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Technical Report 122

BOTANICAL SURVEY OF KILAUEA VOLCANO EAST RIFT CRATERS: HAWAII VOLCANOES NATIONAL PARK

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National Park Service Cooperative Agreement
CA8033-2-9004

November 1998

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ABSTRACT

Three forested craters, Pu'u Huluhulu, Kane Nui O Hamo, and Napau Trail Pit Crater, located on Kīlauea volcano's East Rift Zone, were surveyed for feral pig (*Sus scrofa*) activity, alien plant species, and endangered, rare, and uncommon native plant species in 1995-1997. Plant species lists were prepared and Braun-Blanquet relevé method was used to determine cover and abundance of vegetation. Relevé plots were established at all three craters (two in Pu'u Huluhulu, two in Napau Trail Pit Crater, and five in Kane Nui O Hamo) to characterize forest type, species diversity, and species density occurring at these craters. These plots were replicated in exterior forests near these craters for *qualitative* comparison between interior and exterior forests. A total of eighteen plots were established.

The craters have very steep interior walls inhibiting feral pig ingression. Using USGS- Biological Resources Division feral pig activity survey protocol it was determined that feral pigs have not been present recently within these forested craters. Sources of disturbance to interior crater forests are localized events such as tree and rock fall.

Twenty-one alien plant species were located in the survey areas; nine at Kane Nui O Hamo, six at Napau Trail Pit Crater, and fifteen at Pu'u Huluhulu. The most aggressive alien plant species included firetree (*Myrica faya*), kahili ginger (*Hedychium gardnerianum*), yellow Himalayan raspberry (*Rubus ellipticus*), and beardgrass (*Andropogon virginicus*). Alien plant species diversity in the craters is very low, much lower than the surrounding forests. We attribute this finding to the absence of feral pig disturbance, low levels of natural disturbance such as rock and tree fall, and a high diversity and density of native plant species which enhance recovery of disturbed sites.

Thirteen rare and uncommon plant species were located in the survey areas. Two of these species, *Phyllostegia floribunda*, and *pāwale* (*Rumex giganteus*), had not previously been recorded for the ERZ. Persistence of rare and uncommon native plant species may be attributed to steep interior crater walls and rough and variable terrain of crater floors which act as natural barriers to feral pigs, low intensity of natural disturbance, high diversity and density of other common native plant species, and a unique microclimate and microhabitat.

INTRODUCTION

Because of very steep topography or rough lava, some areas in Hawai'i have remained untouched by the damaging effects of feral herbivores and serve as natural exclosures. Most of these areas are on cliff faces or mountaintops and provide atypical samples of pristine Hawaiian vegetation. Surveys suggest that the plant communities of these undisturbed sites are essentially intact and introduced species are almost lacking (Loope and Scowcroft 1985).

Feral pigs (*Sus scrofa*) are currently the most pervasive and disruptive alien influence on the unique native forests of the Hawaiian Islands. The degradation of natural communities in Hawai'i by pig rooting and trampling is well documented (Baker 1979; Mueller-Dombois *et al.* 1981; Stone 1985; Stone and Loope 1987; Stone and Anderson, 1988; Cuddihy and Stone 1990; Stone, 1991; Katahira *et al.* 1993; Anderson and Stone 1993, Vitousek *et al.* 1996).

Fifty monitored exclosures have shown that the native vegetation holds its own or increases following removal of feral pigs. Nevertheless, the chance of recovery becomes reduced as degradation increases (Loope and Scowcroft 1985, Kathahira 1980, Higashino and Stone 1982, Stone *et al.* 1992). Two exclosures established in Hawaii Volcanoes National Park to monitor recovery of rain forest understory from feral pig damage show rates of native species recovery from 4.5 to 13 years (Higashino and Stone 1982). Depending on the type and duration of the disturbance forest species composition may never recover to its pre-disturbance condition due to elimination of some native plant species combined with persistence of invasive alien plant species (Stone *et al.* 1992).

Objectives of this survey were to: learn if the pit craters are pig free and to detect any past disturbance by pigs; conduct rare plant surveys focusing on endangered plant species, plant species of concern, and uncommon plant species within selected craters of the ERZ; establish Braun-Blanquet relevé plots to illustrate structural composition and cover density of plant species at selected sites; compile a checklist of plant species of the ERZ crater survey areas; to investigate the flora and vegetation of three ERZ craters in wet forest types at HAVO to document the status of native plants and plant communities in potentially naturally pig-free sites and compare with surrounding areas with a long history of pig disturbance.

As no early detailed studies of vegetation exist for the East Rift, original forest conditions, species composition, and densities are not known. It can be inferred from botanical checklists of recent surveys that plant species once documented for the forests of the ERZ no longer occur there or their distributions and densities have been greatly reduced.

G.O. Fagerlund and A.L. Mitchell, who conducted intensive fieldwork at HAVO from 1941-1947, provided historical baseline documentation of rare, uncommon, and alien plant species.

SURVEY AREAS

Three sites were chosen for the survey. All occur along the East Rift Zone of Kilauea volcano within HAVO. This zone trends east from Kilauea caldera to the Puna coast and in recent years has been the focus of significant volcanic activity including the recent flows of Pu'u 'O'o from 1983 to the present. From west to east the survey areas are Pu'u Huluhulu cinder cone, Kane Nui O Hamo shield volcano, and Napau Trail Pit Crater (no mapped name) (Figure 1.). Pu'u Huluhulu is within the prehistoric 'Ailaau lava flows of 250-350 years BP. The Kane Nui O Hamo and Napau sites are within the prehistoric Kane Nui O Hamo lava flows of 500-750 years BP. Historic lava flows from 1840, 1965, 1969, and 1972 occur on or near Kane Nui O Hamo (Holcolmb 1987).

Vegetation maps of HAVO place the survey sites in a montane wet forest environment of open *Metrosideros-Cibotium* forests (Mueller-Dombois and Fosberg 1974, Wagner 1990 *et al.*). Elevations range from ca. 1006m (3,300 ft) at Pu'u Huluhulu to 853m (2,800 ft) at Napau Trail Pit Crater. Crater depths average 76m (250ft). Mean annual rainfall averages 1500 millimeters for the East Rift Zone (Giambelluca *et al.*, 1986).

The craters were selected for survey on the basis of accessibility, their dense forest, and their structural and environmental comparability. No eruptive activity has taken place within these sites for several hundred years. No descriptive studies of forest succession have been conducted within the survey areas but it is assumed that over time forest species composition and density moves toward a dynamic equilibrium with the prevailing climate and topography. Periods of disturbance alternate with periods of stability occurring at scales from isolated rock and tree falls to die back of stands of 'ohi'a (*Metrosideros polymorpha).* Surveys were conducted in October through December 1995, and February 1996, with additional data collected from Pu'u Huluhulu in September 1997 and from Kane Nui O Hamo in December 1997.

All three survey sites are characterized by steep interior slopes ranging from 75 - 90 percent slope. The interior craters are the product of magma retreat, subsidence, and erosion processes. Exposed rock and cliffs are found more frequently on the upper interior slopes creating a rough and varied topographic barrier to feral pigs. With porous cinder soils and exposure to wind the upper interior slopes tend to be drier than the lower interior slopes and crater bottoms where wind influence is minimal and humidity is higher.

