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INVENTORY OF VASCULAR PLANTS OF THE KAHUKU ADDITION, HAWAI`I VOLCANOES NATIONAL PARK

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ABSTRACT

In 2003, the National Park Service acquired 46,943 ha of Kahuku Ranch, in the Ka'ū district of Hawai`i. This addition to Hawai`i Volcanoes National Park includes a diverse assemblage of vegetation communities. No recent vegetation inventories existed, and since the last vegetation map had been created many vegetation types within the former ranch had undergone changes due to grazing pressure, logging and fire. As a result, little was known about the communities and their floristic composition, and appropriate management practices could not be developed. Surveys conducted between 2004 and 2006 in Kahuku described vegetation communities and located rare, threatened and endangered plants, as well as disruptive alien weeds. Forty-one kilometers of transects and 177 vegetation plots were ground-surveyed, and 6.5 hours of helicopter surveys were conducted. Surveys encountered a total flora of 455 vascular plant species, of which 40% were native. Five endangered, one threatened, one candidate endangered, and seven species of concern were found, as well as 26 locally rare native species. Forty-three disruptive alien plant taxa in and near Kahuku were mapped. Several sites containing high numbers of either rare or invasive plants were identified. Information from this inventory allows managers to identify priority areas of alien plant and ungulate control and rare plant recovery, and serves as a baseline to document future changes in the vegetation. Results from this study will also enable managers to develop a framework for long-term management priorities and strategies in Kahuku.

INTRODUCTION

The Kahuku Ranch was acquired by the National Park Service (NPS) on July 6 2003 as an addition to Hawai`i Volcanoes National Park (HAVO). This 46,943-ha acquisition expanded the federally protected lands within HAVO by nearly 50%, to 134,760 ha (National Park Service 2003), and added to the park native montane forests, a vast expanse of subalpine shrublands, pioneer communities, important cultural resources, and unique geological features.

Much of the vegetation in Kahuku has been impacted since the arrival nearly 1,600 ybp (years before present) of Polynesian settlers (Kirch 1985), who cleared lands and introduced plant and animal species for subsistence agriculture. Over the past 200 years, these impacts have accelerated, and the areas below 1,500 m elevation have been extensively modified by cattle ranching, logging, and introduced plant and animal species. The clearing of forests for pastures and the introduction of forage species continued until the late 1980s (Avery 2006). The land management practices at Kahuku are not unique within Hawai'i; throughout the islands, 50% of the land area is used for cattle pastures, 30% consists of plantations and urban areas, and 20% is covered by native and non-native plant communities (Gagné and Cuddihy 1999).

Logging has also impacted the Kahuku landscape. Within the last sixty years, extraction of koa from forests at Kahuku has left a legacy of large stumps and skid roads wherever this activity took place. More recently, Damon Estate, the last private landowner of Kahuku, hired contractors to harvest koa (*Acacia koa*), `ōhi`a (*Metrosideros polymorpha*) and sandalwood (*Santalum paniculatum*) in the late 1980s and 1990s (Avery 2006).

Ungulate grazers, particularly cattle (*Bos taurus*) and mouflon sheep (*Ovis gmelini musimon*), are abundant in Kahuku. Prior to the acquisition of Kahuku by the park, cattle ranching had been an emphasis for nearly 100 years (Avery 2006). Over this period feral pigs (*Sus scrofa*), goats (*Capra hircus*) and sheep (*Ovis aries*) have impacted the ranch, and most recently mouflon sheep were intentionally introduced and now remain. Other game animals introduced relatively recently (1970s) include pheasants (*Phasianus* spp.), turkeys (*Meleagris gallopavo*), and francolins (*Francolinus* spp.) (Avery 2006).

Although very little was previously known about the vegetation in the new Kahuku unit, it was believed to have rich biological and cultural resources and a high potential for conservation. Many endangered bird and plant species were known from Kahuku, including one of only three naturally occurring populations of the Ka‘ū or Mauna Loa silversword (*Argyroxiphium kauense*). Much of Kahuku’s low-elevation lands had been converted to pasture, yet species-rich forest fragments remained, and upper elevations, above the Ka’ū forest reserve, had native mature forest, subalpine and alpine native plant communities. Many plant communities and taxa poorly represented in the older part of HAVO could potentially be found in Kahuku.

Plant inventories were needed before strategic management of native ecosystems could begin in Kahuku. Limited vegetation surveys of forest areas were conducted in the late 1970s by Jacobi (1989). Beyond that, plant knowledge of the area was based largely on informal site visits and inspection of localized sites for project work (e.g., fencing, restoration experiments). Detailed inventories of communities and individual taxa throughout Kahuku had not been compiled.

The primary objectives of the systematic plant surveys of 2004-2006 at Kahuku were to identify the types and distribution of vegetation communities; locate rare, threatened and endangered plant species; determine the distribution of disruptive alien weeds, and develop a vascular plant checklist. This information on vegetation, along with recent surveys of forest birds (Tweed et al. 2007), will allow managers to identify priority areas (e.g., Special Ecological Areas or SEAs, rare plant populations) for immediate ungulate control, alien plant removal, and rare plant recovery. Additional survey goals were identification of species or sites that required more intensive monitoring before management decisions were made and creation of a framework for developing long-term management priorities and strategies in Kahuku.

THE SURVEY AREA

The Kahuku addition to HAVO is located along the Southwest rift of Mauna Loa and comprises an area of 46,943 ha (Figure 1). The former ranch extends upslope from Highway 11 at 600 m and joins the previous park boundary at 3,854 m elevation. The Kahuku addition shares its boundary on the east with the Kapāpala and Ka`ū Forest Reserves, and on the west with Hawaiian Ocean View Estates (HOVE), Manuka Natural Area Reserve, The Nature Conservancy Hawai’i Kona Hema Preserve, and Kīpāhoehoe Natural Area Reserve. On the west boundary there are also sections of State land and privately owned ranches.

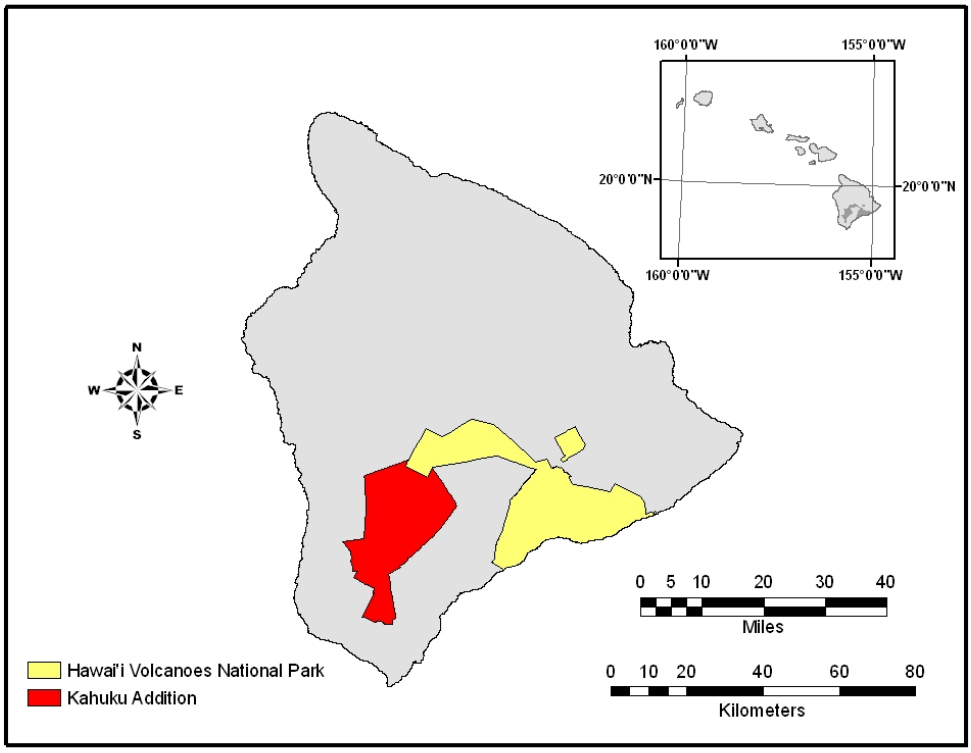

Figure 1. Kahuku addition to Hawai'i Volcanoes National Park

Recent History- Ranching and Resource Extraction

Extractive practices began in the early 1800s in Kahuku, when the endemic tree sandalwood (*Santalum paniculatum*), valued for its aromatic wood and destined for overseas markets, was logged in large quantities from Kahuku's forests (Avery 2006). When Kahuku passed into the private ownership of Charles C. Harris in 1861, pulu (soft hairs collected from the base of tree fern fronds used as mattress stuffing) was the focus of commercial activities (Avery 2006). At this time, cattle and goats already occupied lands in Kahuku.

Alfred Wellington Carter, manager of Parker Ranch, acquired Kahuku in 1911 and prioritized pasture improvement in his campaign for profitable cattle ranching operations in Kahuku's lower elevations. This included stocking of cattle and livestock, forage species introductions, and fencing. Under Carter's management, noxious pasture weeds including guava (*Psidium guajava*), Hilo grass (*Paspalum conjugatum*), and lantana (*Lantana camara*) were also controlled. These efforts had limited success, and the ranch did not live up to Carter's expectations. Nearly 20 years after he assumed ownership, there had been no increase in the estimated 607 ha of land suitable for grazing (Avery 2006).

James Wilson Glover took over Kahuku from 1947 to 1958. During this period, the paddock system was enlarged, road access improved, and koa extensively logged. Though the ranch was stocked with both infrastructure and livestock, it had not developed into a commercially viable operation. Forest was bulldozed to make pastures,

but because the area was not stocked with grasses, much of it was colonized by undesirable species (Avery 2006).

Damon estate (after 1958) accelerated the pasture development, introducing grasses and forage legumes, installing fencing, and clearing undesirable weeds including prickly Florida blackberry (*Rubus argutus*) and Hāmākua pāmakani (*Ageratina riparia*) (Avery 2006). By 1968, ranch managers estimated there were over 9,720 ha (24,000 ac) of pastures in Kahuku, and the ranch continued to develop land into pastures until the late 1980s.

At higher elevations very little manipulation occurred. In the 1930s, Civilian Conservation Corps (CCC) worked on road and fence construction along the boundary between state lands and Kahuku and Kapāpala. The State of Hawai'i allowed koa logging and access roads on adjacent lands, and some activity spilled over into Kahuku. In recent years, recreational all terrain vehicle (ATV) riding in the cinder fields above HOVE has impacted these landscapes.

Recent History- Introduced Ungulates

A number of alien ungulate species have been introduced to Hawai`i, and most of these have impacted Kahuku. European domestic pigs and domestic goats were landed at Niʻihau and later at Kealakekua Bay during Cook's first voyage in 1778. Domestic cattle and additional landings of goats were released by Vancouver at Kawaihae and Kealakekua Bay in 1793 and again in 1794. By the mid-nineteenth century numbers of feral ungulates had risen to such an extent that they likely contributed to the deforestation of the Waimea Plain and the consequent soil erosion and drought (Tomich 1986). It is not recorded when feral pigs and goats reached Kahuku, but they may have been present for almost 200 years.

Mouflon sheep were brought to Hawai`i as a game animal and released on Lāna`i as early as 1954. Additional mouflon were released on Mauna Kea between 1962 and 1968. Eight mouflon were brought to Kahuku in 1968, and an additional three were released in 1974 (Hess et al. 2006). By 1984, a population of several hundred animals had become established largely in the alpine scrub habitat between 1,200 and 1,800 m elevation (Tomich 1986). Currently the numbers of mouflon are conservatively estimated to exceed 2,500 in Kahuku (Hess et al. 2006), where mouflon are abundant in pastures, forests, woodlands, and the subalpine shrublands above the Kaʻū Forest Reserve.

The early 1800s saw the beginning of cattle ranching by Samuel Parker in Kohala. Indeed, Parker Ranch expanded to such an extent that it included Kahuku within its boundaries. At Kahuku, there is still evidence of the old cattle drive trails that crossed the mid-slopes of Mauna Loa and Hualālai to Kona where cattle were sold and loaded on ships for market. Currently, a special use permit issued by the park allows domestic cattle operations to continue in pastures below 1,500 m elevation until April 2009.

