy and had fruits present in July 1995, although no seedlings were observed. The long term status of this individual should be monitored, and fruits should be collected for future propagation and planting.

Native: indigenous to all the main islands except Ni'ihau and Kaho'olawe, and occurring in the Pacific Basin.

Senna pendula (Humb. & Bonpl. ex Willd.) H. Irwin & Barneby

Non-native: native to the New World tropics and subtropics.
ACL27, LF16

Tephrosia purpurea (L.) Pers. *'AUHUHU*
Growing on the inside rim of the crater, particularly on the north and northeastern sides.

Non-native: Polynesian introduction native from Africa to southern Asia and Malesia, tropical Australia and the Tuamotus.

GOODENIACEAE — GOODENIA FAMILY

Scaevola gaudichaudii Hook. & Arnott *NAUPAKA KUAHIWI*
A single colony of at least 20 individuals observed below the southwestern rim of the crater (Asherman et al. 1990).

Native: endemic to all the main islands except Ni'ihau and Kaho'olawe.
ACL28

Scaevola sericea Vahl *NAUPAKA KAHAKAI*
[= Scaevola taccada (Gaertn.) Roxb. sensu LF14]
Linney (1987) states that "highly stunted plants are characteristic of the north-facing outer slope where lantana does not thrive. Possibly a former co-dominant with Fimbristylis before the arrival of exotics." Axis deer also prefer to browse on plants and denude all branches within reach of green foliage. Fencing off of any plants from browsing pressure should yield dramatic results.

Native: indigenous to all the main islands, and occurring throughout tropical and subtropical Pacific and Indian Ocean coasts.
ACL28, LF14

LAMIACEAE — MINT FAMILY

Hyptis pectinata (L.) Poit. **COMB HYPTIS**
Characteristic on roadsides, reaching a height of up to two or more meters (Linney 1987).

Non-native: Native to tropical America.
ACL28, LF15

Plectranthus parviflorus Willd. **SPURFLOWER,** ***'ALA'ALA'WAI NUI***
A minor element of the rocky, scree community in the *'Ohe-Hala pepe* remnant forest (Linney 1987).

Native: Indigenous from Australia to Melanesia and Polynesia, as well as all of the main Hawaiian islands except Kaho'olawe.
ACL28, LF15

LAURACEAE — LAUREL FAMILY

Cassytha filiformis L. — *KAUNA'OA PEHU*
This native plant has the capability of forming dense shrouds over host plants, and as a parasite with detrimental effects, may warrant control on certain of the rare plants (Linney 1987). It comprised an insignificant amount of the vegetative cover in the monitoring plots, and was rather inconspicuous in many areas.

Native: Indigenous on all of the main Hawaiian islands except Kaho'olawe, and pantropical.
ACL28, LF15

MALVACEAE — MALLOW FAMILY

Abutilon grandifolium (Willd.) Sweet — **HAIRY ABUTILON, *MA'O***
Non-native: Native to the New World.
ACL28, LF17

Malvastrum coromandelianum (L.) Garcke subsp. **coromandelianum** — **FALSE MALLOW**
Non-native: Pantropical.
ACL29, LF17

Sida fallax Walp. — *'ILIMA*
A common component on the outer crater slopes in areas of low-statured shrubs and vegetation (Linney 1987).

Native: Indigenous from several Pacific islands to China, as well as all of the main Hawaiian islands.
ACL29, LF17

Thespesia populnea (L.) Sol. ex Correa — **PORTIA TREE, *MILO***
Native?: Native to the Old World, although questionably indigenous to Ni'ihau, Kaua'i, O'ahu, Moloka'i, Maui and Hawai'i.
ACL29, LF17

MENISPERMACEAE — MOONSEED FAMILY

Cocculus trilobus (Thunb.) DC — *HUEHUE*
This native vine is a minor component of the remnant *'Ohe-Hala pepe* forest, accounting for less than one percent of the ground cover in the monitoring plots. Despite this low cover value, it was still one of the five most common native taxa, by ground cover, in the area.