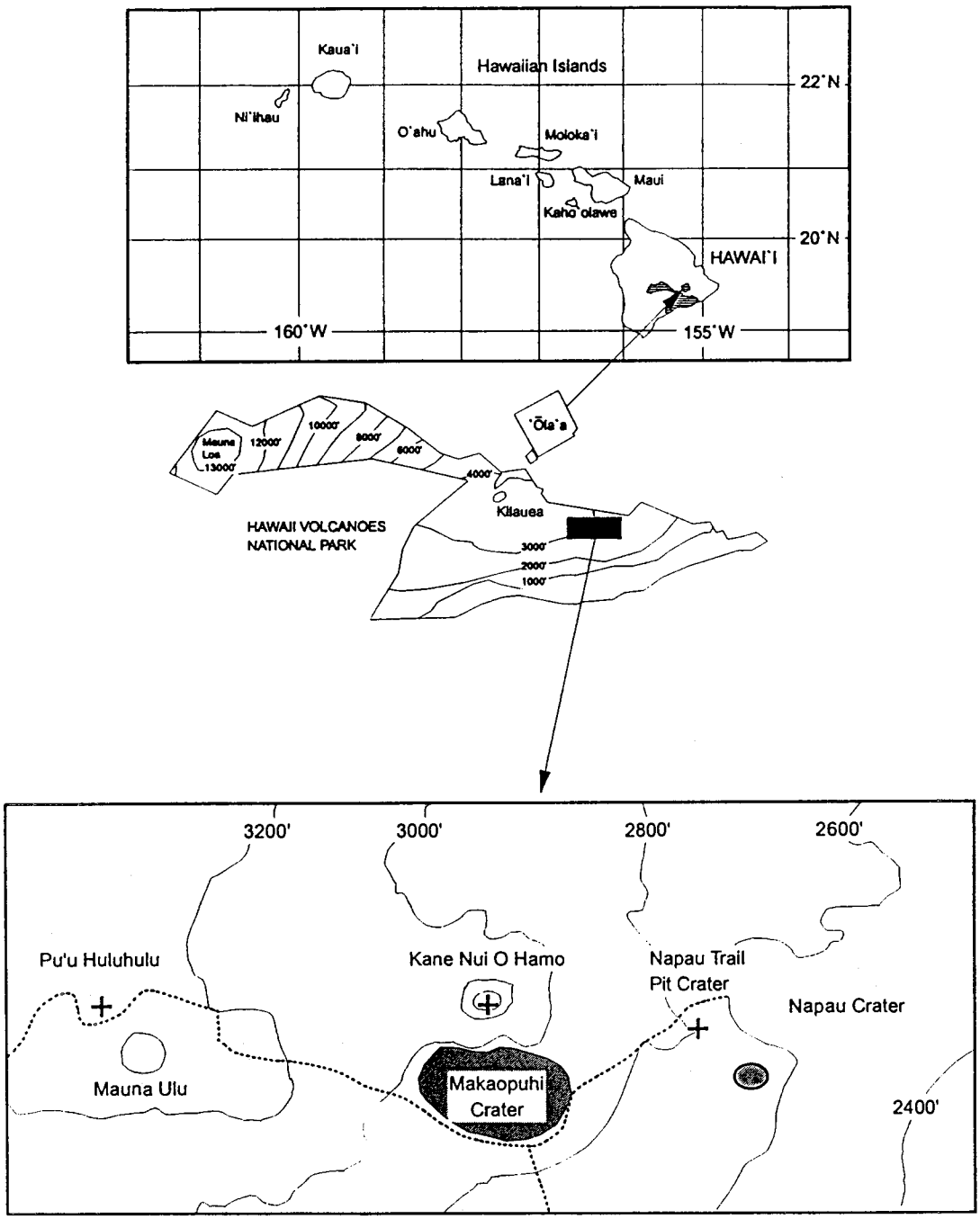

Figure 1. Map of East Rift Craters (study sites indicated as +), Hawaii Volcanoes National Park, island of Hawai'i.

As a consequence of substrate and exposure the upper interior slopes carry different configurations of plant species usually representing a younger forest type. Open rock and cliff faces on upper crater slopes commonly support alien grass species.

Kane Nui O Hamo has multiple bottoms separated by interior crater walls. Five of these pits were investigated; all are characterized by cool temperatures, high humidity, and dense bryophyte cover. Water was observed dripping from the interior walls at these sites even during an extended period of dry weather. We also measured temperature along one transect at Kane Nui O Hamo. A temperature decrease of 6.7° F. over 240ft (73m) decrease in elevation was observed. This exceeds the standard adiabatic rate of 4° F. per 1000ft (ca. 300 m) of elevation loss or gain. In addition, clouds were observed forming within the crater in the early morning hours as warm moist air flowed into the crater, cooled with decreasing elevation, and water vapor condensed. It is likely that fog drip significantly contributes to the local moisture regime. Because of their depth these sites are protected from the drying effects of wind and wind disturbance.

METHODS

Entry points at the crater rims were determined by accessibility. From the entry point a compass bearing was taken and the transect begun. Observations of the presence or absence of pig activity along the transect and throughout the survey area followed USGS - Biological Resources Division protocol criteria for pig activity (Anderson and Stone 1993). A species checklist was begun at the entry point on the crater rim. Plant species were recorded as they were observed along the transect. Areas such as crater floors, cliffs, bryophyte rich substrates, and large tree ferns and trees that support dense arrays of epiphytes were surveyed intensively.

The Braun-Blanquet relevé method (Mueller-Dombois and Ellenburg 1974) was used to sample vegetation cover in five strata and assign cover class in six cover abundance (by per-cent cover) ratings (Table 1). The relevé method also provided ease of use and rapid assessment of vegetation with limited time in remote areas of the East Rift Zone.

Table 1. Braun-Blanquet Relevé Stratum and Cover Abundance Ratings

Stratum
Bryophyte layer : <5cm., ground-apressed, low carpet
Ground layer : <30 cm to 1m, or woody tree species seedling
Shrub layer : 1m to 5m
Sub-Canopy : >5m and not emergent
Canopy : emergent above sub-canopy

Rating (cover class)

+ = 0-1 %	3 = 25 - 50 %
1 = 1 - 5 %	4 = 50 - 75 %
2 = 5 - 25 %	5 = 75 - 100 %

A total of 18 Braun-Blanquet relevé plots were established during this survey. Nine plots (each 20x20 m) were established in the interior crater forests: two plots each for Pu'u Huluhulu and Napau Trail Pit Crater and five at Kane Nui O Hamo. Nine plots were replicated in the exterior forests of the craters for comparative purposes. Elevation, substrate, size class, and total percent cover for each plant species were recorded for each plot. Sites for interior crater plots were selected on the criteria of accessibility and floristic diversity (e.g. survey areas on crater floors as opposed to upper interior crater walls). Plot data is presented in Appendix I and is a *qualitative representation* of stand structure, species composition, and species density at these sites.

RESULTS

Feral Pig Activity

In September 1997, low levels of feral pig activity (scat, trails, and rooting) were restricted to the north side of the exterior cone of Pu'u Huluhulu. This was the only crater surveyed where recorded feral pig activity was seen. No intermediate or old feral pig activity (e.g., scat, trails, wallows, uprooted and damaged *Cibotium* sp.) was detected in any of the interior crater survey areas. Management of feral pigs through snaring, hunting, and fencing have significantly reduced the density of the feral pig population in the East Rift Zone (Hoshide pers. comm.). Recent lava flows from Mauna Ulu, Napau, and Pu'u 'O'o create partly effective barriers to feral pigs. Pu'u Huluhulu and Kane Nui O Hamo are nearly surrounded by such flows. However, the most significant deterrent to feral pigs is the steepness of interior slopes and cliffs of the craters that act as efficient exclosure barriers.

In forests outside of Kane Nui O Hamo and Napau Trail Pit Crater evidence of previous pig damage is observable in old recovering wallows, uprooted and pig-damaged hapu'u trunks, and at some sites areas dominated by alien plant species. A small crater adjacent to Napau Trail Pit Crater, and used for an exclosure experiment in the 1970's (Katahira 1980), still shows a legacy of past pig damage. While some recovery was noted for the enclosed area between 1975 and 1980, the floor of this crater is currently dominated by Hilo grass (*Paspalum conjugatum*) while bryophyte, ground, and shrub layers are depauperate. The nearby Napau Trail Pit Crater exhibits none of these conditions and alien plant species are not common or abundant. Findings suggest that alien plant species density and diversity is dependent on the duration, frequency, intensity, and type of disturbance.

Alien Plants

Twenty-one alien plant species were documented in the survey areas (Table 1). Nine species were found in Kane Nui O Hamo, six in Napau Trail Crater, and 15 in Pu'u Huluhulu. The most disruptive alien plants species located in the three survey sites were faya tree (*Myrica faya*), strawberry guava (*Psidium cattleianum*), kahili ginger (*Hedychium gardnerianum*), yellow Himalayan raspberry (*Rubus ellipticus*), and broomsedge (*Andropogon virginicus*). Data show (Appendix I) that where alien plant species occurred on interior crater plots they rarely exceeded one percent of ground cover. Only *Tibouchina herbacea* at Kane Nui O Hamo had higher cover estimated at five percent.