Climate

Prevailing northeast trade winds are a dominant feature of Hawai`i's climate, and they interact with the physical geography of the islands to influence wind and rain patterns. Resulting orographic effects are responsible for rainfall maxima generally occurring along windward slopes, and leeward climates being generally dry. The larger volcanoes Hualālai, Mauna Kea and Mauna Loa create large expanses of areas

sheltered from tradewinds with locally developed circulations. These volcanoes are so effective in blocking the prevailing northeast trade winds that leeward Hawai`i is dominated by a diurnal wind pattern of downslope breezes at night and upslope winds from the sea during the day (Giambelluca and Schroeder 1998).

These two climate regimes, tradewind flow and land–sea breeze, affect the climate within Kahuku. Eastern Kahuku is most strongly influenced by the trade wind flow, and western Kahuku is most affected by the land breeze–sea breeze flow (Figure 2). Diurnal variation in wind speeds and direction occur throughout Kahuku, and upslope winds are a common feature of higher elevations.

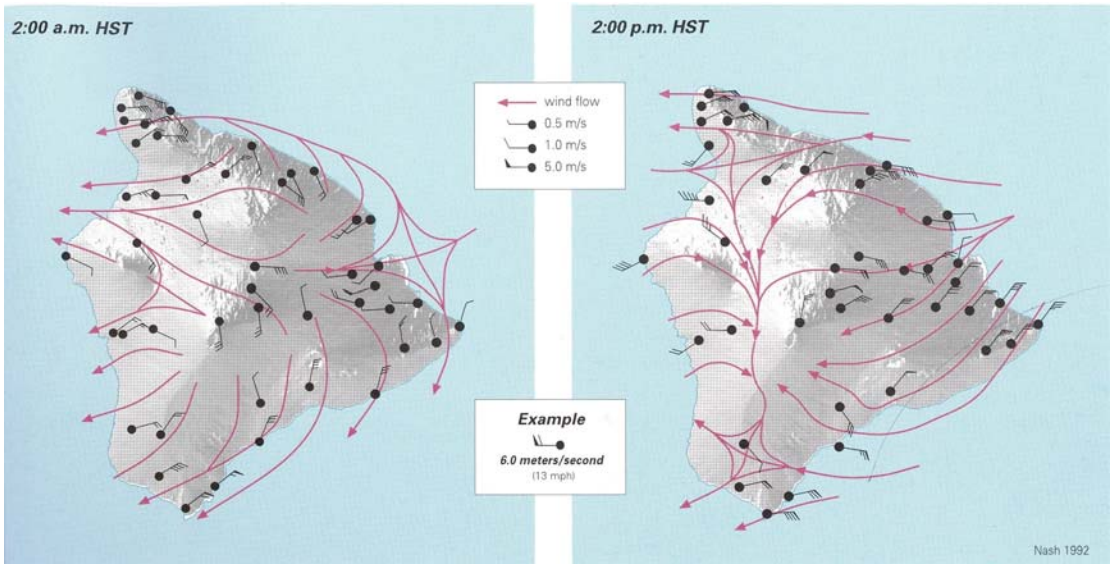

Figure 2. Wind patterns on Hawai'i Island showing diurnal variation (modified from Chen and Nash 1992)

Highest average rainfall totals occur in the summer months on the southwest slopes of Kahuku, and in the winter months on the southeast slopes of Kahuku. Kona storms of low-pressure originating in the sub-tropics are accompanied by southerly winds and high rainfall events; these are most frequent in winter. Mid-latitude storm fronts can influence Kahuku weather throughout the year. Both of these features are exceptions to the norm of the prevailing northeast trade winds (Juvik and Juvik 1998).

The work of Giambelluca et al. (1986) shows that median annual rainfall at Kahuku increases from 1,000 mm at 600 m just south of the Kahuku boundary, to 1,500 mm at 1,300 m (Figure 3). The 1,500 mm isohyet parallels both the southeast and southwest Kahuku boundary, and much of the native forest at Kahuku is found near this line.

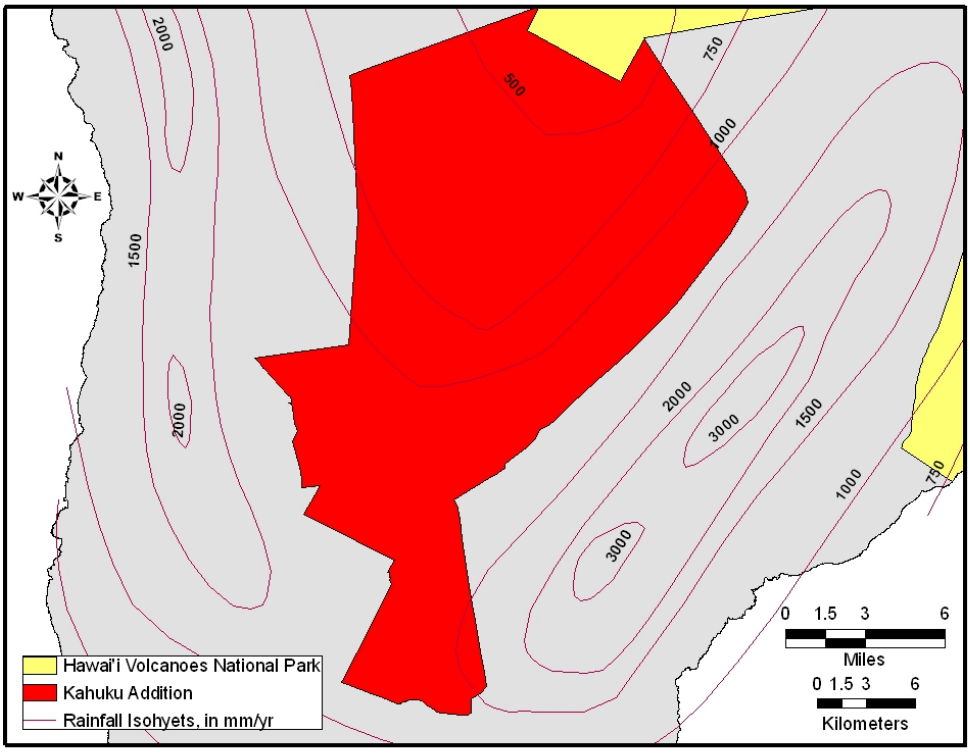

Figure 3. Median annual rainfall in the Kahuku addition, Hawai'i Volcanoes National Park. Isohyets based on: An Inventory of Basic Water Resources Data: Island of Hawaii (DLNR 1970)

An important climate feature of high slopes of Mauna Loa is the tradewind inversion zone, which lies between 1,525 and 3,050 m elevation and is regulated by descending tropical air masses that meet the prevailing northeast trade winds. Descending air masses have a warming and drying effect, and the inversion acts to keep rising, humid marine air from reaching high altitudes. Above the inversion clear skies, low humidity, and minimal precipitation prevail (Giambelluca and Schroeder 1998). Another effect of the trade wind inversion is the capture of rising moist marine air below the inversion, creating a fog zone along both the southeast and southwest Kahuku boundaries near the 1,500 mm isohyet. Fog drip from low clouds is an important source of moisture for plants in this zone and can increase measurable precipitation by 20% (Juvik and Perreira 1973; Juvik and Nullet 1995).

Above the 1,500 mm isohyet at Kahuku, a dry moisture regime persists. The 500 mm isohyet is located close to 3,300 m elevation. Frost is common in the winter months above 1,828 m, and snowfall occurs at higher elevations.

Geology and Soils

The Kahuku addition of HAVO constitutes a complex geologic matrix of lava flows, straddling the Southwest Rift of world's largest active volcano, Mauna Loa. Sixty-six percent of the lava flows at Kahuku have occurred since the arrival of Polynesians. Recent lava flows (1851-1950) cover 26% of the Kahuku addition (Figure 4; Figure 5). In the eastern section of Kahuku, recent lava flows occurred in 1916, 1926, and 1950. Lava

flows in the western section include those of 1887, 1907, 1916, 1919 (`Ālika flow), 1926 (Ho`ōpūloa flow), and 1950. Other prominent historic flows are the 1868 flow in southern Kahuku and the 1949 flow near the Mauna Loa summit. Sixteen percent of the Kahuku addition is estimated to be 200 to 750 year old lava flows, and 24% is between 750 and 1,500 years old. The most abundant age class is the 1,500 to 3,000 year old substrates; these encompass (30%) of Kahuku. Less than 5% of Kahuku's substrates are dated greater than 3,000 years old, and Pleistocene Pāhala ash deposits cover only 1% of Kahuku's eastern section (Trusdell et al. 2005).

The Southwest Rift of Mauna Loa (a fractured zone of eruptive activity on the flank of the volcano) terminates within Kahuku at 1,524 m elevation just above HOVE and includes many prominent features. These are Red Cone and Sulphur Cone at ~3,475 m elevation, `Ālika Cone at 2,390 m, and Pu`u o Ke`oke`o, Kapō`ala`ala, and Ihuanu at ~1,615 m elevation. In the southern section of Kahuku between 670 and 910 m elevation are Pu`u `Akihi, Pu`u o Kahuku, and Pu`u o Lokuana, and to the west of these hills is a prominent fault scarp (a cliff formed by ground movement on one side of a geological fault), Pali O Ka Eo. A large (2.3 ha) unnamed pit crater is known from south-central Kahuku at 1,250 m elevation, and several smaller craters and flow channels have been identified in Kahuku. (A pit crater is formed by surface sinking and is not typically a lava vent.) Near the western boundary with Manuka Natural Area Reserve (NAR) is a large cinder cone called Pu`u `Ōhohia. (Cinder cones are built of material ejected from volcanic vents.)

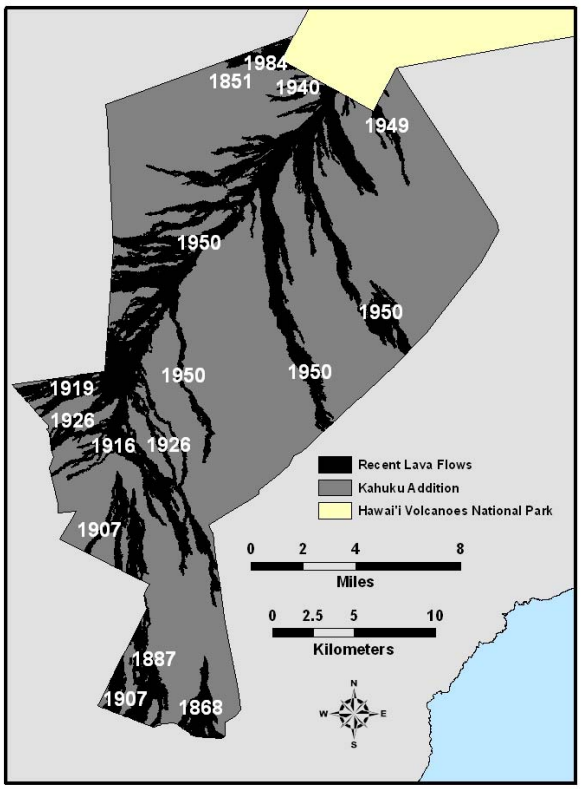

Figure 4. Recent Lava Flows in the Kahuku addition, Hawai'i Volcanoes National Park.