Native: Indigenous from southeastern Asia to the Himalayas, Malesia and areas of the Pacific including all of the main Hawaiian islands except Kaho'olawe.
ACL29, LF17

MORACEAE **MULBERRY FAMILY**

Artocarpus altilis (Parkins. ex Z) Fosb. **BREADFRUIT, *'ULU***
The few large trees which are present in the crater are located in the vicinity and above the pit crater in the northeast corner at the beginning of the lava tube (Linney 1987).

Non-native: Polynesian introduction native to Malesia and widely cultivated in the tropical Pacific.
ACL29, LF17

Ficus microcarpa L. fil. **CHINESE BANYAN**
This non-native tree has the potential to become a serious problem in the crater due to its strangling and shading effects on trees, especially natives, as well as its disruptive nature on stonework and other archeological structures. Small individuals and larger plants were found scattered throughout the crater, growing both on the floor and epiphytically on trees. This weed should be controlled while the invasion is still in its incipient stages and can be managed with a minimal amount of disturbance to both the crater's flora and archeological sites.

Non-native: Native from Ceylon to India, southern China, Ryukyu Islands, Australia, and New Caledonia.
ACL29, LF17

MYRTACEAE **MYRTLE FAMILY**

Psidium cattleianum Sabine **STRAWBERRY GUAVA, *WAIAWI***
Although recognized as one of the worst weeds in the wet forests of the islands, with its fruits and seeds readily spread by birds and pigs, only small strawberry guava saplings were recorded in the monitoring plots, and accounted for a minimal percentage of the vegetative cover. Due to the relatively dry microclimate of the crater region, and following the exclusion of feral animals by means of fencing, it is unlikely that this plant will become as serious a problem as it has in wet forest regions. Nevertheless, the spread of this plant should be monitored and individuals removed when feasible to prevent its further establishment and development into a more serious management problem.

Non-native: Native to the Neotropics.
ACL30

Psidium guajava L. **COMMON GUAVA, *KUAWA***

Common guava is widespread both inside and outside the crater, but is nowhere near as common as christmas berry or Java plum and does not dominate in any areas where it is present. It does account for one of the higher percentage covers of alien plants in the monitoring plots, but this amount is still relatively negligible. Nevertheless, because of its potential to spread and form monotypic stands, its spread should be followed.

Non-native: Native to the Neotropics.
ACL30, LF17

Syzygium cumini (L.) Skeels **JAVA PLUM**

Java plum, although considered a problem, provides an open forest in the crater which seems to support understory growth and may hold back the spread of christmas berry. (Linney 1987). This tree is one of the dominants on the crater floor, and accounts for the highest average percentage canopy cover in all of the monitoring plots. It will likely be necessary to selectively remove trees in certain areas to assist in the recovery of native vegetation.

Non-native: Possibly native to India, Ceylon and Malesia.
ACL30, LF17

OXALIDACEAE — WOOD SORREL FAMILY

Oxalis corniculata L. **YELLOW WOOD SORREL, *'IHI MAKOLE***

A roadside weed of no significance.

Non-native: possible Polynesian introduction of unknown origin.
ACL30, LF18

PASSIFLORACEAE — PASSION FLOWER FAMILY

Passiflora edulis Sims **PASSION FRUIT, *LILIKO'I***

Non-native: Native to Brazil.
ACL31, LF18

Passiflora subpeltata Ort. **WHITE PASSION FLOWER**

[= Passiflora sp. sensu LF18]

This plant accounted for an insignificant portion of the vegetative cover in the monitoring plots and is only an occasional presence in the crater. As Linney (1987) discovered, "many unidentified seedlings were seen" which "may represent a future problem, or perhaps high germination rates and low survival to maturity." The findings in this survey suggest the latter to be true.

Non-native: Native to Mexico, Central America, and northern South America.
ACL31, LF18

PHYTOLACCACEAE **POKEWEED FAMILY**

Phytolacca octandra L. **SOUTHERN POKEBERRY**
A few plants were found by Linney (1987) on the floor of the crater and along the road, but were not recorded in the monitoring plots and are apparently uncommon in both areas.