The intact native vegetation in "natural enclosures" indicates that chronic damage by alien vertebrates is a prerequisite for large-scale invasions of alien plant species (Loope and Scowcroft 1985). Disturbance of soils can promote successful invasions of forests by alien plant species. Sources of disturbance observed in the survey areas were rock and tree fall, and volcanic events such as tephra fallout and geothermal events associated with eruptions or movement of magma below ground (e.g., heating of ground). While these disturbance events

themselves can be significant they are of relatively short duration, and the presence of intact plant communities allows for quick occupation of these sites by native plants. The absence of feral pigs in the survey areas suggests that the alien plant species have dispersed from nearby seed sources by wind or birds.

Table 2. Alien Plant Species at Three Craters on Kilauea's East Rift

Species	Kane Nui O Hamo	Napau Trail Crater	Pu'u Huluhulu
FERNS			
Macrothelypteris torresiana	x	x	x
Nephrolepis multiflora			x
FLOWERING PLANTS - DICOTS			
Ageratina riparia	x	x	x
Anemone hupehensis			x
Conyza bonariensis			x
Erechtites valerianafolia	x		x
Myrica faya			x
Physalis peruviana		x	
Psidium cattleianum	x	x	x
Rubus ellipticus			x
Rubus rosifolius	x	x	x
Tibouchina herbacea	x		
Youngia japonica			x
MONOCOTS			
Andropogon virginicus	x	x	x
Arundina graminifolia	x		
Hedychium gardnerianum			x
Phaius tankarvilleae	x		
Paspalum conjugatum		x	
Setaria gracilis			x
Setaria palmifolia	x		
Species total: 20	10	7	14

Kane Nui O Hamo

Tree and rock falls were observed in many areas surveyed in this crater. Only one tree fall site (see Plot 4 below) supported *Tibouchina herbacea* in a 2m x 2m area. Other alien plant species occurred as individual plants or as small isolated clumps of plants composed of single or few individuals (e.g., Chinese ground orchid (*Phaius tankarvilleae*) and palm grass (*Setaria palmifolia*). Strawberry guava is present but uncommon at Kane Nui O Hamo as sterile seedlings and saplings.

Napau Trail Crater

Alien plant species within the Napau Trail Pit Crater survey area occurred as individual plants or small isolated clumps of plants composed of a few individuals (e.g., *Hamakua pamakani* (*Ageratina riparia*), and broomsedge. One tree fall site supported a small clump of thimbleberry (*Rubus rosifolius*). A single individual of broomsedge was found growing epiphytically on an 'ohi'a log. Strawberry guava, as at Kane Nui O Hamo, were young, sterile, and uncommon.

Pu'u Huluhulu

Pu'u Huluhulu supports a diverse array of alien plant species including some of the most invasive plant species known in HAVO, e.g., fayatree, yellow Himalayan raspberry (*Rubus ellipticus*), kahili ginger (*Hedychium gardnerianum*). Two large fayatree (and seedlings) were located within Pu'u Huluhulu crater. Though the density of yellow Himalayan raspberry and kahili ginger is low these species are present in a widely scattered distribution and are reproducing as indicated by the presence of individuals in several class sizes. Broomsedge occurs on the upper interior crater walls on open rocky sites.

Rare and Uncommon Plants

For this survey rare and uncommon plant species include native plants federally listed as endangered or as "species of concern", species with limited distribution at HAVO, and species that are common in the park but are uncommon to the forests of the ERZ based on previous surveys. There is limited information on the historical distribution of rare and uncommon plants in this area and many changes have occurred in the last 50 years. Forests which once occurred near 'Aloi and 'Alae pit craters and in the area of Napau crater and Pu'u 'O'o have been covered by lava flows. Furthermore, forests at Kane Nui O Hamo and west and south of Napau crater have long been occupied by feral pigs. Fragmentation, degradation, and loss of habitat, native pollinators and dispersal agents are significant limiting factors regarding the distribution and reproduction of rare and uncommon native plant species.

A Checklist of the Plants of Hawaii National Park (Fagerlund and Mitchell 1944) and the Botanical Field Forms (Unpublished, Herbarium, HAVO) of G.O. Fagerlund and A.L. Mitchell were reviewed for sightings and collections of rare and uncommon plants from the ERZ. Fagerlund and Mitchell conducted their fieldwork and made botanical collections at HAVO between 1941 and 1947. Fagerlund and Mitchell collections were deposited in the Hawaii Volcanoes National Park Herbarium and at the Bishop Museum, Honolulu. In 1966 F.R. Fosberg updated and annotated Fagerlund and Mitchell's original checklist (Doty and Mueller-Dombois 1966). The Fagerlund and Mitchell records and current rare plant species status are found in Table 2. Fourteen of the 20 species in Table 2 were documented during the current survey and are listed in below (Table 3).

Table 3. Rare and Uncommon Plants of Kilauea Volcano, East Rift Zone

Species	Historical and Current Status
Adenophorus periens	F&M: Not Recorded. Endangered. Near KNOH.[2]
Anoectochilus sandvicensis	"Rare" (F&M 943) Napau Trail, 1 mile east of KNOH; (F&M 969) small crater to right of trail to Napau Crater at 2700', found on bottom and one on wall.[1] Rare in HAVO with only two recent sightings in the ERZ.[2]
Clermontia hawaiiensis	Rare in HAVO (former candidate T&E species), population at Pu'u Huluhulu and found elsewhere in the ERZ.[2]
Cyanea degeneriana	(F&M 973) small crater ½ mile Kilauea of Napau at 2800'. Several plants in crater.[1] Rare in HAVO, seen infrequently in 'Ola'a, one sighting in ERZ near Napau Crater.[2]
Cyanea pilosa subsp. longipedunculata	Rare in HAVO, Rare to uncommon in 'Ola'a.[2]
Cyanea tritomantha	Species of Concern, present in 'Ola'a and lower East Rift outside of the park. Vulnerable (known sites have been damaged by pigs).[2]
Cyrtandra lysiosepala	Relatively common in 'Ola'a, very rare in ERZ.[2]
Cyrtandra paludosa	(F&M 190, 834, 829, 566), known from KNOH and Makaopuhi.[1] Uncommon in HAVO.[2]
Cyrtandra " ramosissima"	(F&M 580) Makaopuhi; (F&M 971) bottom of crater, stem 4" diam, 15' high, 2700', abundant in this area.[1] No longer a recognized species, considered a hybrid between *C. platyphylla* and *C. giffardii*.[2]
Eurya sandvicensis	"Infrequent" (F&M and s. Coll. 944) (1 mile east of KNOH, several trees).[1] Species of Concern, not seen at HAVO for over 20 years.[2]

Table 3. Rare and Uncommon Plants of Kilauea Volcano, East Rift Zone, Continued

Species	Historical and Current Status
Liparis hawaiensis	"Rare" (F&M 200) Napau Crater rim; (F&M 942) Kane Nui O Hamo, 1/4 mile SE of summit.[1] Rare in HAVO.[2]
Marattia douglasii	Uncommon in HAVO, most often seen in 'Ola'a.[2]
Perrottetia sandwicensis	(F&M 833) Kane Nui O Hamo.[1] Common in HAVO, uncommon in ERZ.[2]
Phyllostegia floribunda	Species of special concern 1995.[2]
Phyllostegia vestita	Species of special concern 1995.[2]
Stenogyne rugosa	(F&M 3) Pu'u Huluhulu.[1] Former candidate species, uncommon in HAVO.[2]
Rumex giganteus	Rare in HAVO, found at 'Ola'a, at open sites near Kilauea (Devastation Trail) and on Mauna Loa at 6000 ft.[2]
Tetraplasandra hawaiiensis	Former candidate species, Rare in HAVO, near Napau, Kahaualea, and elsewhere in the ERZ.[2]
Trematalobelia grandifolia	Former Category 2 candidate T&E species, now species of concern. Previously known population at KNOH.[2]
Urera glabra	"Infrequent" (F&M 584, 585) Makaophi.[1] Uncommon in HAVO, present in Kipuka Puaulu, Kipuka Ki, 'Ola'a, ERZ mauka of Kamoamoa.[2]

1 = Fagerlund and Mitchell; 2 = Current Status

Kane Nui O Hamo

Six rare and uncommon native plant species were documented in Kane Nui O Hamo. *Phyllostegia vestita* and *Opuhe* (*Urera glabra*) were located at three sites, separated by interior crater walls. Single individuals of *Marattia douglasii* and *Pawale* (*Rumex giganteus*) were seen. *Pawale* is previously unknown from the ERZ. A population of *Trematolobelia grandifolia* was previously documented for Kane Nui O Hamo near the northeast rim of the crater; during this survey plants were found on the west rim and scattered within the crater on the edges of the interior headwalls. *Olomea* (*Perrottetia sandwicensis*), a common plant species in some sections of the park, particularly 'Ola'a forest, is uncommon in the forests of the ERZ. It occurred infrequently at Kane Nui O Hamo, on wet, bryophyte rich sites.