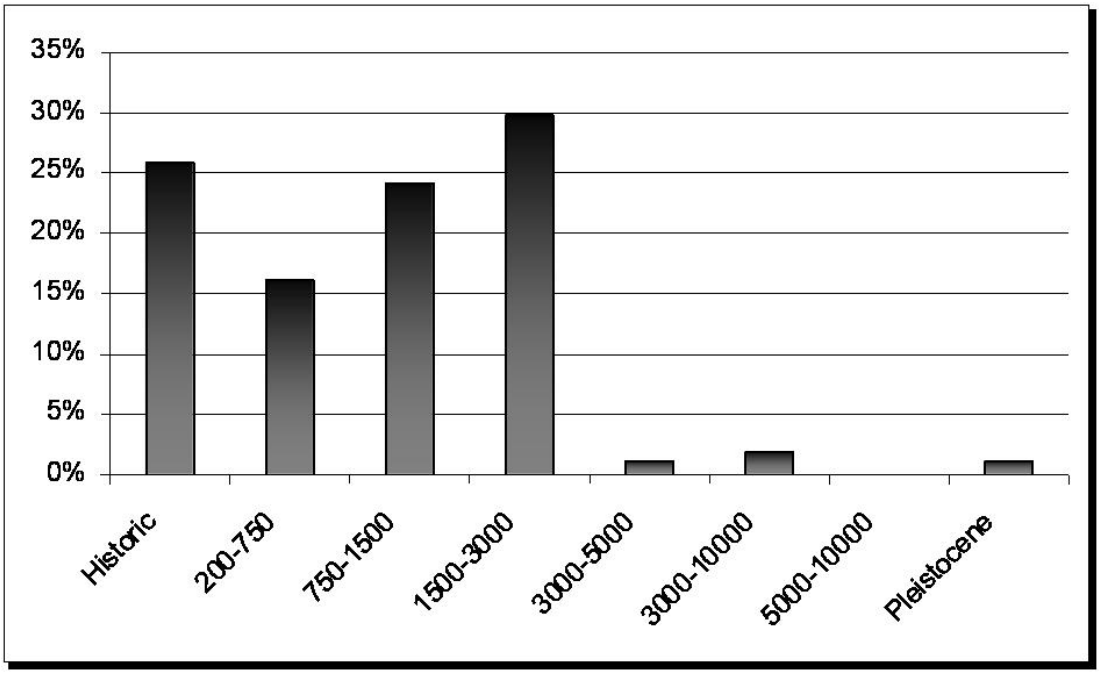

Figure 5. Geological age of substrates by percent area, Kahuku addition, Hawai'i Volcanoes National Park.

Soils form over time through the breakdown of parent materials by water, wind, and organic processes. Over 90% of the soils at Kahuku are typed as lava flows, rock land, rough broken land, and cinder land (Figure 6). The remaining soils are classed in broad categories of loam based on their content of rock, stone, sand, silt, and clay. They are of young age and not well developed. A very small percentage (0.18% or 108 ha) of Kahuku soils on the western boundary are classed as Hydrandept-Tropofolist Association, a soil type common to windward Mauna Loa and the Ka`ū Forest Reserve. They are thin, organic soils on lava flows, with 10-30 cm of organic material over fragmented `ā`a or pāhoehoe lava. `Ā`a lava has a rough and fragmented surface of blocks or clinkers, while pāhoehoe lava has a smooth or ropy surface. The slope throughout Kahuku is predominantly six to 20% (Natural Resources Conservation Service 2007).

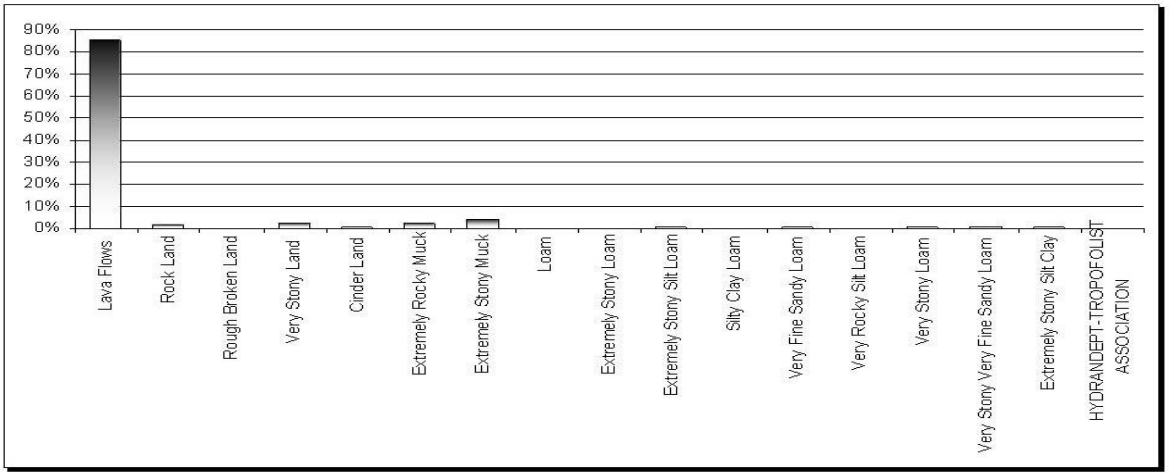

Figure 6. Soil type coverage by percent area, Kahuku addition, Hawai'i Volcanoes National Park.

Lava flows are primarily associated with the Southwest Rift of Mauna Loa; rock lands occur along the Western Kahuku boundary; and cinder lands are associated with the Ihuanu and Pu`u `Ōh`ōhi`a area in the West and Pu`u o Lokuana in the south. The southern and western Kahuku boundary areas are a complex of soil types ranging from stony mucks to loam.

Previous Vegetation Mapping

Prior to the 2005-06 Kahuku vegetation surveys, our knowledge of the vegetation of Kahuku was based on vegetation maps produced after the Hawai`i Forest Bird Survey of the 1970s and early 1980s (Jacobi 1978; Jacobi et al. 1983). Because the focus of the earlier survey was forest bird habitat, little vegetation of Kahuku above 1,830 m elevation was mapped. Jacobi (1978) mapped much of the Ka`ū Forest Reserve as closed tall `ōhi`a forest; this vegetation type extended north of the Reserve boundary into eastern Kahuku. Interspersed among closed forest units were small patches of mixed grassland and lower-stature open `ōhi`a forests. Upslope of the forest edge, most of eastern Kahuku was scattered medium-stature `ōhi`a with a treeless alpine native scrub community well represented in the central portion of this region.

Much of central Kahuku between 600 m and 1,500 m elevation has been intensively managed as pastureland in the recent past. During the Hawai`i Forest Bird Survey, the active pastures were mapped as open `ōhi`a forest with koa and mixed native trees. Also prominent in central Kahuku were kīpuka (islands of vegetation surrounded by less vegetated or more recent lava flows) with scattered koa and `ōhi`a trees, open `ōhi`a forest, and closed `ōhi`a forests with tall koa and mixed native tree understory. Historical lava flows of central Kahuku were mapped as dry bare substrate with scattered native shrubs. Above 1,525 m elevation, vegetation was open low-stature `ōhi`a forest with native trees and shrubs (Jacobi et al. 1983).

The western section of Kahuku was not well covered by the Hawai`i Forest Bird Survey, but the upper reaches of transects did extend into the Ranch. Western Kahuku forests were classified as dry open to scattered `ōhi`a with native trees and shrubs. The

scattered tree map units were at higher elevations than the open forests. A large expanse of cinder-covered land above HOVE, historical lava flows of western Mauna Loa, and subalpine regions above 2,010 m elevation were mapped as dry bare areas with or without native shrubs (Jacobi et al. 1983).

METHODS

Sampling Design

The objective of the sampling design was to describe as many vegetation types as possible, in addition to identifying rare and species-rich communities that may require immediate management attention. Vegetation sampling was conducted along transects (Figure 7), using pre-established bird survey transects wherever possible. Not all of the bird survey transects were used, and some were extended. One in three transects established by the bird survey was inventoried for plants along the eastern survey region. These transects were extended above the forest line to include shrubland, grassland, and pioneer communities in the subalpine zone near. 2,480 m elevation, and one transect extended to 2,830 m elevation. Portions of four bird census transects were sampled in the lower elevations between 610 and 1,520 m elevation, and two additional transects were added. In western Kahuku, three existing bird transects were inventoried; these were extended above the forest line to 1,950 m elevation.

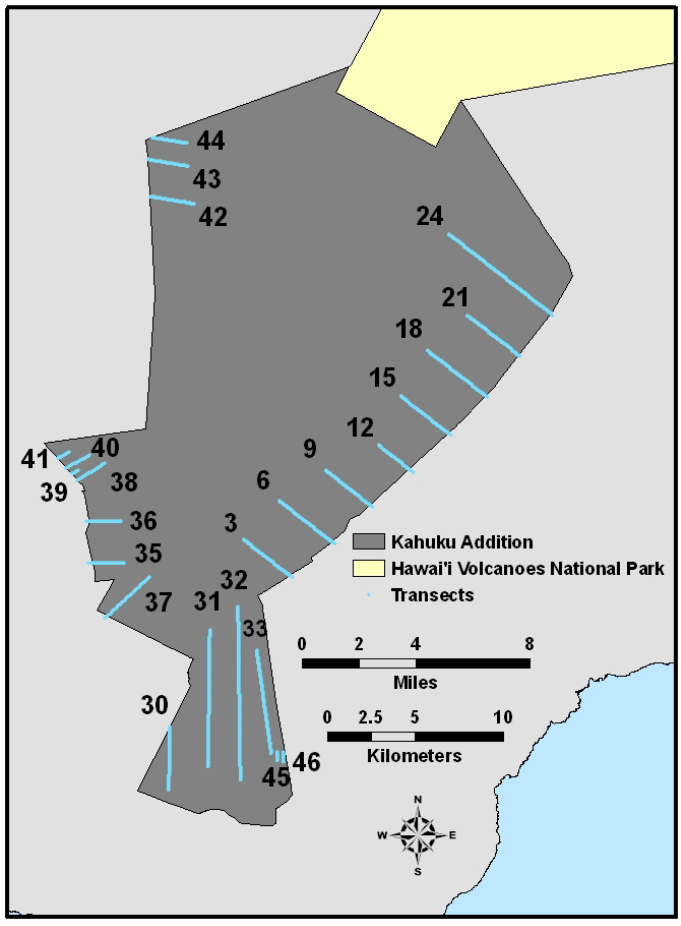

Figure 7. Distribution of vegetation survey transects in the Kahuku addition, Hawai`i Volcanoes National Park.

Additional transects were established to encompass vegetated areas not included in the bird survey transects. This sampling included four additional transects in the koa forest located north of the bird survey transects adjacent to TNCH Kona-Hema Preserve and three transects in Kahuku's northwestern region. Transects were marked using blue flagging at 5-15 meter intervals. Transect stations (every 100 m) were flagged with blue and orange/black. Rare plants were marked with pink flagging adjacent to the target plant; small plants were not flagged. Flagging was placed out of sight of roads and trails.

The Kahuku addition was parceled into five survey regions to facilitate field sampling (Figure 8). These were the northwestern survey region, a remote northwestern corner of the former ranch; the western survey region, including the southwestern slopes of Mauna Loa from HOVE to the 1919 lava flow; the eastern survey region, above the Ka`ū Forest Reserve; the central survey region composed of pastures, grazed open forest, lava flows, and wet forest remnants; and the southwestern survey region, including kīpukas separated by lava flows of 1868 and 1887. Above 2,800 m vegetation development is minimal, and these areas were not surveyed.

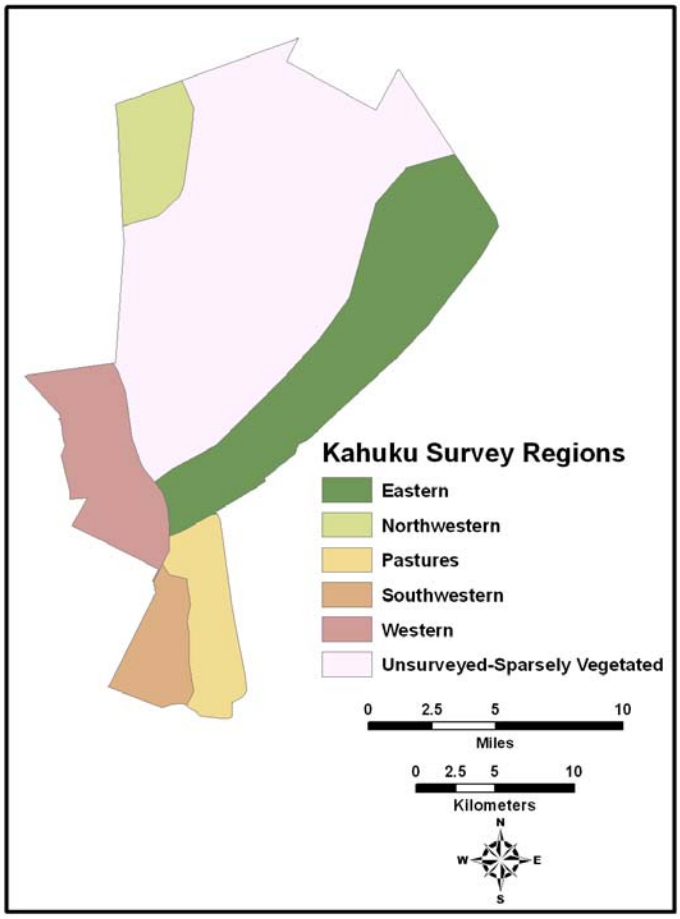

Figure 8. Distribution of vegetation survey regions in the Kahuku addition, Hawai`i Volcanoes National Park.