Non-native: Native to the Neotropics.
ACL31, LF18

PIPERACEAE **PEPPER FAMILY**

Peperomia leptostachya Hook. & Arnott ***'ALA'ALA WAI NUI***
This native plant is relatively common in the rocky slopes of the *'Ohe-Hala pepe* remnant forest and at the eastern side of the lava tube's source (Linney 1987). It was one of the most common native plants, by percentage ground cover, in the monitoring plots situated around *'Ohe* and *Hala pepe* trees, but its presence was not noted in any of the *Wiliwili* plots.

Native: Indigenous from Micronesia and Queensland, Australia, through Melanesia to Polynesia and all of the main Hawaiian islands except Kaho'olawe.
ACL31, LF18

PLANTAGINACEAE **PLANTAIN FAMILY**

Plantago lanceolata L. **NARROW-LEAVED PLANTAIN**
Non-native: Native to Europe and north-central Asia.
ACL32

PLUMBAGINACEAE **PLUMBAGO OR LEADWORT FAMILY**

Plumbago zeylanica L. ***'ILIE'E***
Locally common on the crater floor (Linney 1987), although presence not recorded in any monitoring plots during the 1995 survey.

Native: Indigenous to the Old World tropics and the Hawaiian Islands.
ACL32, LF18

POLYGONACEAE — BUCKWHEAT FAMILY

Rumex crispus L. — **CURLY DOCK, YELLOW DOCK**
Linney (1987) found only one plant at the water seep along the road, but Asherman et al. (1990) recorded its presence in Kalawao, Waile'ia Valley and Waikolu Valley only. Although listed as a secondary noxious weed by the USDA, the crater's climate is probably too dry for it to become much of a problem there.

Non-native: Native to Europe.
ACL32, LF18

PORTULACACEAE — PURSLANE FAMILY

Portulaca oleracea L. — **PIGWEED, *'IHI***
Non-native: Presumably native to the Old World.
ACL32

Portulaca pilosa L.
Common component of crater rim vegetation in the eastern half of the crater (Linney 1987). It can be found growing with the endangered Portulaca villosa Cham. and can be distinguished from the latter by its dark blue seeds with a metallic luster versus dark reddish brown seeds in P. villosa (Wagner et al. 1990).

Non-native: Pantropical.
ACL32, LF19

Portulaca villosa Cham. — ***'IHI***
Asherman et al. (1990) found six plants, both young and mature, growing in the southwestern rim of Ka'uhako Crater, to the east of the cross and just below the crater rim. This population was relocated in the 1995 survey and those individuals present were found to be fruiting. P. villosa is a Category 2 candidate under consideration for listing as endangered, although more information on its vulnerability and threats to its survival are required to substantiate such a designation.

Native: Endemic to all of the main Hawaiian islands except Ni'ihau and Kaua'i.
ACL32

PRIMULACEAE — PRIMROSE FAMILY

Anagallis arvensis L. — **SCARLET PIMPERNEL**
An insignificant component of the vegetation (Linney 1987) not recorded inside the monitoring plots during this survey.

Non-native: Native to Europe.
LF19

ROSACEAE — ROSE FAMILY

Osteomeles anthyllidifolia (Sm.) Lindl. — ***'ULEI***

A few plants can be found in the remnant *'Ohe-Hala pepe* forest and make up a rather insignificant percentage of the ground cover within the monitoring plots.

Native: Indigenous to the Cook Islands, Tonga, and all of the main Hawaiian Islands except Ni'ihau and Kaho'olawe.
ACL33, LF19

Rubus rosifolius Sm. — **THIMBLEBERRY**

A thorny weed not common in the crater (Linney 1987) and not recorded inside the monitoring plots of this survey.

Non-native: Native to Asia.
LF19

RUBIACEAE — COFFEE FAMILY

Morinda citrifolia L. — *NONI*

Occasional in the crater and comprising a minor portion of the percentage cover in the *'Ohe-Hala pepe* monitoring plots.

Non-native: Polynesian introduction native from southeastern Asia to Australia.
ACL33, LF

Psydrax odorata (Forst. f.) A.C. Sm. & S. Darwin, comb. nov. — *ALAHE'E*

[= Canthium odoratum (G. Forster) Seem. sensu ACL33, LF19]

A single plant was found in the crater by Linney (1987) and Asherman et al. (1990) in Ka'uhako Crater on the inner northeastern slope. Two individuals were discovered and tagged in the same area during the course of this survey. Vital statistics were recorded for both individuals, and their long term progress will be monitored in the future.