Napau Trail Pit Crater

Eight species of rare and uncommon plants were located at Napau Trail Pit Crater in 1995-1996. Four individual plants of *Phyllostegia floribunda* were found within the Napau Pit Crater represent the first documentation for this species in the ERZ. Three species of *Cyrtandra* were seen at the Napau Crater Trail Site: *Cyrtandra lysiosepela*, *Cyrtandra paludosa*, and *Cyrtandra ramossissima*. *C. lysiosepela* is relatively common in 'Ola'a rainforest but very rare in the ERZ. *C. paludosa* is uncommon in Hawaii Volcanoes National Park. *C. ramosissima* is not currently recognized as a distinct species, but is thought to be a hybrid between *C. giffardii* and *C. platyphylla* (Wagner *et al.* 1990). The genus *Cyrtandra* is complex in Hawai'i and is characterized by extensive polymorphism in a limited geographical area. Fagerlund and Mitchell collected what was called *C. ramossissima* in 1944 near Napau crater. The plants were described as four inches in diameter, fifteen feet tall, and located at the "bottom of the crater." They were noted as being "abundant" at an elevation of 2700' (Table 2). This is likely the same population we observed.

Cyanea degeneriana was found in the same locality it was collected 52 years ago by Fagerlund and Mitchell. Their description of the collection site (Table 2) places this collection from the Napau Trail Pit Crater. They made note of "several plants." *C. degeneriana* is very rare in the ERZ with only one other recent sighting near Napau Crater in 1986 (pers. comm. L. Pratt). *Cyanea pilosa* subsp. *longipedunculata* was also found during this survey at both Kane Nui O Hamo and Napau Trail Crater. This species is rare at HAVO and rare to uncommon at 'Ola'a. *Perrottetia sandwicensis* was located on wet, bryophyte rich sites similar to those found at Kane Nui O Hamo.

The persistence of rare species at this site illustrates the ecological stability of crater environments. With low levels of disturbance and an absence of feral pig activity these species have sustained themselves on this site for at least the last half century.

Pu'u Huluhulu

Two rare and uncommon species were located at Pu'u Huluhulu: *Clermontia hawaiiensis* and *Stenogyne rugosa*. The *C. hawaiiensis* population was previously known at this site (Fosberg 1966). During the current study 45 individual plants were mapped and heights and basal diameters measured in varying class sizes.

This population of *Clermontia hawaiensis* is the largest and most concentrated documented for the ERZ. *Stenogyne rugosa* is present both on the exterior of Pu'u Huluhulu and within the crater. It is a former candidate endangered species and is considered uncommon at HAVO.

Rare Species Not Located During 1995 - 1996 Survey

Several rare plant species formerly known from the ERZ were not found during the 1995-96 survey.

Anini (*Eurya sandwicensis*), an endemic tree in the Tea Family, has not been seen at Hawaii Volcanoes National Park in 20 years. It was collected one mile east of Kane Nui O Hamo by Fagerlund and Mitchell from a site supporting "several trees" of this rare species.

Adenophorus periens, an endangered endemic fern, was known from Kane Nui O Hamo with plants documented not far from the summit area. Located during botanical surveys in 1983 and 1988 on the northeast slope of Kane Nui O Hamo, by 1992 this fern was no longer present at this locality. Further surveys are needed to determine if *A. periens* has become locally extinct at Kane Nui O Hamo.

Jewel orchid (*Anoectochilus sandvicensis*) and *'Awapuahiakanaloa* (*Liparis hawaiiensis*) were not observed during this survey. Fagerlund and Mitchell collected Jewel orchid at the "bottom" of Napau Trail Pit Crater and noted one individual plant on the interior wall at this site. Both the Jewel Orchid and *'Awapuahiakanaloa* are small, cryptic orchids and could be easily overlooked. A recent survey (1992-94) noted *A. sandvicensis* at two sites near Napau, but *L. hawaiiensis* was not seen (Pratt *et al.* in prep.).

Cyanea tritomantha is known from the lower East Rift (Char and Lamoureux 1985) and 'Ola'a forest and was not located during this survey.

'Ohe (*Tetraplasandra hawaiiensis*) is known from Kane Nui O Hamo and southeast of Napau crater but no new locations were found.

Table 4. Rare and Uncommon Plant Species at Three Craters on Kilauea's East Rift

Species	Kane Nui O Hamo	Napau Trail Crater	Pu'u Huluhulu
FERNS			
Marattia douglasii	x		
FLOWERING PLANTS			
Clermontia hawaiiensis	x		x
Cyanea degeneriana	x	x	
Cyanea pilosa subsp. longipedunculata	x	x	
Trematalobelia grandifolia	x		
Perrottetia sandwicensis	x	x	
Cyrtandra lysiosepala		x	
Cyrtandra paludosa		x	
Cyrtandra "ramosissima"		x	
Phyllostegia floribunda		x	
Phyllostegia vestita	x		
Stenogyne rugosa			x
Rumex giganteus	x		
Urera glabra	x		
Species total: 15	9	7	2

Braun-Blanquet Relevé Data

The interior crater forests, as reflected in our plot data, show high percentage cover in bryophyte, ground, and shrub layers. These levels of cover occur more consistently and are significantly higher than observed in forests outside of the crater enclosures. For example three 10m x 10m ground cover plots established on permanent transects on the exterior of Kane Nui O Hamo show terrestrial bryophyte cover at less than one percent (three 10m x 10m plots near Napau Trail pit crater show this same percent cover). In a previous study, 20 plots in ERZ forests averaged terrestrial bryophytes at 1.2 per cent in 1993 and 1.3 per cent in 1994 (Pratt, Abbott, Palumbo, in prep). Our exterior crater plots are consistent with these findings with all exterior crater plots not exceeding 1% terrestrial bryophyte cover. In contrast, seven of nine interior crater plots terrestrial had bryophyte cover in the highest cover classes with ranging from 75-100%. Comparisons between interior and exterior plots show similar results with ground and shrub layers.

Pu'u Huluhulu

Observations at Pu'u Huluhulu clearly illustrate the difference between interior and exterior forest structure and species composition. The south side of the crater, facing the past eruptive activity of Mauna Ulu, is dominated by alien grass species, while the north side is invaded by fayatree. Twenty-two species of vascular plants in the ground stratum are documented for the interior plots of Pu'u Huluhulu. Fern species such as *palapalai (Microlepia strigosa)* and *ho'i'o* (*Diplazium sandwichianum*) have high cover ratings of 5-25% and 25-50% respectively. *'Ala'ala wai nui* (*Peperomia hypoleuca*) was also rated at 5-25% of cover on some plots. Sixteen species of vascular plants are found in the exterior plots of Pu'u Huluhulu. Two alien grass species, broomsedge (*Andropogon virginicus*) and beardgrass (*Schizachyrium condensatum*), and one native grass species *'ohe* (*Isachne distichophylla*) have cover ratings of 5-25%. Ground stratum ferns are entirely lacking. Though pig activity is clearly present and ongoing at Pu'u Huluhulu, the absence of ground ferns in this case is likely due in part to past volcanic activity from Mauna Ulu. It is also known that ground ferns such as *ho'i'o* (*Diplazium sandwichianum*) are highly palatable to pigs.