Additional surveys to describe vegetation were conducted in small kīpukas, pit craters, forested ravines, and other localized habitats not included in the transect surveys. These areas were selected after reviewing available Geographic Information System (GIS) imagery and aerial photographs of the survey area. These off-transect surveys consisted of systematic sweeps of the entire habitat to identify all plant species in the area. Off-transect data collection included noting both rare and alien plant species and abundances within the survey area and along roads to and from the work site.

Aerial surveys along pre-determined flight transects were also used to locate potential rare plant populations and habitat and to target alien species in open and remote areas, such as woodlands and lava flows with little vegetation development. Six and a half hours of helicopter time were employed surveying vegetation from the air and ferrying field teams to remote locations for ground survey work. Aerial surveys were conducted between 30 and 150 m above ground level at speeds up to 120 km/h.

Digital imagery (LANDSAT, IKONOS, SPOT) was used to identify remote vegetated areas and to determine the upper and lower elevation limits for transect work. Sampling was conducted primarily within the Kahuku's boundaries, but extended as much as 500 m into adjacent lands along the eastern and western survey regions.

Field sampling of vegetation was conducted between January 2005 and January 2006. Findings from previous field and aerial surveys dating to January 2004 were utilized to augment data for western survey regions and adjacent lands.

Data Collection

Alien Plant Inventories

Distribution and cover-abundance of target alien weeds (Table 1) were quantified in 10-m wide by 100-m long segments that subdivided each belt transect. Target weeds were selected to include invasive taxa previously found in Kahuku and adjacent areas, and invasive species managed in the older portions of HAVO. Additional invasive species encountered during surveys were added to the target list if they were highly abundant or known to be invasive elsewhere in Hawai'i.

Presence/absence of alien species was recorded for each 100-m interval. Percent cover of each species was estimated using modified Daubenmire percent cover classes (<1, 1-5, 5-25, 25-50, 50-75, 75-95, >95) (Mueller-Dombois and Ellenberg 1974). Additional point location data (Global Positioning System or GPS) were collected for individuals observed near transects but not within the belt, from aerial surveys, and systematic surveys of localized habitats (kīpukas, pit craters, rare habitats). GPS data were collected using a Garmin V handheld unit, with accuracies ranging between 3-15 meters. Where GPS signals could not be collected (i.e., dense forest, pit crater) transect stations were noted or a distance and bearing was estimated from the last known reference point.

Table 1. Pre-survey list of invasive alien weeds targeted for monitoring in the Kahuku addition, Hawai`i Volcanoes National Park.

SPECIES*	HABITAT	HABIT
Acacia confusa	Dry - mesic disturbed areas	Tree
Agave sisalana	Dry rocky areas	Large herb
Ageratina riparia	Dry disturbed – mesic forest	Herb
Andropogon virginicus	Dry - mesic shrubland, forest	Grass
Anemone hupehensis	Wet forest, disturbed areas	Herb
Archontophoenix alexandrae	Dry - mesic, disturbed areas	Tree
Bocconia frutescens	Dry - mesic forest, woodlands, disturbed areas	Shrub
Buddleia asiatica	Mesic - wet disturbed areas, cinder, forest	Shrub
Buddleia madagascariensis	Mesic disturbed areas	Shrub
Casuarina equisetifolia	Dry areas	Tree
Cestrum nocturnum	Wet forest	Shrub
Cirsium vulgare	Dry - mesic areas	Herb
Clidemia hirta	Mesic - wet forest	Shrub
Delairea odorata	Dry forest, disturbed areas	Vine
Ehrharta stipoides	Wet - mesic forest, woodland	Grass
Eucalyptus spp	Disturbed planted areas, mesic - wet forest	Tree
Falcataria moluccana	Disturbed mesic - wet	Tree
Fraxinus uhdei	Planted areas	Tree
Furcraea foetida	Dry-mesic disturbed sites, rocky areas	Large herb
Grevillea banksii	Dry-wet forest, disturbed areas	Tree
Grevillea robusta	Dry-mesic forest, woodlands, disturbed areas	Tree
Hedera helix	Cultivated, disturbed areas	Vine
Hedychium gardnerianum	Mesic - wet forest	Herb
Helichrysum foetidum	Disturbed areas	Herb
Hyparrhenia rufa	Disturbed areas	Grass
Juncus effusus	Wet forest, standing water	Herb
Kalanchoe pinnata	Dry - mesic disturbed areas	Herb
Lantana camara	Dry - mesic forest, woodland, shrubland	Shrub
Leucaena leucocephala	Dry disturbed areas	Tree
Ligustrum sinense	Cultivated, disturbed areas	Shrub
Melinis minutiflora	Dry-mesic disturbed areas	Grass
Melochia umbellata	Disturbed areas	Tree
Miconia calvescens	Mesic-wet forest	Tree
Morella faya	Mesic - wet woodlands, forest	Tree

SPECIES*	HABITAT	HABIT
Neonotonia wightii	Dry - mesic disturbed areas	Vine
Olea europaea ssp. *cuspidata*	Cultivated, dry - mesic disturbed areas	Tree
Panicum maximum	Dry - mesic disturbed areas	Grass
Passiflora ligularis	Mesic - wet forest	Vine
Passiflora tarminiana	Mesic - wet forest	Vine
Pennisetum clandestinum	Dry - wet forest, pastures	Grass
Pennisetum polystachion	Dry - mesic disturbed areas	Grass
Pennisetum setaceum	Dry disturbed areas, lava flows	Grass
Persicaria capitata	Dry - wet disturbed areas, lava flows	Herb
Pluchea carolinensis	Dry - mesic areas	Shrub
Psidium cattleianum	Mesic - wet forest, disturbed areas	Tree
Pyracantha koidzumii, P. crenatoserrata	Mesic disturbed areas	Shrub
Ricinis communis	Dry disturbed areas	Tree
Rubus argutus	Mesic - wet forest, pastures, disturbed areas	Shrub
Rubus ellipticus	Mesic - wet forest	Shrub
Rubus rosifolius	Mesic - wet forest	Shrub
Schefflera actinophylla	Disturbed areas	Tree
Schinus terebinthifolius	Mesic disturbed areas, pastures, woodlands	Tree
Schizachyrium condensatum	Mesic shrubland, grassland, pastures	Grass
Senecio madagascariensis	Disturbed areas, pastures	Herb
Setaria palmifolia	Wet forest	Grass
Solanum pseudocapsicum	Mesic - wet forest	Shrub
Sphaeropteris cooperi	Mesic - wet forest	Tree
Sporabolus africanus	Disturbed areas, shrubland, pastures	Grass
Tibouchina spp.	Mesic-wet forest, disturbed areas	Shrub
Trema orientalis	Disturbed mesic forest	Tree
Tropaeolum majus	Mesic forest, disturbed areas	Vine
Verbascum thapsus	Lava flows, open areas	Herb

*Additional invasive species were included when they were encountered during field surveys

Rare Plant Inventories

Presence/absence and number of rare species were recorded in 10-m wide by 100-m long segments that subdivided each transect. In addition, location of all rare plants observed in the vicinity of transects (inside or outside 10 m belt width), from aerial surveys, and systematic surveys of localized habitats was recorded with a GPS unit. A field form for collection of rare plant data and a list of potential endangered and rare species in the region were developed prior to surveys. Data recorded at each rare plant sighting included number of individuals, height, phenology, threats to the population (i.e., browsers, pig digging) and estimated vigor. When possible, propagules of fertile rare plants encountered were collected for propagation at HAVO and the Volcano Rare Plant Facility.

Plant Community Data for Vegetation Classification

Plant composition was sampled in non-permanent circular plots that were established at 500-m intervals along transects or wherever there was a sustained change in vegetation type. Plots were rejected if they occurred within 30 m of the boundary between two vegetation types to avoid capturing community edge effects. A GPS waypoint was collected at plot center and recorded on the field form. Plot size varied from 15 m to 30 m radius depending on the density and homogeneity of the vegetation. Typical plots had a radius of 15 m (area=707 m^2). Within the plot, species composition and abundance in each vegetation tier or stratum (forest, shrub, herbaceous) were quantified using the relevé method (Mueller-Dombois and Ellenberg 1974). Cover-abundance of species and vegetation tier were estimated using the following categories: <1, 1-5, >5-10, >10-25, >25-60, >60% foliar plant cover; these data will facilitate future classification in accordance with the NPS Vegetation Mapping Program (USGS-NPS 1994). Vegetation tiers were defined by a combination of height and life form in the field. Information on substrate type (soil, ʻāʼa, pāhoehoe), vegetation height, and elevation was collected. A total of 177 plots were sampled, and the data were input in a Microsoft Excel spreadsheet that could be exported as a text file and viewed in ArcGIS 9.1.

Vascular Plant Checklist

All vascular plants encountered in Kahuku were recorded as they were observed along transects, systematic surveys of localized habitats, en route to study sites, and in vegetation plots. These species were incorporated into a vascular plant checklist including general location, ecological zone, status, and estimated abundance (Appendix A). Voucher specimens were made for those species not previously reported from HAVO, as well as species of uncertain identification. Specimens were pressed, dried, and stored in the HAVO Herbarium. Labels will be written for all specimens to be incorporated in the HAVO Natural History Collection, and mounted specimens will be submitted to HAVO curators for cataloging and accessioning.

Data Analysis and Data Management

Presence and absence data for this inventory were entered into NPSpecies the National Park Service's Biodiversity database.

Alien Plant Inventories

Presence/absence data and cover abundance (%) of target weeds, measured along transects and in systematic surveys of localized habitats, were input in ArcGIS 9.1, and stored in projected shapefiles and associated .dbf files. The data format design is compatible for export into additional GIS and database programs to allow for future analysis by multivariate statistical packages (e.g., SYSTAT, SAS, Minitab). These data will 1) provide baseline data for comparison with future surveys to determine changes in alien species abundance and distribution over time, and 2) identify high priority areas for weed management.

Rare Plant Inventories

Presence/absence data of rare species, number of individuals, height, length, vigor, phenology, and other quantitative measurements taken along transects, off transects, and during systematic surveys of localized habitats were entered into an Microsoft Excel spreadsheet and exported to an Microsoft Access database to generate distribution maps and metadata in ArcGIS 9.1. The data format design is compatible for export into additional GIS and database programs, and allows for future analysis by multivariate statistical packages (e.g., SYSTAT, SAS, Minitab). These data will 1) provide baseline data for comparison with future surveys to determine changes in rare plant abundance and distribution over time, and 2) identify high priority areas for rare plant management (e.g., protection from ungulates, removal of disruptive weeds).

Plant Community Data

Species cover and abundance data were entered into a Microsoft Excel spreadsheet that is compatible with export into Microsoft Access database for viewing, or to .txt files for export into multivariate statistical and ordination programs (e.g., MVSP, SYSTAT, SAS) for future vegetation classification. Metadata for the vegetation dataset were generated using ArcCatalog 9.1 and are FDGC compliant.

RESULTS AND DISCUSSION

Vascular Plant Checklist

The survey of the Kahuku Ranch Unit resulted in a vascular plant checklist of 471 plant taxa (Table 2, Appendix A), including plants sighted during the field survey, plants collected by Resources Management personnel at Kahuku, and those documented by specimens in the herbaria of Bernice P. Bishop Museum and the Smithsonian Institution National Museum of Natural History (17 species, Appendix B). This total number also includes alien plant species observed in lands adjacent to Kahuku that are considered to be encroaching on the park (18 species, Appendix C). A more thorough inventory of alien plants within HOVE would likely result in additions to the list of encroaching species. A separate USGS-sponsored expedition into the steep-sided pit crater at Kahuku observed 98 plant taxa, including several rare plants not found elsewhere in Kahuku (Bio et al. 2005); these sightings were also incorporated into the Kahuku checklist.