Native: Indigenous to Micronesia, and the South Pacific from the New Hebrides and New Celedonia east to the Tuamotus, as well as all of the main Hawaiian Islands except Ni'ihau and Kaho'olawe.
ACL33, LF19

SOLANACEAE **NIGHTSHADE FAMILY**

Nicotiana tabacum L. **TOBACCO, *PAKA***
Non-native: Native to western South America.
ACL34

Solanum americanum Mill. **GLOSSY NIGHTSHADE, *POPOLO***
Native?: Indigenous to warm tropical areas and possibly all of the main Hawaiian Islands.
ACL34

Solanum capsicoides All. **COCKROACH BERRY, *KIKANIA LEI***
[= Solanum aculeatissimum Jacq. sensu LF19]
Non-native: Native to extra-tropical North and South America.
LF19

Solanum seaforthianum Andr.
Occasional on the crater floor (Linney 1987) and comprising an insignificant percentage cover of the monitoring plots.

Non-native: Native to the West Indies.
ACL35, LF19

STERCULIACEAE **CACAO FAMILY**

Waltheria indica L. ***'UHALOA, HI'ALOA***
A common member of the summit flora, especially on the northeastern quadrant (Linney 1987).

Native?: Pantropical and questionably indigenous to all of the main islands.
ACL35, LF19

THYMELACEAE ***'AKIA* FAMILY**

Wikstroemia oahuensis (A. Gray) Rock ***'AKIA***
Native: Endemic to Kaua'i, O'ahu, Moloka'i, Lana'i, and Maui.
ACL35

Wikstroemia uva-ursi A. Gray ***'AKIA***
Linney (1987) states that this *'Akia* is "common only at the summit on the northeastern quadrant and cliff faces of the inner slope immediately adjacent." It was most common in the monitoring plots surrounding the *'Ohe* trees in the remnant dryland forest but still only accounted for a relatively small percentage of the overall cover.

Native: endemic to Kaua'i, O'ahu, Moloka'i and Maui.
ACL35, LF20

TURNERACEAE — TURNERA FAMILY

Turnera ulmifolia L. — **YELLOW ALDER**

Yellow alder is nearly ubiquitous in the crater but does not form ground covers exclusive to other plants and is not a real threat to the survival of any native species.

Non-native: Native to Florida, the West Indies and tropical America.
ACL35, LF20

URTICACEAE — NETTLE FAMILY

Pilea peploides (Gaud.) Hook. & Arnott

Native: Indigenous to northern South America, Galapagos Islands and all of the main Hawaiian Islands except Ni'ihau and Kaho'olawe.
ACL35

VERBENACEAE — VERBENA FAMILY

Lantana camara L. — **LANTANA, *LAKANA***

Linney (1987) call this plant "the single most pervasive species in the area". It forms a dense scrub on the outer slopes of the crater, especially in the northeastern half and is fairly common within the crater itself, except where christmas berry and Java plum predominate. Although it is one of the more common taxa in the monitoring plots, it did not form exclusive stands in any areas around the native trees and was mostly scrubby, and low statured.

Non-native: Probably native to the West Indies.
ACL35, LF20

Stachytarpheta jamaicensis (L.) Vahl — **JAMAICA VERVAIN, *OWI, OI***

[= Stachytarpheta sp. sensu LF20]
Non-native: Native to tropical and subtropical areas of the New World.
ACL35, LF20

Stachytarpheta urticifolia (Salisb.) Sims — ***OI***

[= Stachytarpheta sp. sensu LF20]
Non-native: Probably native to tropical Asia.
ACL36, LF20

Verbena **litoralis** Kunth *OWI, OI*

An uncommon and insignificant roadside weed (Linney 1987).

Non-native: Native from southern Mexico through Central America and South America.
LF20

Vitex **trifolia** L. *POLINALINA*

A single plant was seen along the road by Linney (1987) but no plants were recorded in the 1995 survey.

Non-native: Native from Asia to Australia.
LF20