Six species of vascular plants in the shrub stratum occur in both the interior and exterior plots at Pu'u Huluhulu but are differentiated by habitat and tolerance of disturbance. In the interior plots *'ilihia* (*Cyrtandra platyphylla*) and *'ohelo* (*Vaccinium calycinum*) have 25-50% cover. In the exterior plots uluhe (*Dicranopteris linearis*) is present at 75-100% cover and *'uki* (*Machaerina angustifolia*) and *pukiawe* (*Styphelia tameiameiae*) occur at 5-25% cover each.

The interior sub-canopy layer of Pu'u Huluhulu is dominated by *hapu'u pulu* (*Cibotium glaucum*), *kolea lau nui* (*Myrsine lessertiana*), and *mamaki* (*Pipturus albidus*) with cover ranging from 5-25% and 50-75%. The exterior plots have three dominant species *uluhe* (*D. lineraris*), *'ohi'a* (*Metrosideros polymorpha*), and fayatree (*Myrica faya*) all rated at 50-75%.

The interior canopy layer at Pu'u Huluhulu is dominated by large emergent *'ohi'a* at 25-50%. The exterior emergent canopy at Pu'u Huluhulu is indicated only by standing dead *'ohi'a.*

Napau Trail Pit Crater and Kane Nui O Hamo

The bryophyte layers on the interior plots of Napau and Kane Nui O Hamo have high cover ratings of 50-75% and 75-100% while bryophyte cover in all exterior plots in this survey area did not exceed 1%. This is consistent with the findings at Pu'u Huluhulu.

The number of plant species in the ground layer at Napau differed greatly between interior and exterior plots, with thirty-two vascular plant species occurring in the interior

plots and thirteen vascular plant species in exterior plots. In interior plots species such as *pa'iniu* (*Astelia menziesiana*), *ho'i'o* (*D. sandwichianum*), *kilau* (*Vandenboschia davallioides*), and *kopiko 'ula* (*Psychotria hawaiiensis*) occurred in cover classes ranging from 1-5% for *kopiko 'ula*, 5-25% for pa'iniu, and 25-50% for *ho'i'o* these species were not present in any of the exterior plots. The native grass *'ohe* (*I. distichophylla*) and the alien Hilo grass (*Paspalum conjugatum*) were present on exterior plots with 5-25% and 50-75% cover respectively. The alien scaly swordfern (*Nephrolepis multiflora*) occurred with 5-25% cover.

Ten species of vascular plants were found in the shrub layer in the interior plots of Napau, including rare *Phyllostegia* and *Cyanea* species, and twelve species of vascular plants were documented in the exterior plots. *Kanawao* (*Broussassia arguta*) occurred at 25-50% cover in the interior plots and 1-5% cover in the exterior plots. *'Oha* (*Clermontia parviflora*) and *Cyrtandra ramossissima* were significant elements in the shrub layer at Napau with 1-5% and 5-25% cover respectively. These species did not occur on any of the exterior plots.

The sub-canopy layer at Napau also showed a significant difference between exterior and interior plots with seven vascular plants in the interior plots and three vascular plant species in the exterior plots. *Hapu'u* (*C. glaucum*), *mamaki* (*P. albidus*), and *kopiko 'ula* (*P. hawaiiensis*) occurred as significant elements of the sub-canopy, and estimated cover ranged from 1-5% for *hapu'u* to5-25% for *mamaki* and *kopiko 'ula*. In the exterior plots hopu'u occurred at 25-50% cover and *'Olapa* (*Cheirodendron trigynum*) occurred at 5-25% cover.

There was no significant difference in the emergent canopy with *'ohi'a* occurring at 5-25% cover in both interior and exterior plots.

The Kane Nui O Hamo plots follow the same pattern at those at Pu'u Huluhulu and Napau. The interior plots contained 30 species of vascular plants with significant elements such as *pa'iniu*, *ho'i'o*, *'ie'ie* (*Freycinetia arborea*), and *'ala'ala wai nui* (*Peperomia* species) occurring in cover ranges from 1-5% for *'ie'ie* to 25-50% for *ho'i'o*. None of these species occurred on any of the exterior plots at Kane Nui O Hamo. In addition the rare *Phyllostegia* and *Cyanea* species found on the interior plots were not present on the exterior plots. Ground layer vascular plants in the exterior plots were represented by 22 species, including two grasses. The alien Hilo grass (*P. conjugatum*) has 5-25% cover and the native grass *'ohe* (*Isachne distichophylla*) occurred at 1-5% cover.

Fifteen species of vascular plants were documented for the interior plots and eleven species were found for the exterior plots at Kane Nui O Hamo. *Kanawao* (*B. arguta*) occurred at 5-25% in both interior and exterior plots. Interior plots were represented by *kopiko 'ula, olomea* (*Perrottetia sandwicensis*), *'ilihia* (*Cyrtandra platyphylla*), *pilo* (*Coprosma ochracea*), and *'Oha* all of which occurred in the 5-25% cover range. These species, except for *'Oha* that occurred epiphytically in one exterior plot, were not present in any of the exterior plots.

Seven vascular plants species occurred in the sub-canopy layer in the interior plots and six in the exterior plots. *Hopu'u* and *'Olapa* occurred in both interior and exterior plots with cover ranging from 25-50% and 75-100% for *'Olapa* and 25-50% and 75-100% for *hopu'u*. The interior plots contained *Opuhe* (*Urera glabra*), *olomea* (*P. sandwicensis*), and *kawa'u* (*Ilex anomala*) with cover ranging from 1-5% to 5-25%. These species did not occur on any of the exterior plots. The exterior plots were dominated by 'ohi'a with 50-75%. A single individual of *'akia* (*Wikstroemia phillyreifolia*) occurred on one exterior plot. This species was not present in any of the other survey areas.

The emergent canopy in both interior and exterior plots was represented by *'ohi'a* at 5-25% cover. However, on three of the five exterior plots the emergent canopy was standing dead *'ohi'a.*

SUMMARY

Terrestrial bryophytes seem especially sensitive to damage from feral pig activity, and consequent loss of bryophyte cover may affect important nutrient and hydrological cycles. Where a significant "bryomass" occurs these bryophyte conditioned nutrient and hydrological cycles may be a significant factor in the ability of these sites to support specific plant species.

The craters we examined also exhibit unique microclimate and microhabitat sites not often encountered in the exterior forests. We measured a significant drop in temperature and rise in humidity as we approached the bottom of Kane Nui O Hamo. Similar temperature and humidity changes were observed at Pu'u Huluhulu and Napau Trail Pit Crater. What role these unique microsites play in relation to the species found there is in need of further investigation. These sites appear to be ecologically stable regarding temperature, moisture, and disturbance regimes. The most significant finding is that all the rare and uncommon species recorded during the survey were located within them.

The relevé plots reflect an exterior forest largely depauperate of bryophyte and ground stratum ferns, a shrub stratum with fewer vascular plants than in interior crater forest plots, a sub-canopy somewhat similar to that of the interior crater forest though with significant common elements missing, and an emergent canopy dominated by 'ohi'a (*M. polymorpha*), though on the exterior plots these trees were standing dead. In part these findings may be attributed to microclimate and microhabitat differences and in part by volcanic activity but the initial primary reasons for these differences likely is the result of long occupation by feral pigs in the East Rift Zone. The craters we examined have been effective barriers to invasion by feral pigs. Protected from wind and the extreme effects of volcanism the disturbance regime within these craters consisted of tree and rock fall. With the absence of feral pigs, a major cause of forest disturbance, native species have maintained their populations within these craters with high diversity and density.

Volcanic activity in the East Rift Zone does influence species composition and species diversity of the area. For example, it has been suggested that high levels of volcanic fumes, especially sulphur dioxides, has caused the decline if not the local extinction of the rare fern *Adenophorus periens*. Elsewhere in our survey area tephra fallout has continued to suppressed the recovery of native plants to some sites and has enhanced disturbance tolerant alien plant species such as Hilo grass (*P. conjugatum*) in others. If feral pigs have had significant impact on bryophytes, and ground and shrub layer vascular plants, and likely have been responsible for the local extinction of some of the already rare *Phyllostegia* and *Cyanea* species, then the recent volcanism in the East Rift Zone has further suppressed the recovery of these species through volcanic emissions, tephra fallout, and destruction of suitable habitat. What seems most remarkable is that the craters we surveyed in the East Rift Zone have retained a high level of species composition and diversity, including viable populations of rare plants found infrequently or not at all in the East Rift forests.