Native plants (194 taxa) comprised 41% of the total flora at Kahuku; most of these were endemic species or varieties (Table 2). Only a few Polynesian introductions were established at Kahuku, but more than half of the observed taxa (272 taxa, 58%) were alien in origin. Sixty-eight ferns and fern allies occurred in Kahuku, and almost all of these (84%) were native species (endemic and indigenous). Monocots were well

represented at Kahuku, with 106 species total, of which 70% were alien. Not surprisingly for a former ranch, 39 alien grass species were present in surveyed portions of Kahuku. Dicots were the largest taxonomic group in the Kahuku flora; approximately one-third of observed dicot species were native and two-thirds were alien. At least seven alien gymnosperm species have been planted at Kahuku near buildings and boundary fences, adjacent to a reservoir, and in a stand with other potential timber trees.

An attempt was made to record the occurrence of plant species in each of Kahuku's survey regions. We also used the results of the USGS survey and listed species found in the steep-sided pit crater at 1,250 m elevation in central Kahuku; 10 native plant species (or varieties) observed within the pit crater were not seen elsewhere in Kakuku during the survey. These species are discussed in the "Kahuku Pit Crater Vegetation Description" section below.

Table 2. Summary of vascular plant taxa of the Kahuku addition

Taxa	End.	%	Ind.	%	Pol.	%	Alien	%	Total
Ferns and Fern Allies	39	57	18	27	0	0	11	16	68
Gymnosperms	0	0	0	0	0	0	7	100	7
Monocots	18	17	11	10	3	3	74	70	106
Dicots	97	33	11	4	2	1	180	62	290
Total	154	-	40	-	5	-	272	-	471

End. = Endemic, unique to the Hawaiian Islands
Ind. = Indigenous, native to Hawai`i and other lands
Pol. = Non-native, Polynesian introduction
Alien = Non-native, introduced after 1778

Vegetation Descriptions

Vegetation of Kahuku's Eastern Survey Region

The eastern survey region of Kahuku was defined as the area that stretches along the top of the Ka`ū Forest Reserve from the northwestern corner near the 1926 lava flow to the eastern boundary of the unit adjacent to the Kapāpala Forest Reserve. Only the vegetated portion of this region was surveyed with transects below approximately 2,350 m elevation, except for one survey line that reached 2,800 m elevation on a very sparsely vegetated lava flow.

A band of wet forest vegetation extended into Kahuku from the contiguous Ka`ū Forest Reserve. Except for a few stands of koa at both the eastern and western extent of the region, the forest canopy was dominated by `ōhi`a. The canopy was closed (>60%), and the stature of the dominant trees was typically greater than 20 m. An open subcanopy ranging from six to 12 m in height typically included `ōlapa (*Cheirodendron trigynum*), kāwa`u (*Ilex anomala)*, kōlea lau nui (*Myrsine lessertiana),* `ōhi`a, and pilo (*Coprosma ochracea*). Hāpu`u tree ferns (*Cibotium* spp.) were not prominent understory components except on the western side of the region. The shrub layer was usually open with less than 25% cover; pūkiawe was the most abundant shrub, but `ōhelo (*Vaccinium calycinum*), pilo, and kanawao (*Broussaisia arguta*) were also common. Uluhe (*Dicranopteris linearis*) had high cover in patchy areas of forest on the western end of this region. The ground cover was typically greater than 60% and dominated by native

ferns and sedges. `I`o nui (*Dryopteris wallichiana*) and palapalai a kamapua`a (*Amauropelta globulifera*) were the most common ferns, and the most abundant sedges were *Carex alligata* and *Uncinia uncinata*. Disturbed areas with less herbaceous cover were frequent throughout this survey region; many of these appeared to be the result of feral pig activities.

Further above the boundary with Ka`ū Forest (within one km) the Kahuku forest became less diverse in composition, although it maintained a closed canopy of tall ‘ōhi’a (ranging to >25 m in height). The subcanopy became sparser with fewer trees of the same species as found at lower elevations below. The shrub layer became more prominent and was dominated by pūkiawe, with lesser cover of pilo and kūkaenēnē (*Coprosma ernodeoides*). Ground cover was predominantly the native grass *Deschampsia nubigena* or a mixture of grass, native sedges, and native ferns.

At the edge of the closed forest there was a transition, sometimes abrupt, to open woodland or shrubland; this occurred at lower elevations in the southwestern portion of the east slope. The east slope shrublands were composed of an open matrix of native shrubs (usually 25-60%), including pūkiawe, `a`ali`i (*Dodonaea viscosa*), `ōhelo, and kūkaenēnē; the first two species were typical co-dominants. Emergent trees in the shrubland were very scattered, low-stature (3-7 m) ‘ōhi’a. Ground cover was variable in amount and composition; *Deschampsia nubigena* was abundant in some areas, while the alien rattail grass (*Sporobolus africanus*) was prominent in shrublands in the southwestern part of the east slope. Shrublands became more sparsely vegetated (5-10% or 1-5% cover) with elevation; this transition occurred at the relatively low elevation of 1,890 m in the southwestern section, while open shrublands with cover greater than 25% persisted above 2,150 m in the far east. High-elevation sparse shrublands typically had <1% cover of ‘ōhi’a trees and 1-5% cover of native shrubs. Ground cover was rarely more than 5% and was composed of native and alien grasses, alien forbs, native sedges, and ferns. Above an elevation of 2,750 m and on historical and recent lava flows, the landscape was barren with <1% cover of native shrubs, ferns, sedges, and grasses.

Vegetation of Kahuku’s Central Survey Region

Except for historical lava flows and other recent substrates, the central survey region of Kahuku consisted primarily of relictual forest fragments and recently grazed pastures that were developed from wet and mesic `ōhi`a and koa forests in the 19th and 20th centuries. The southwestern corner of the central section below 950 m elevation has not been heavily grazed and continues to support dry woodlands.

Upper pastures of central Kahuku had an open canopy of tall (12-22 m) `ōhi`a or mixed koa and `ōhi`a trees and a subcanopy of very scattered `ōhi`a, naio (*Myoporum sandwicense*), or kōlea lau nui. There was rarely a shrub layer, and ground cover was dominated by alien grasses, particularly kikuyu (*Pennisetum clandestinum*), meadow ricegrass (*Ehrharta stipoides*), and sweet vernal grass (*Anthoxanthum odoratum*). Barbwire grass (*Cymbopogon refractus*) was prominent in western central pastures.

The eastern central pastures supported clumps of remnant forest scattered through more intensively grazed pastures. The sides of ridges and gulches were also forested in this area. Tree cover was greater in pastures above an elevation of 900 m and in a narrow band along the eastern boundary to ca. 750 m elevation. Overall, the tree canopy

was estimated as 10-25% and was composed of relatively tall `ōhi`a (12-25 m). Subcanopy trees restricted to forest patches included `ōlapa, kāwa`u, alani (*Melicope clusiifolia*), and kōpiko`ula (*Psychotria hawaiiensis* var. *hawaiiensis*). Tree ferns (primarily hāpu`u) typically had 1-5% or 10-25% cover in forest remnants and were absent from treeless areas. Ground cover of forest remnants was highly disturbed by ungulates, but included meadow ricegrass, young tree ferns, and a number of native terrestrial ferns, such as `amau (*Sadleria* spp.), hō`i`o (*Diplazium sandwichianum*), palapalai (*Microlepia strigosa*) and *Dryopteris* spp. The most abundant pasture grass was kikuyu, but narrow-leaved carpet grass (*Axonopus fissifolius*), pangola (*Digitaria eriantha*), and rattail were also common. A suite of small alien herbs, including intentionally introduced legumes, was scattered throughout the pasture, and boggy sites supported stands of Japanese mat rush (*Juncus effusus*).

A triangular area adjacent to a water reservoir was fenced to restrict cattle access, and this semi-protected area supported the only closed wet forest vegetation of the eastern central region other than the ravine near Pu`u `Akihi. The forest canopy was composed of tall `ōhi`a to 32 m, with estimated tree cover ranging from 1-5% to 10-25%. The subcanopy was relatively sparse (5-10%) with a mean height of eight m. `Ōlapa and young `ōhi`a were the most common subcanopy trees, but kāwa`u, kōpiko`ula, and pilo were also present. Shade was provided by a closed layer of tree ferns comprised of hāpu`u pulu (*Cibotium glaucum*) and taller hapu'u 'i'i (*C. menziesii*) with scattered olomea (*Perrottetia sandwicensis*), pilo, and climbing `ie`ie (*Freycinetia arborea*). The herbaceous layer was sparse, only 5-10% cover, and was composed of young tree ferns, hō`i`o, `ie`ie, tree seedlings, and a few other terrestrial ferns.

The pastures of the southeastern corner of Kahuku were almost devoid of trees, except for narrow ravines and steep slopes that supported `ōhi`a trees and large Christmasberry shrubs (*Schinus terebinthifolius*). Pastures were dominated by kikuyu grass, but taller bunchgrasses such as fuzzy top (*Bothriochloa barbinodis*) and broomsedge (*Andropogon virginicus*) were common, as were the pasture weeds elephant's foot (*Elephantopus mollis*) and vervain (*Stachytarpheta australis*).

Vegetation of Kahuku's Southwestern Survey Region

Dry woodlands of the southwestern survey region appeared to vary considerably in structure and composition on different substrates. Surveyed areas on either side of the 1887 flow supported open-canopy or sparse `ōhi`a woodland of small (2-7 m) to moderate stature (5-10 m) with no real subcanopy. The shrub layer was well developed east of the flow with at least 25-60% cover of mixed `a`ali`i, pūkiawe, `ākia (*Wikstroemia phillyreifolia*) and `ūlei (*Osteomeles anthyllidifolia*). West of the flow, shrub cover was usually <10%, although some areas had shrubs covering 10-25%. In these western kīpuka, `a`ali`i was more common than pūkiawe, and alien shrubs such as lantana (*Lantana camara*) or sourbush (*Pluchea carolinensis*) were rarely seen. `Ā`a substrates had sparse ground cover (typically 1-5%) dominated by alien grasses, primarily broomsedge and bush beardgrass (*Schizachryrium condensatum*) east of the flow and barbwire grass to the west. Native sedges, particularly *Carex wahuensis* and *Cyperus hillebrandii,* were present with very little cover, as were the native fern *Pellaea ternifolia* and alien swordfern (*Nephrolepis multiflora*). `Iliahi or sandalwood (*Santalum paniculatum* var. *pilgeri*) and native panicgrass (*Panicum konaense*) were uncommon native species noted in these dry woodlands.

The best developed dry woodland was found in a kīpuka 43 ha in size on very blocky `ā`a substrate dated 1,500 to 3,000 ybp east of the 1887 flow and directly north of the old highway. Here the open `ōhi`a canopy (25-60%) averaged seven m in height. Although the woodland was largely composed of `ōhi`a, several native trees such as lama (*Diospyros sandwicensis*), māmane, naio, and sandalwood were rare elements. A small section in the southwest of this kīpuka was the only site at Kahuku in which a relictual dryland `ōhi`a-lama forest was present. There was no distinct subcanopy, but a sparse shrub layer (1-5%) was dominated by alahe`e (*Psydrax odorata*) and pūkiawe, averaging 1.2 m in height. `Ūlei, `a`ali`i, and huehue vine (*Cocculus orbiculatus*) were scattered with little cover in the shrub layer. Dry forest kōlea (*Myrsine lanaiensis*) occurred at Kahuku only on this site and was rarely encountered among more common shrubs. A single hōawa (*Pittosporum terminaliodes*) found here was the only tree of its species noted on the survey. Lantana had <1% cover in the upper portion of the woodland, but increased in cover and frequency near the old highway. Herbaceous vegetation was very patchy on the `ā`a substrate, but achieved 25-60% cover in some areas; barbwire grass was the dominant grass of the woodland.

The 1868 flow, although centrally located at Kahuku, had more in common with the southwest woodlands. The pāhoehoe substrate supported an open shrubland of `ōhi`a and pūkiawe averaging 1-1.2 m tall with sparse cover of emergent `ōhi`a trees 3.5-4 m in height. `A`ali`i and `ōhelo were rare on the 1868 flow, and herbaceous plants comprised less than 5% of the cover. `Uki (*Machaerina angustifolia*) and broomsedge were the most common sedge and grass species.

Vegetation of Kahuku's Western Survey Region

The western survey region of Kahuku from HOVE to the `Alika Flow of 1919 is much dissected by historical flows and also includes vegetated kīpukas and large expanses of cinder fields. The region upslope of HOVE was a dramatic landscape of deep cinder substrates vegetated sparsely by native shrubs, sedges, and ferns. At higher elevations (>1,650 m) above HOVE, these substrates were sparsely vegetated (<1% cover) with low herbs and shrubs. A notable exception was a 20-ha kīpuka on older pāhoehoe substrate located 600 m east of transect 37, at 1,740 m elevation. Vegetation cover throughout was 10-25%, with `ōhi`a trees to eight m high and mixed native shrubs and herbs. Below 1,650 m elevation and south to the Kahuku/HOVE boundary, vegetation cover was sparse (1-5%) and was comprised of native shrubs and herbs with occasional, short-stature `ōhi`a. Substrates in these areas transitioned from cinder and lava at higher elevation to deep cinder at the lower elevations.

Three prominent geological features surveyed in the western section of Kahuku were the spatter cones Pu`u `Ōhohia, Ihuanu, and an unnamed cone located above HOVE along the Southwest Rift of Mauna Loa. These features are separated by approximately four km. This region is characterized by extreme volcanic disturbance of recent lava flows and large tracts of open cinder flats.

Ihuanu, at 1,620 m elevation, is a large cone with south-facing open rifts and cracks. The cone dates from 750–1,500 ybp, and archaeological surveys indicated a number of pre-contact Hawaiian rock shelters in the area; this feature is locally known as Hāpai Mamo (C. Quiseng, HAVO-RM, pers. com., 2005). Another cone at 1,570 m elevation also dates to 750-1,500 ybp and is surrounded by the historic lava flow of 1907. Pu`u

`Ōhohia at 1,624 m elevation is older (1,500-3,000 ybp) and is surrounded by 200-750 year old lava flows.

This area is dry with average annual rainfall of approximately 1,000 mm. Vegetation types were extreme and varied with substrate, aspect, exposure and especially local micro-climates (i.e., lava tubes, cracks, fissures, interiors of craters, and larger rift areas). Young lava flows in the area, such as the 1907 flow, were barren of vegetation except for extensive *Stereocaulon* spp. lichen communities. In the area of Ihuanu, there were sparse and open `ōhi`a woodlands with scattered `a`ali`i and pūkiawe, and occasional dense clusters of `a`ali`i growing on shallow cinder soils over shelly pāhoehoe. In areas where deeper cinder occurred, such as at Hāpai Mamo, the tree layer was represented by scattered `ōhi`a. The vegetation of the cinder flats was composed of scattered individuals or clusters of mixed pūkiawe, `a`alii`i, `ōhelo, kūkaenēnē, and kūpaoa (*Dubautia scabra*). West of these sites in the area of Pu`u `Ōhohia the vegetation was a sparse `ōhi`a woodland with `a`ali`i and pūkiawe dominant in the understory and occasional kōlea lau nui, `iliahi, and naio trees.

Specialized habitats in the area included cracks and rifts to the west of Ihuanu and between the 1907 lava flow and Hāpai Mamo. In this area there were open, sparse `ōhi`a woodlands and occasional lava tubes in which `ama`u (*Sadleria cyatheoides*) and pilo (*Coprosma* spp.) were observed. In the central craters of Ihuanu and Pu`u `Ōhohia vegetation was composed of dense stands of tall `ōhi`a with an understory of `a`al`ii and pūkiawe. Forests at these sites appeared quite different from those on the exterior slopes of the cones; the `ōhi`a trees were larger and taller, understory vegetation was denser, and the number of species was higher. These interior sites were protected from wind and had less cinder cover. It is likely that crater interiors provided more favorable conditions for plant growth including more moderate temperatures, higher humidity, and more accessible ground water.

West of Pu`u `Ōhohia, the boundary of Kahuku follows the 1,600 m elevational contour. Vegetation between historic lava flows of this slope varied from very sparse `ōhi`a woodland with few shrubs and little herbaceous vegetation to open forest with a closed shrub layer. In vegetated kīpukas upslope of the boundary, there was a narrow band of open `ōhi`a-koa woodland with an occasionally dense shrub layer of `a`ali`i, pūkiawe, and `ōhelo. A well developed herbaceous layer contained either native bunchgrass *Deschampsia nubigena* or alien meadow ricegrass and kikuyu, and the drier, more open sites supported the endemic sedges *Carex wahuensis* and *Morelotia gahniiformis*. Over a short distance koa trees disappeared, and vegetation transitioned to an open 'ōhi'a woodland canopy (25-60%) with a more open native shrub layer. Ground cover remained a mix of native and alien grasses and sedges, but herbaceous plants occupied less than 25% of the area, and the alien meadow ricegrass became less abundant, often replaced by rattail grass. Above an elevation of 1,770 m, `ōhi`a trees decreased to less than 10% cover, and native shrubs typically had less than 25% cover. The herbaceous layer became sparse and covered <10% of the ground, but was composed of the same suite of native grass, alien grass, and native sedges as was found at lower elevation. Alien forbs, native ferns, lichens, and mosses were present with very little cover.

All of these sites were accessible to feral animals and evidence of damage to plants by feral animals was noted throughout the survey region, including the craters. Impacts of browsing on koa were widespread in older kīpukas (koa seedling regeneration has

occurred following animal reduction efforts in 2003). Few rare plants and very few māmane were noted. Only one mau`u lā`ili (*Sisyrinchium acre*) plant was located on the crater rim of Pu`u `Ōhohia, and scattered individuals of heau (*Exocarpus menziesii*) were observed along the Kahuku/HOVE boundary. Naio was present on the crater rim of Pu`u `Ōhohia and in a fire-damaged kīpuka, and scattered `iliahi were present on the exterior slopes as far down as the boundary of the Manuka Natural Area Reserve. No rare or uncommon plants were observed in the Hāpai Mamo area.

Alien taxa were infrequent with the exception of alien grasses that were associated with koa in older kīpukas. Common mullein (*Verbascum thapsus*) was seen near the Kahuku/HOVE boundary, on western lava flows, and in a fire-disturbed kīpuka. Madagascar fireweed (*Senecio madagascarensis*) plants were present along the rim and interior walls of the crater of Pu`u `Ōhohia; this weed was also observed scattered in low numbers on the lower slopes of Ihuanu along the boundary with HOVE and the park. A single sterile fountain grass (*Pennisetum setaceum*) plant was found in this area and was removed. Populations of fountain grass were found throughout the neighboring HOVE.

Vegetation of Kahuku's Northwestern Survey Region

The northwestern survey region contained a mosaic of plant communities, including naio-māmane woodlands, sparse `ōhi`a-māmane woodlands, subalpine shrublands, mixed grasslands of alien and native species, and sparsely vegetated lava flows. Alien grasses, particularly meadow ricegrass and the invasive perennial herb common mullein, occurred in all community types sampled. Feral sheep were ubiquitous in the area, and heavy trampling and browsing was observed in all vegetated communities.

Naio-dominated woodland communities were found in three small kīpukas (<two ha) at 2,160-2,400 m elevation. Tree canopies averaged 10 m in height, with a maximum height of 14 m for trees one m in diameter. Pilo (*Coprosma montana*) was occasional in the subcanopy, and the shrub layer (<25% plant cover) included pūkiawe, `a`ali`i, occasional `ōhelo, `ākala (*Rubus hawaiiensis*), and thimbleberry (*Rubus rosifolius*) of two meters or less in stature. Two naio kīpukas had 25-60% cover of mostly alien herbs (meadow rice grass, kikuyu) and ferns; the other kīpuka's lowest tier was sparse (1-5% cover) and dominated by meadow rice grass. A one-meter square patch of the rare native herb *Hesperocnide sandwicensis* was encountered in this kīpuka. Signs of heavy browsing were observed on shrubs and herbaceous plants. Seedlings and saplings of māmane were rare, but naio saplings were noted in one kīpuka.

Shrublands (>25% shrub cover, <10 % canopy cover) were sparingly distributed along transects, and were dominated by native pūkiawe, `a`ali`i, and less frequently `ōhelo. `Ōhi`a and māmane, ranging from five to 10 m in height, were infrequent (ca. 1% cover) in these communities. Heavy browsing and trampling were evident across the shrub layer (0.5-2 m high) and the herbaceous layer (prostrate-one m high). Herbs were sparse (<5%) and consisted primarily of native *Deschampsia nubigena* and alien meadow ricegrass, but a suite of native and alien herbs and sedges was also present. The rare native nettle *Hesperocinde sandwicensis* and the native mint *Stenogyne rugosa* were found in these habitats.

Sparse shrublands (10-25% shrub cover) were infrequently encountered along transect lines in the survey area. The floral composition and abundance of taxa were

comparable to those of shrublands, but the sparse shrublands differed by having occasional māmane (to eight m height) and more abundant herbs.

Grasslands and sparse grasslands were found in the survey area. These had less than 10% tree canopy (`ōhi`a-māmane), less than 10% cover of shrubs (pūkiawe and `a`ali`i), and a suite of native and alien grasses, sedges, and forbs. Meadow ricegrass, kikuyu, and *Deschampsia nubigena* were the principal grasses, while rattail and mountain pili (*Panicum tenuifolium*) were occasional but sometimes locally abundant. Ubiquitous herbs included the invasive common mullein, sheep sorrel (*Rumex acetosella*), selfheal (*Prunella vulgaris*), horehound (*Marrubium vulgare*), and bull thistle (*Cirsium vulgare*). Native ferns observed were *Pellaea ternifolia*, Cretan brake (*Pteris cretica*) and bracken (*Pteridium aquilinum* var. *decompositum*) with occasional ka`upu (*Polystichum hillebrandii*) at lower elevations.

Kahuku Pit Crater Vegetation Survey

The large pit crater in the central pastures near 1,250 m elevation is a unique remnant of habitat within the Kahuku Ranch Unit. Its vegetation reflects both its protracted ungulate-free remnant status and the physical structure of the crater itself. Although the vegetation surrounding the crater is composed of alien pasture grasses with scattered native trees and shrubs, the crater's interior is dominated by native species across all vegetation tiers.

The subsidence crater was bounded on all sides by nearly vertical walls ranging between 50-70 meters high. Along the crater's rim and upper slopes was a narrow margin of vegetation containing at least 32 species of mesic to wet forest plants. The near-vertical layered crater walls were almost barren of vegetation on the solid 'ā'a core layers, and were partially vegetated on ledges and at interfaces of clinkery 'ā'a surfaces. A few common mesic species occurred in these sites. The bottom of the crater slopes toward the center and was entirely covered with large (2-4 m) angular blocks of 'ā'a flow core. Around the base of the crater walls, accumulations of smaller talus material partially filled the gaps between blocks. The upslope portion of this talus was well exposed, well-drained, and appeared to have mesic conditions.

Below the talus toward the crater center, there was diverse wet vegetation beneath a closed `ōhi`a canopy. Numerous species of native trees, shrubs, and smaller plants were present, as well as a few alien weeds. Farther below, conditions were wet, where tree canopies, dense shrubs, and heavy ground cover reduced sun exposure. Here, away from the talus fill, the gaps between blocks tended to be larger and deeper; ferns and a few dicots adapted to deep shade dominated vegetation growing out of gaps and on much of the relatively smooth block surfaces. Other plants, such as māmaki (*Pipturus albidus*), were frequent in the area of deep gaps and formed much of the open to sparse upper canopy with scattered `ōhi`a. Below the māmaki, ferns such as `ama`u, waimakanui (*Pseudophegopteris keraudreniana*), hāpu`u, hō`i`o, hō`i`o kula (*Pneumatopteris sandwicensis*), palapalai, and pala (*Marattia douglasii*) formed a dense layer. Emergent between these ferns were scattered to frequent shrubs, mainly kanawao, ha`iwale (*Cyrtandra menziesii*), and mints *Phyllostegia* spp. Where greater volumes of talus accumulations between the blocks extended farther down toward the central portions of the crater, denser 'ōhi'a canopies and greater species diversity were found. No signs of ungulate activity were observed in this crater.