Through review of historical survey records and herbarium collections we have an indication of rare and uncommon species that were known to occur in the forests of the ERZ but now only occur as relict populations within craters where some populations have persisted for at least half a century. The new botanical discoveries made on our survey imply that other rare and uncommon native plants may yet be found in the forested craters of the East Rift Zone of Kilauea.

MANAGEMENT RECOMMENDATIONS

In 1985, the concept of Special Ecological Areas was developed as an approach to alien plant management in Hawaii Volcanoes National Park. Management emphasis was placed on those alien plant species most disruptive to those areas within the Park that represent valuable biological sites. Sites were selected on the basis of representativeness, rarity of vegetation type, vegetation intactness, plant species diversity and richness, manageability, presence of rare flora, preserve design considerations, immediacy of threat from alien plants, and research and interpretive values (Tunison and Stone 1992).

In 1992, a portion of the East Rift, comprising some 2,700 ha, was proposed as an SEA with feral pigs and strawberry guava targeted for management. Kane Nui O Hamo and Napau Trail Pit Crater are not within the SEA yet these sites represent a significant and valuable biological resource to the Park and warrant research and management such as periodic monitoring of feral pig activity and alien plant species status in these craters (see Table 4).

In 1996, Pu'u Huluhulu was designated as a mini-SEA based on the criteria listed above. Fifteen of the 21 alien plant species recorded for the survey areas were located at Pu'u Huluhulu. These included fayatree, yellow Himalayan blackberry, and kahili ginger. Alien plant species will be managed at intervals that minimize disturbance with small work crews.

Perhaps the most important management consideration is feral pigs. Active management of feral pig populations in the ERZ must continue with the goal of keeping these populations at a minimum.

Table 5. East Rift Zone Crater SEA's

Site	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria
Kane Nui O Hamo	Montane rainforest	'ohia/hopu'u	Intactness Representativeness Rare and Uncommon Plants
Napau Trail Pit Crater	Montane rainforest	'ohia/hopu'u	Intactness Representativeness Rare and Uncommon Plants
Pu'u Huluhulu	Montane rainforest	'ohia/hopu'u	Rare and Uncommon Plants Interpretive

Pu'u Huluhulu Continued				
Species	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Ground Layer				
Dryopteris wallichiana	+	+		
Elaphoglossum alatum	+			
Freycinetia arborea	+			
Hedychium gardnerianum	+			
Hedyotis centranthoides	+			
Ilex anomala			+	
Isachne distichophylla			2	1
Juncus sp.			+	
Labordia hedyosmifolia		+		
Palhinhaea cernua			1	
Macrothylepteris torresiana	+			
Mecodium recurvum	+			
Metrosideros polymorpha	+	+	+	
Microlepia strigosa	2	+		
Myrica faya			1	
Myrsine lessertiana	1			
Peperomia hypoleuca	2			
Phaius tankarvilleae			+	
Pneumatopteris sandwicensis		1		
Sadleria pallida	+			
Setaria gracilis			+	1
Schizachyrium condensatum				2
Stenogyne rugosa	+		+	+
Rubus rosifolius	+		+	
Uncinia uncinata	+			
Vaccinium calycinum	+			+
Vandenboschia davallioides	+			

APPENDIX I. PLOT DATA BY STRATUM WITH BRAUN-BLANQUET RATINGS

Stratum
Bryophyte layer : <5cm., ground-hugging, low carpet
Ground layer : <30 cm to 1m, or woody tree species seedling
Shrub layer : 1m to 5m
Sub-Canopy : >5m and not emergent
Canopy : emergent above sub-canopy

Rating (cover class)
+ = 0-1 %
1 = 1 - 5 %
2 = 5 - 25 %
3 = 25 - 50 %
4 = 50 - 75 %
5 = 75 - 100 %
epi. = epiphytic
SD = standing dead i = interior plot e = exterior plot

SITE	PU'U HULUHULU			
Species	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Bryophyte Layer				
Bryophytes	4	5	+	+
Ground Layer				
Ageratina riparia	+			
Andropogon virginicus	+			2
Asplenium lobulatum		+		
Athyrium microphyllum				
Callistopteris baueriana		+		
Carex wahuensis			1	
Cibotium glaucum			1	
Coprosma ernodeiodes				+
Cyrtandra platyphylla	+			
Diplazium sandwichianum	3	3		

Pu'u Huluhulu Continued				
Species	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Shrub Layer				
Cibotium glaucum			2	
Clermontia hawaiiensis	+			
Cyrtandra platyphylla	1	3		
Dicranopteris linearis			4	5
Ilex anomala	+			
Machaerina angustifolia			1	2
Metrosideros polymorpha			1	
Psidium cattleianum	1			
Rubus hawaiiensis	+	+		
Styphelia tameiameiae				2
Vaccinium calycinum	2			1
Sub-Canopy Layer				
Cibotium glaucum	3	3		
Dicranopteris linearis			4	
Ilex anomala			2	1
Metrosideros polymorpha			4	4
Myrica faya			4	2
Myrsine lessertiana	2	1		
Pipturus albidus	4	2		
Canopy Layer				
Metrosideros polymorpha	3	2		

SITE	Napau Trail Pit Crater			
Species	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Bryophyte Layer				
Bryophytes	5	4	+	+
Ground Layer				
Adenophorus tamariscinus		+		
Ageratina riparia	+			
Alyxia oliviformis			+	1
Asplenium lobulatum	+	+		
Astelia menziesiana	1	2		
Athyrium microphyllum	+	+		
Cheirodendron trigynum		+	1	+
Cibotium glaucum		+		
Cibotium menziesii				+
Coniogramme pilosa	+			
Cyanea degeneriana		+		
Cyrtandra platyphylla				+
Diplazium sandwichianum	3	1		
Elaphoglossum alatum		+	+	+
Elaphoglossum pelucidum		+		
Freycinetia arborea	+	+		
Grammitis tenella		+		
Hedyotis terminalis			+	
Isachne distichophylla			2	+
Macrothelypteris torresiana	+			
Mecodium recurvum	+			
Melicope clusiifolia	+		+	+
Metrosideros polymorpha	+	+	+	+
Microlepia strigosa	+	+		
Myrsine lessertiana		+		

Napau Trail Pit Crater Continued				
Species	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Ground Layer				
Nephrolepis multiflora				2
Ophioglossum pendulum		+	+	
Paspalum conjugatum		+	4	3
Pepperomia hypoleuca	+	+		+
Phyllostegia floribunda	+			
Pipturus albidus	+	+		
Pneumatopteris sandwicensis	+			
Psychotria hawaiiensis	1			
Rubus rosifolius		+		
Sadleria pallida		+		
Selaginella arbuscula		+		
Vaccinium calycinum		+		+
Vandenboschia davallioides	2			
Shrub Layer				
Broussaisia arguta	1	3	1	+
Chierodendron trigynum		+		
Cibotium glaucum			+	
Clermontia parviflora		1	+	
Coprosma ochracea		+	+	
Cyrtandra paludosa	+			
Cyrtandra platyphylla	+	+		
Cyrtandra ramosisima	3			
Dicranopteris linearis			1	
Hedyotis terminalis	+	1		1
Ilex anomala			+	
Melicope clusiifolia		1	1	+
Psidium cattleianum			+	

Napau Trail Pit Crater Continued				
Species *Ground Layer*	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Psychotria hawaiiensis		+		
Metrosideros polymorpha			1	
Psychotria hawaiiensis				1
Vaccinium calycinum			+	
Sub-Canopy				
Cibotium glaucum	1	2	3	2
Cibotium menziesii	+			
Cheirodendron trigynum			2	1
Ilex anomala		1		
Melicope clusiifolia		1	1	
Perottetia sandwicensis	+	+		
Pipturus albidus	2	2		
Psychotria hawaiiensis	2			
Canopy	**Plot 1(i)**	**Plot 2 (i)**	**Plot 1 (e)**	**Plot 2 (e)**
Metrosideros polymorpha		2	2	2

SITE	KANE NUI O HAMO									
Species	**Plot 1 (i)**	**Plot 2 (i)**	**Plot 3 (i)**	**Plot 4 (i)**	**Plot 5 (i)**	**Plot 1 (e)**	**Plot 2 (e)**	**Plot 3 (e)**	**Plot 4 (e)**	**Plot 5 (e)**
Bryophyte Layer										
Bryophytes	4	2	5	+	4	1	epi +	1	1	1
Ground Layer										
Asplenium lobulatum				+						
Astelia menziesiana	1	2	1	1	1					
Broussaisia arguta						+			+	+
Cheirodendron trigynum			+	1				+		+
Cibotium glaucum						+			+	+
Clermontia parviflora	+						+epi			
Coniogramme pilosa	+									
Coprosma ochracea			+							
Cyanea degeneriana			+							
Cyanea pilosa subsp. longipedunculata			+							
Diplazium sandwichianum	1	2	3	1	3					
Dubautia scabra						+			+	
Elaphoglossum pelucidum		+				+	+		+	+
Erechtites valerianifolia			+			+				
Freycinetia arborea	1	1	+	+						
Grammitis tenella								+	+	+
Hedyotis centranthoides	1	+		1						
Hedyotis terminalis	+									
Ilex anomala	+									
Isachne distichophylla						1	+		1	
Machaerina angustifolia						+				
Mecodium recurvum			+					+	+	
Melicope clusiifolia			+			+	+	1		+

Kane Nui O Hamo Continued										
Species *Ground Layer*	**Plot 1 (i)**	**Plot 2 (i)**	**Plot 3 (i)**	**Plot 4 (i)**	**Plot 5 (i)**	**Plot 1 (e)**	**Plot 2 (e)**	**Plot 3 (e)**	**Plot 4 (e)**	**Plot 5 (e)**
Metrosideros polymorpha	1	+		+		+	+	+	+	+
Paspalum conjugatum								2		
Peperomia hypoleuca	2	+	1		1					+
Phaius tankarvilleae	+									
Phyllostegia vestita		1								
Pipturus albidus	1	1								
Psidium cattleianum		+								
Pislotum nudum						+	+	+	+	
Selaginella arbuscula	1	+				+				+
Smilax melastomifolia				+						
Tibouchina herbacea				1			+			
Uncinia uncinata	+	+				+	+		+	
Vaccinium calycinum	+	+		+		+	+	+	+	+
Shrub Layer										
Broussaisia arguta	2	1	1		2	2	1		1	2
Cheirodendron trigynum	+							+	+	+
Cibotium glaucum							1			+
Clermontia parviflora	1	+	+		1	+				
Coprosma ochracea	1	+		2	+					
Cyrtandra platyphylla	1	1	2	2	+					
Dicranopteris linearis		1		2						
Hedyotis terminalis	2		1	2	1		1			
Ilex anomala	1	+								
Machaerina angustifolia						1				
Melicope clusiifolia	1	+	+	+		+			+	+

Kane Nui O Hamo Continued										
Species *Shrub layer*	**Plot 1 (i)**	**Plot 2 (i)**	**Plot 3 (i)**	**Plot 4 (i)**	**Plot 5 (i)**	**Plot 1 (e)**	**Plot 2 (e)**	**Plot 3 (e)**	**Plot 4 (e)**	**Plot 5 (e)**
Metrosideros polymorpha						2		+		+
Myrsine lessertiana		+								+
Perottetia sandwicensis					2					
Pipturus albidus	1									
Psidium cattleianum	+					1				
Psychotria hawaiiensis	1		+		+					
Sadleria cyatheoidies							+			
Vaccinium calycinum	+	+		+		1		1		+
Sub-Canopy										
Cheirodendron trigynum	2	1	2	1		2	5	3	2	2
Cibotium glaucum	3	3	3		4	3	5	3	4	3
Cibotium menziesii						+				
Coprosma ochracea	2				1					
Dicranopteris linearis						2				1
Ilex anomala				2					+	
Metrosideros polymorpha						3		4		
Perrottetia sandwicensis		1		1						
Pipturus albidus		+	1							
Urera glabra			1		2					
Wikstroemia phyllyreifolia								+		
Canopy										
Metrosideros polymorpha	2	1	1	2	1	SD+	1	SD+	SD+	2

APPENDIX II. PLANT SPECIES LIST FOR FORESTED PIT CRATER SURVEY
Hawaii Volcanoes National Park

	Status	Site 1	2	3
BRYOPHYTES (partial list)				
MOSSES – MUSCI				
HOOKERIACEAE				
Distichophyllum paradoxum (Mont.) Mitt.	E	x	x	x
POLYTRICHACEAE				
Pogonatum sp.	I			x
Polytrichum sp.	I			x
RHIZOGINIACEAE				
Rhizogonium sp.	I			x
THUIDIACEAE				
Thuidium crenulatum Mitten	E	x	x	x
LIVERWORTS – HEPATICAE				
MARCHANTIACEAE				
Dumortiera hirsuta (Sw.) Nees	I	x	x	x
FERNS AND FERN ALLIES				
PSILOTACEAE				
Psilotun complanatum Sw. Moa	I	x		
Psilotum nudum (L.) Beauv. Moa	I	x		
LYCOPODIACEAE				
Phlegmariurus phyllanthus (H. & A.) Dixit	E		x	

Palhinhaea cernua (L.) Franco & Carv. Vasc. Wawae'iole	E			x
SELAGINELLACEAE				
Selaginella arbuscula Kaulf. Lepe'lepe'amoa	E	x	x	x
ADIANTACEAE				
Coniogramme pilosa (Brack.) Hieron. Lo'ulu	E	x	x	x
Pteris excelsa Gaud.	I			x
ASPLENIACEAE				
Asplenium cookii Copel.	E			x
Asplenium lobulatum Mett.	I	x	x	x
Asplenium macraei H. & G.	E		x	x
Asplenium normale Don	I			x
BLECHNACEAE				
Sadleria cyatheoides Kaulf. 'Ama'u	E			x
Sadleria pallida H. & A. 'Ama'u	E	x	x	x
CYATHEACEAE				
Cibotium glaucum (Sm.) Hook. & Arnott Hopu'u pulu	E	x	x	x
Cibotium menziesii Hook. Hopu'u 'i'i	E	x	x	x
DENNSTAEDTIACEAE				
Microlepia strigosa (Thunb.) Presl Palapalai	I	x	x	x

	Status	Site 1	2	3
DRYOPTERIDACEAE				
Dryopteris wallichiana (Spreng.) Hyl. Wallich's oak fern	I		x	x
Athyrioideae				
Athyrium microphyllum (Sm.) Alston 'Akolea	E	x	x	x
Diplazium sandwichianum (Presl) Diels Ho'i'o	E	x	x	x
Elaphoglossum parvisquameum Skottsb.	E	x	x	x
Elaphoglossum crassifolium (Gaud.) Anderson & Crosby	E	x	x	x
Elaphoglossum paleaceum (Hook & Grev.) Sledge Ekaha	E		x	
Elaphoglossum pellucidum Gaud.	E	x	x	
Nephrolepis cordifolia (L.) Presl	I	x	x	
Nephrolepis exaltata (L.) Schott. Kupukupu	E			x
Nephrolepis multiflora (Roxb.) Jarrett ex Morton Scaly sword fern	X			x
GLEICHENIACEAE				
Dicranopteris linearis (N.L. Burm.) Underw. Uluhe	I	x	x	x
GRAMMITIDACEAE				
Adenophorus hymenophylloides (Kaulf.) Hook. & Grev. Pai	E			x

Adenophorus tamariscinus (Kaulf.) Hook. & Grev. Wahine noho mauna	E		x	
Grammitis hookeri (Brack) Copel. Maku'e lau li'i	E		x	
Grammitis tenella Kaulf. Kolokolo	E		x	
HYMENOPHYLLACEAE				
Mecodium recurvum (Gaud.) Copel. 'ohi'a ku	E	x	x	x
Callistopteris baueriana (Endl.) Copel.	I	x	x	x
Sphaerocionium lanceolatum (Hook & Arn.) Copel. Palai hinahina	E	x		
Vandenboschia davallioides (Gaud.) Kilau	E	x	x	x
MARATTIACEAE				
Marattia douglasii (Presl) Baker Pala	E	x		
OPHIOGLOSSACEAE				
Ophioglossum pendula (L.) Presl Lau'kahi	I		x	
POLYPODIACEAE				
Polypodium pellucidum Kaulf. Ae	E	x		
THELYPTERIDACEAE				
Christella cyatheoides (Kaulf.) Holttum Pakikawaio	E		x	
Macrothelypteris torresiana (Gaud.) Ching	X	x	x	x