`Ōhi`a dominated much of the pit crater's canopy, particularly on and below the talus slope. `Ōhi`a ranged from 20 to >30 m in height. An average canopy height of 28.5 m was estimated within the vegetation plot sampled in representative vegetation in the crater's southeast quadrant. `Ōhi`a canopy cover exceeded 60% of the vegetation plot and of the entire crater. `Ōhi`a trees were less abundant and of shorter stature among talus slopes adjacent to the crater walls and in a small, rocky aggregate area near the crater's center.

The crater's subcanopy was generally sparse and was dominated by `olapa, kōlea lau nui, kāwa'u, manono (*Kadua affinis*), and `ōhi`a, with occasional large pilo (*Coprosma rhynchocarpa, C. ochracea*) and māmaki. Two ōpuhe (*Urera glabra*) were seen, each approximately 10 m tall. The subcanopy within the vegetation plot ranged in height between 10 and 12 m.

A tall shrub layer existed within the crater, dominated by māmaki, kanawao, `ākala, and native tree ferns. Occasional kōpiko`ula (*Psychotria hawaiiensis* var. *hillebrandii*) and *Hedyotis centranthoides* were found in this layer. Within the vegetation plot, shrubs ranged from two to eight m in height, with a mean estimated height of five meters. The alien prickly Florida blackberry (*Rubus argutus*) was found in this tier, occurring in shaded sites at less than one percent by cover of the plot and the crater,.

The crater's herbaceous tier was dominated by native ferns, and herbs comprised greater than 60% of the vegetation plot by cover. The most abundant terrestrial ferns encountered were hō`i`o kula, pala, ʻākōlea (*Athyrium microphyllum*), waimakanui, and `i`o`nui. *Unicina uncinata* was the most common sedge. The invasive knotweed (*Persicaria capitata*) was estimated to occupy 1-5% of the plot, and the weed was seen occasionally in the forest and along exposed talus. Two alien grasses were noted within the plot with <1% cover. Both sweet vernal grass and meadow rice grass grew in the crater in small, scattered clumps generally less than one square meter.

Ten rare species were found in the Kahuku pit crater, including the federally endangered hāhā (*Cyanea stictophylla*). Additional restricted species included hāhā (*Cyanea pilosa*), `ala`ala wai nui (*Peperomia hypoleuca*), ōpuhe, the mint *Phyllostegia ambigua*, an unidentified *Phyllostegia* sp., kōpiko`ula, and three ferns: pāmoho (*Asplenium excisum*), palai hinahina (*Sphaerocionium lanceolatum*), and uluhe (*Sticherus owhyhensis*).

Invasive Alien Plant Species

Alien plants are widespread in the new Kahuku Ranch addition. Of the 471 plant taxa species inventoried, over half (272) were alien (Appendix A). Many species were deliberately planted for landscaping around buildings and structures, as pasture grasses, and in tree plantations in the central paddock system, and some of these were found spreading into more natural areas. Other species' mechanisms of arrival remain unknown.

Forty-four of the 62 invasive alien weeds originally targeted for surveys along transects were present in Kahuku (Table 1). Individual distribution accounts are provided for these species and for a handful of additional invasive alien species that were not originally intended for mapping but were encountered during surveys of Kahuku. These

latter include species that are either candidates for management because of their known impacts to native plant communities elsewhere or require further evaluation.

Lower elevations were most severely impacted by alien plants. This may be due to extensive habitat modifications, a recent history of ranching, and more numerous species introductions, both accidental and deliberate. Recent lava flows (e.g., 1868, 1926) were exceptions, as they were relatively weed free. Likewise, wet forest on Kahuku's eastern edge and forest inside the large, steep-sided pit crater in the central survey region were also relatively weed-free.

We found elevations above 1,500 m generally less weedy, and alien taxa were of a more localized distribution. Alien grasses were generally sparser and less numerous, and weeds were concentrated in discrete populations (e.g., faya tree). The northwestern survey region and koa forest previously logged, burned, or cleared for cattle grazing in the western survey region were exceptions. Alien grasses and other herbaceous weeds were prevalent throughout these highly modified areas.

The inventories are a first step towards identifying the alien species present in Kahuku. The distances between transect survey lines (1-3 km apart) did not permit a comprehensive inventory of species, and additional surveys will likely result in new species being identified at Kahuku. Also, more intensive surveys may be needed to adequately map the occurrence of highly disruptive invasive species and allow park staff to accurately evaluate the extent of infestations and formulate appropriate management actions. These needs are discussed below in Management Considerations.

Invasive Alien Plant Species: Trees

Thirty-four alien tree species were encountered within Kahuku, including tree species cultivated near buildings or used in forestry plantings. Of the 19 invasive tree species originally targeted for surveys, 12 were found. Christmasberry was the most widespread and abundant alien tree throughout the southwestern and central survey regions, and strawberry guava was common in two small (<eight ha) forested kīpukas. All other alien tree species were found as single individuals or in discrete populations with as many as 322 individuals. Approximately 24 tree species were apparently in cultivation or deliberately planted at Kahuku; some of these had also become naturalized.

Formosa Koa (Acacia confusa Merr.)

A four-meter tall Formosa koa was found along the principal ranch road in the central pastures at an elevation of 750 m. No additional Formosa koa were observed in the vicinity or elsewhere in Kahuku.

Native to Taiwan and the Philippines (Wagner et al. 1999), Formosa koa is a tenacious pest of dry to mesic areas in Hawai`i, capable of forming monotypic stands in pastures and disturbed forests (Motooka et al. 2003). Formosa koa is cultivated and apparently naturalized in the Ka'ū district, including HOVE (Benitez 2004). In the Kīlauea section of HAVO, Formosa koa infestations occur in several locations between 80-940 m elevation, and the park's largest infestation (130 ha) is found in mesic grasslands and woodlands at the `Āinahou ranch (Benitez and Loh in prep). Efforts to eradicate Formosa koa in older HAVO have been in place since 1984, and over 4,000 individuals

have been removed. In 2006, the single individual discovered in Kahuku was removed by the Pacific Islands Exotic Plant Management Team (PIEPMT).

Swamp Mahogany (Eucalyptus robusta Sm.), Sydney Blue Gum (Eucalyptus saligna J. E. Smith)

Two populations of *Eucalyptus* were found in central Kahuku. The larger population consisted of large Sydney blue gum trees in a 10.8-ha planting area at 730 m elevation. Individuals exceeding 25 m in height and smaller, naturalized individuals were observed throughout the planting site among other exotic trees that were introduced for forestry purposes.

A smaller population of approximately 20 juvenile individuals was found near a spur road at 640 m elevation, near the ranch entrance. Although no mature individuals were noted in the vicinity, these appeared to be swamp mahogany. Additional *Eucalyptus* spp. were not encountered in vegetation plots or along transects in Kahuku.

More than 90 species of *Eucalyptus* spp. have been planted in support of forestry throughout Hawai`i, and several species are spreading in the islands (Wagner et al. 1999). In HAVO, two mature populations of *Eucalyptus* occur. Approximately 20 trees are planted at park headquarters, and numerous large blue gum trees (*Eucalyptus globulus*) are spread over three ha at Nāmakani Paio campground. These original planted areas remain as part of the historic cultural landscape. However, both species have the potential to spread, and seedlings and saplings growing beyond the originally planted area are annually removed to contain the populations.

Silk Oak (Grevillea robusta A. Cunn. Ex R. Br)

A population of more than 50 silk oak trees was observed on the eastern edge of the 1887 lava flow at 740 m elevation in the southwest section of Kahuku. This population was growing in a sparse `ōhi`a woodland with native and alien shrubs and alien grasses.

Two mature trees were found along the principal ranch road, approximately 400 m south of the ranch house in the central Kahuku pastures. No additional trees, including seedlings or saplings, were observed in the vicinity of these individuals. These trees were removed by the PIEPMT in March 2006. Silk oak was not observed along transects, in vegetation plots, or in additional off-transect searches in Kahuku.

Native to Australia, silk oak is a serious pest of mesic-dry woodlands in Hawai`i (Smith 1985). Dense stands occur in the Kona and Ka`ū districts of Hawai`i, and silk oak is abundant in adjacent HOVE, where plantings and naturalized individuals were found on 13% of the roadsides in the subdivision (Benitez 2004). In HAVO, silk oak infests 5,300 ha across southwestern Kīlauea between 325 and 975 m elevation (Benitez and Loh in prep). The largest known population contains an estimated 1,000 trees with numerous satellite populations of 1-20 individuals. The management strategy is to remove and prevent establishment of individuals in SEAs and to contain core populations by removing outlying individuals.

Koa Haole (Leucaena leucocephala (Lam.) de Wit)

One koa haole was encountered in Kahuku during park-wide surveys, at 640 m elevation along the old highway upslope of Highway 11. No additional koa haole was observed along transects or within vegetation plots in Kahuku. Subsequent to the survey, koa haole seedlings have been noted on soil piles near the existing Ranch buildings.

Koa haole is a nitrogen-fixing fodder plant of neotropical origin (Wagner et al. 1999; Motooka et al. 2003) and a serious pest of dry-mesic habitats on all the main Hawaiian Islands (Smith 1985). Infestations can dominate low-elevation, dry disturbed sites (Wagner et al. 1999). In the older section of HAVO, koa haole occurs in coastal sites, alien grasslands, mesic woodlands, and roadsides from sea level to 1,080 m elevation. Fifteen infestations of three to 72 ha have been mapped, with smaller populations throughout the range. Selected populations of koa haole have been controlled since 1976 in HAVO (Tunison and Stone 1992), but the species has not been eradicated.

Faya Tree (Morella faya (Aiton) Wilbur)

Populations of faya, an invasive evergreen tree, were found growing in `ōhi`a woodlands in the western and eastern survey regions between 1,690 and 2,290 m elevation. Kahuku's largest population of 170 trees was growing in the western survey region. Trees ranged from seedlings to six-m tall adults. The `ōhi`a woodland in which they were found had an understory dominated by native shrubs (`a`ali`i and pūkiawe) and alien meadow ricegrass. Two additional faya, one adult and one juvenile, were found in 2004 on the edge of an `ōhi`a kīpuka and `ā`a lava flow, 4.1 km east of this population. A resurvey of this area in 2006 encountered two additional mature trees and 65 seedlings, located within 70 m of the original population. Searches by foot and helicopter in surrounding areas, including adjacent State lands, did not encounter additional faya beyond these treated areas.

Fifteen faya trees were found in the eastern survey area. Seven individuals were clustered within a five-ha area near the principal jeep road and transect 9. These included a 6-m tall, highly-branched tree that was the largest faya encountered in Kahuku. Five individuals in this population were less than one m tall. The remaining eight faya trees were scattered; a roadside juvenile was located 2.6 km east of the previous population, two adult trees were found between transects 3 and 6, and five adult faya were found east of transect 18, including one mature tree found roadside at 2,200 m elevation. Evidence of ungulate browsing was noted on juvenile plants.

Faya tree was not observed in the northwestern, southwestern or central survey regions, or during systematic surveys of the adjacent HOVE subdivision (Benitez 2004). While in helicopter transit to the Kahuku's eastern survey region, a large population (>1,000 trees) of faya was incidentally observed above Kapāpala ranch on State land. It appears that adjacent lands harbor significant stands of this pest. Because of its limited distribution and highly invasive behavior, HAVO began control of faya in Kahuku in 2004, and more intensive surveys and control work to locate and treat additional individuals are planned for 2007-2008.