	Status	Site 1	2	3
Pneumatopteris sandwicensis (Brack.) Holttum Ho'i'o kula	E	x	x	x
FLOWERING PLANTS - DICOTS				
APOCYNACEAE - Dogbane family				
Alyxia oliviformis Gaud. Maile	E			x
AQUIFOLIACEAE - Holly family				
Ilex anomala Hook. & Arnott Kawa'u	E	x	x	x
ASTERACEAE (COMPOSITAE) - Sunflower family				
Ageratina riparia (Regel) R. King & H. Robinson Hamakua pamakani	X	x	x	x
Conyza bonariensis (L.) Cronq. Hairy horseweed	X			x
Dubautia scabra (DC) D. Keck Na'ena'e, K_paoa	E	x	x	
Erechtites valerianifolia (Wolf) DC Fireweed	X	x		
Youngia japonica (L.) DC Oriental hawksbeard	X			x
CAMPANULACEAE - Bellflower family				
Clermontia parviflora Gaud. ex A. Gray 'Oha	E	x	x	
Clermontia hawaiiensis (Hillebr.) Rock 'Oha k_pau	E	x	x	x
Cyanea degeneriana F. Wimmer	E	x	x	

	Cyanea pilosa A. Gray subsp. longipedunculata (Rock) Lammers	E	x	x	
	Trematolobelia grandifolia (Rock) Degener	E	x		
CELASTRACEAE - Bittersweet family					
	Perottetia sandwicensis A. Gray Olomea	E	x	x	
EPACRIDACEAE - Epacris family					
	Styphelia tameiameiae (Cham. & Schlechtend.) F.v. Muell. Pukiawe	I			x
ERICACEAE - Heath family					
	Vaccinium calycinum Sm. 'ohelo	E	x	x	x
GESNERIACEAE - African Violet family					
	Cyrtandra paludosa Gaud. Moa, hahala	E		x	
	Cyrtandra platyphylla A. Gray 'Ilihia	E	x	x	x
	Cyrtandra lysiosepala (A. Gray) C.B. Clark	E		x	
*	Cyrtandra ramosissima Rock hybrid C. platyphylla X C. giffardii	E		x	
HYDRANGEACEAE - Hydrangea family					
	Broussaisia arguta Gaud. Kanawao	E	x	x	
LAMIACEAE - Mint family					
	Phyllostegia floribunda Benth.	E		x	
	Phyllostegia vestita Benth.	E	x		
	Stenogyne rugosa Benth. Ma'ohi'ohi	E			x

	Status	Site 1	2	3
LOGANIACEAE - Logania family				
Labordia hedyosmifolia Baill. Kamakahala	E	x	x	x
MELASTOMATACEAE - Melastoma family				
Tibouchina herbacea (DC) Cogn.	X	x		
MYRICACEAE - Bayberry family				
Myrica faya Aiton Fayatree, faya tree	X			x
MYRSINACEAE - Myrsine family				
Myrsine lessertiana A. DC Kolea lau nui	E	x	x	x
Myrsine sandwicensis A. DC Kolea lau li'i	E	x		
MYRTACEAE - Myrtle family				
Metrosideros polymorpha (Gaud.) 'ohi'a lehua	E	x	x	x
Psidium cattleianum Sabine Strawberry guava	X	x	x	x
PIPERACEAE - Pepper family				
Peperomia hypoleuca Miq. 'Ala'ala wai nui	E	x	x	x
Peperomia cookiana C. DC 'Ala'ala wai nui	E		x	x
POLYGONACEAE - Buckwheat family				
Rumex giganteus W.T. Aiton Pawale	E	x		
RANUNCULACEAE - Buttercup family				
Anemone hupehensis Lemoine Japanese anemone	X			x

ROSACEAE - Rose family				
Rubus ellipticus Sm. Yellow Himalayan raspberry	X			x
Rubus hawaiiensis A. Gray 'Akala	E			x
Rubus rosifolius Sm. Thimbleberry	X	x	x	x
RUBIACEAE - Coffee family				
Coprosma ochracea W. Oliver Pilo	E	x	x	x
Hedyotis centranthoides (Hook. & Arnott) Steud.	E	x	x	x
Hedyotis terminalis (Hook. & Arnott) W.L. Manono	E	x	x	x
Psychotria hawaiiensis (A. Gray.) Fosb. Kopiko 'ula	E	x	x	
RUTACEAE - Rue family				
Melicope clusiifolia A. Gray	E	x	x	
SOLANACEAE - Nightshade family				
Physalis peruviana L. Poho, Cape gooseberry	X			x
THYMELAEACEAE				
Wikstroemia phillyreifolia A. Gray 'akia	E	x		
URTICACEAE - Nettle family				
Pipturus albidus (Hook & Arnott) A. Gray Mamaki	E	x	x	x
Urera glabra (Hook. & Arnott) Wedd. Opuhe	E	x		

FLOWERING PLANTS - MONOCOTS

	Status	Site 1	2	3
AGAVACEAE - Agave family				
Cordyline fruticosa (L.) A. Chev. Ki, ti	P	x		
CYPERACEAE - Sedge family				
Machaerina angustifolia (Gaud.) T. Koyama 'Uki	I			x
Machaerina mariscoides (Gaud.) J. Kern 'Ahaniu	I	x		
Uncinia uncinata (L. fil.) Kukenth.	I	x		x
LILIACEAE - Lily family				
Astelia menziesiana Sm. Pa'iniu	E	x	x	x
ORCHIDACEAE - Orchid family				
Arundina graminifolia (D. Don) Hochr. Bamboo orchid	X	x		
Phaius tankarvilleae (Banks ex L'Her.) Blume Chinese ground orchid	X	x		x
PANDANACEAE - Screwpine family				
Freycinetia arborea Gaud. 'Ie'ie	E	x	x	x
POACEAE - Grass family				
Andropogon virginicus L. Broomsedge	X	x	x	x
Isachne distichophylla Munro ex Hillebr. 'Ohe	E	x	x	x
Paspalum conjugatum Bergius Hilo grass	X		x	
Setaria palmifolia (J. Konig) Stapf. Palm grass	X	x		

Setaria gracilis Kunth Yellow foxtail	X		x
SMILACACEAE - Catbrier family			
Smilax melastomifolia Sm. Hoi kuahiwi	E	x	
ZINGIBERACEAE - Ginger family			
Hedychium gardnerianum Ker-Gawl. Kahili ginger	X		x

Status
P - Polynesian Introduction
E - Endemic
I - Indigenous
X - Alien

Site
1 - Kane Nui O Hamo
2 - Napau Trail Pit Crater (no mapped name)
3 - Pu'u Huluhulu

Nomenclature of flowering plants follows that of W. L. Wagner, D. L. Herbst, and S. H. Sohmer 1990, Manual of the Flowering Plants of Hawai'i, University of Hawai'i Press. Nomenclature of ferns and fern allies is based on W. H. Wagner, Jr. & F. S. Wagner, Revised Checklist of Hawaiian Pteridophytes, July, 1992, Unpublished. Additonal fern and fern allies information from T. Herat & R. Herat, Checklist of Ferns for Hawai'i Volcanoes National Park, Cooperative National Park Resources Studies Unit, Tech. Report 8. Nomenclature of mosses follows W. Hoe 1974 "Annotated Checklist of Hawaiian Mosses", Lyonia 1: 1-45. *Nomenclature follows St. John, 1973.

ACKNOWLEDGEMENTS

Lyman Abbot, Renee Chester, Chris Hayward, Dawn Holmes, Casey Lett, Linda Pratt, Tim Tunison and all the folks at Hawai'i Volcanoes National Park. This report is dedicated to G.O. Fagerlund and A.L. Mitchell.

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