Native to the Canary Islands, Madeira, and the Azores (Wagner et al. 1999), faya tree is one of HAVO's worst invaders of native forests and woodlands. Faya occurs over 15,700 ha of the Kīlauea district of HAVO between 135 and 1,700 m in elevation and

forms monospecific stands across 10% of this range (Benitez and Loh in prep.). Mature trees produce abundant fruits, which are readily dispersed by birds. On young volcanic soils, faya tree alters ecosystem properties by greatly increasing nitrogen inputs in invaded areas (Vitousek and Walker 1989); such changes may favor the establishment of weedy species, although several studies have indicated that the association between faya and other alien plants is complex (Mueller-Dombois and Whiteaker 1990; Adler et al. 1998).

African Olive (Olea europaea ssp. cuspidata)

Twenty-nine mature African olive trees and numerous seedlings were found in the vicinity of the Kahuku ranch buildings. Some individuals were deliberately planted, while others appear to have escaped cultivation. Mature trees grew up to five m tall. Several saplings and seedlings were observed in landscaped grounds and in the surrounding `ōhi`a/Christmasberry forest. Plants along a rock wall had plastic bags and pots surrounding their rootmass, suggesting relatively recent planting. No African olive trees were observed beyond these areas.

African olive was observed throughout the adjacent HOVE subdivision, apparently naturalized; a roadside survey found African olive on 5% of the streets in the subdivision. Individuals were found at a maximum elevation of 1,160 m and within 500 m of the Kahuku boundary (Benitez 2004). African olive trees have also been used in landscaping around private residences along Lorenzo Road, located east of the Kahuku boundary. During the Kahuku survey two seedlings were pulled and all remaining individuals (90 seedlings and 29 adults) were removed by the PIEPMT in 2006.

Native to the Mediterranean region, African (or Russian) olive (formerly known as *Linociera ligustrina* and *Olea europaea* ssp. *africana* in Hawai`i) (Higashino et al. 1988, Wagner et al. 1999) is a tenacious pest of Hawaiian ecosystems (Smith 1985). In the Kīlauea district of HAVO, African olive plants infest 700 ha of dry to mesic woodlands and form dense monospecific thickets across portions of this range (Benitez in prep.).

Strawberry Guava (Psidium cattleianum Sabi)

Within the central Kahuku survey area, strawberry guava was locally abundant in low-elevation mesic to wet forests near Pu`u `Akihi and an associated ravine. The greatest infestation observed was in a 7.8 ha forested ravine at 810 m elevation, where seedlings, saplings and mature trees covered 1-5% of the ravine's understory. No strawberry guava was observed along transect lines in the open pastures, forest fragments, or within the forested pit crater. Likewise, no strawberry guava was found in native forest at 1,000 m along the Kahuku/ Ka`ū forest reserve boundary. Strawberry guava was not encountered along transect lines or in vegetation plots in other areas of Kahuku. However, additional surveys may result in further discoveries of individuals in mesic and wet forest in Kahuku.

Native to South American Atlantic rainforests, strawberry guava is one of the worst weeds of wet to mesic forests in Hawai`i (Smith 1985). In Hawai`i, clonal growth, abundant seed production, and allelopathic leaf litter may contribute to the successful invasion of plants into native forests and the formation of dense, monospecific thickets (Huenneke and Vitousek 1990; Wagner et al. 1999). In HAVO, strawberry guava is most abundant in mesic to wet environments between 910-1,400 m elevation, where it is intensively managed to contain its spread and impact on native forest ecosystems.

Common Guava (Psidium guajava L.)

Individual common guava trees were occasional in dry woodlands and disturbed habitats throughout the southwest and central survey regions of Kahuku, but were not located along transects or vegetation plots. A three-meter tall individual was found at the Kahuku ranch house in landscaped grounds among alien grasses and cultivated trees. Common guava was found near the rim of the forested pit crater but not in the crater's interior.

Common guava is of Neotropical origin and is cultivated in the tropics worldwide for its edible fruit (Staples and Herbst 2005). A serious pest on tropical oceanic islands (Wagner et al. 1999, Motooka et al. 2003), common guava trees form dense stands at low elevations on all main Hawaiian islands except Ni`ihau and Kaho‘olawe. In the older part of HAVO, common guava occurs between 300 and 1,420 m elevation, but dense infestations are rare. Common guava is controlled in HAVO principally in montane mesic forest SEA units.

Castor Bean (Ricinus communis L.)

Two castor bean populations were found growing among alien vegetation in disturbed habitats at 670-780 m elevation. Twenty-seven plants were found behind the Kahuku ranch house at the edge of an `ōhi`a/Christmasberry forest at 680 m elevation. Eleven plants were found along a roadside spur leading to a lava trench near the northern edge of the 1868 lava flow, less than 50 m from the main ranch road at 730 m elevation. Both populations were removed by the PIEPMT in December 2005 and March 2006.

Castor bean is of paleotropical origin (Wagner et al. 1999) and is a pest of dry, disturbed habitats in Hawai`i. In the original section of HAVO, localized castor bean populations occur along roadsides, growing mostly among alien vegetation. Distributed from sea level to 1,190 m elevation (Benitez and Loh in prep.), the species is controlled parkwide.

Octopus Tree (Schefflera actinophylla (Endl.) Harms)

One eight-meter tall octopus tree and 10 seedlings were found growing among alien grasses including molasses grass (*Melinus minutiflora*) near the Kahuku ranch house. This tree was removed by the PIEPMT in March 2006. No additional octopus trees were found elsewhere in Kahuku.

Octopus tree is native to Australia and New Guinea. In Hawai`i, infestations are found at lower elevation on all of the principal islands (Wagner et al. 1999). Dense stands can develop in wet forest (Motooka et al. 2003), and Staples and Herbst (2005) consider octopus tree to be a very serious weed of wet forests. A related species, the dwarf umbrella tree (*Schefflera arboricola*), was found planted along a rock wall near the ranch house. This individual was removed in September 2006. The dwarf octopus tree is not yet known to be naturalized in Hawai`i (Staples and Herbst 2005).

Christmasberry (Schinus terebinthifolius Raddi)

Christmasberry was found in woodlands, shrublands, and alien grasslands in dry to mesic environments between 610 and 1,500 m elevation in the southwest and central survey areas. Above 1,500 m elevation, only a single juvenile plant was found along the

primary road in the west survey region. Christmasberry was not detected in the northwestern or eastern survey regions.

In the southwestern survey area, Christmasberry was most abundant on older (>1,500 yrs) soils receiving between 1,000 and 1,500 mm rainfall per year. Aerial surveys and transects identified 325 ha of highly infested kīpukas. Within these kīpukas, Christmasberry up to five meters tall occupied 25-60% of the plant cover, and alien barbwire grass dominated the ground cover. Only a few scattered native ‘ōhi’a trees were present. In woodlands located above these kīpukas; Christmasberry was less abundant, where trees were found at <1% plant cover in six of 77 stations.

Christmasberry was common throughout most environments sampled from 640 to 1,310 m elevation in the central Kahuku survey region. These included landscaped grounds, open pastures, `ōhi`a woodland, and remnant forest. Dense infestations grew on the slopes and edges of a 77-ha forested ravine. Christmasberry was less abundant in deeply shaded environs; trees were sparse in the interior of the ravine (<1% cover), and no Christmasberry was found within the large unnamed forested pit crater.

Christmasberry was abundant on lands adjacent to Kahuku. Plants were present on 11% of roads within HOVE (Benitez 2004), and dense stands were observed in the residential area southeast of Kahuku. Christmasberry was also abundant east of Kahuku, where extensive stands occurred on deep soils surrounding the towns of Waiohinu and Pāhala. Native to Brazil, Christmasberry is considered one of Hawai`i’s worst weeds (Smith 1985). On the Big island, Ka`ū is notable as a site of Christmasberry infestation (Motooka et al. 2003). In older HAVO where the species is selectively controlled in SEAs (intensive management units), plants are found from sea level to 1,280 m elevation and are most prevalent in kīpukas on the southwest flank of Kīlauea.

Rose Apple (Syzygium jambos (L.) Alston)

A population of 322 individuals of rose apple was found in lowland pasture in the central survey region. No additional rose apple was encountered in parkwide surveys in Kahuku. Although not initially targeted for mapping, rose apple is invasive in Hawai’i, thus it was added to the survey list.

Native to Southeast Asia, rose apple has become naturalized in mesic to dry lowland forest in Hawai`i (Wagner et al. 1999). In HAVO, plants primarily occur in eastern lowland forest below 500 m elevation. This species is a potentially serious weed (Motooka et al. 2003), and additional populations should be searched for and controlled.

Other Alien Trees

Twenty-two additional alien trees, including two Polynesian introductions, were found during surveys. These included several species regarded as invasive to native ecosystems in Hawai`i.

Ten planted tree species (not included in the previous discussion) were found in the central Kahuku survey area. These were mostly ornamental and horticultural taxa planted near the Kahuku ranch house and within a forestry planting area. Four of the planted species found near the ranch house possess traits commonly associated with invasiveness, such as rapid growth and bird-dispersed fruits. These potential invaders include jaboticaba (*Myrciaria cauliflora*), Prunus spp., dwarf octopus tree, and pepper

tree (*Schinus molle*). Future monitoring will determine whether these species are invasive in Hawaiian ecosystems.

A 10-ha site along the western side of the 1868 flow supported plantings of trees introduced for forestry purposes. This area was planted with Cook pine (*Araucaria columnaris*), Sydney blue gum, ironwood (C*asuarina glauca*), jacaranda (*Jacaranda mimosifolia*), tropical ash (*Fraxinus uhdei*), and several species of pines (*Pinu*s spp.). Some of the pines and tropical ash appeared to be escaping from plantings and may eventually become pests. A similar, smaller planted area containing several pine species was found near a reservoir located along the eastern edge of the Kahuku boundary in the central survey area.

At upper elevations (near 1,950 m) three alien tree taxa were planted near two cabins in the eastern survey region. Several individuals of Monterey pine (*Pinus radiata*), Methley plum (*Prunus cerasifera x salicina*), and an undetermined fruit tree (*Prunus* sp.) were observed in those locations. Native to Northern California, Monterey pine has attributes commonly associated with invasiveness (Rejmánek and Richardson 1996). Naturalized individuals of Monterey pine and *Prunus* spp. have been noted near the cabins. Similar pine and fruit tree species are known from the original section of HAVO. Naturalized but non-invasive *Prunus* cf. *serrulata* has been observed in mesic and wet forest, and pines of several species are sparingly found in woodlands near the Kīlauea summit and at `Āinahou ranch.

Seven invasive tree species targeted in surveys were not encountered within Kahuku. These were ironwood (*Casuarina equisetifolia*), albizia (*Falcataria moluccana*), kahili flower (*Grevillea banksii*), melochia (*Melochia umbellata*), miconia (*Miconia calvescens*), Australian tree fern (*Sphaeropteris cooperi*), and gunpowder tree (*Trema orientalis)*. Some of these species (e.g., Australian tree fern, melochia, albizia) are recent invaders in the Kīlauea district of HAVO (Benitez and Loh in prep.) and are currently under management to eradicate or contain their populations.

Eight potentially invasive species were noted near park lands, and were classified as encroaching upon Kahuku. Black wattle (*Acacia mearnsii*), autograph tree (*Clusia rosea*), loquat (*Eriobotrya japonica*), Chinese banyan (*Ficus microcarpa*), kahili flower, gunpowder tree, bingabing (*Macaranga mappa*), and Victorian box (*Pittosporum undulatum*) were cultivated or naturalized near Kahuku's boundaries. Due to the highly invasive nature of these species, there is a possibility that individuals may remain undetected within the park or that these species will establish in Kahuku in the near future.

Invasive Alien Plant Species: Shrubs

Thirty-four alien shrub species were encountered in Kahuku (Appendix A). Of the 14 invasive species originally targeted for surveys, seven were found inside the park, and six were near park lands. One Polynesian introduction, ti or ki (*Cordyline fruticosa*), was planted near the ranch house.

Asiatic Butterfly Bush (Buddleia asiatica Lour)

Asiatic butterfly bush was found as scattered individuals primarily in disturbed areas in the west and central survey regions. Individual Asiatic butterfly bush plants were found twice along transects in the west survey region in a 'ōhi'a woodland and on the edge of a

`ā'a lava flow at 1,870 m elevation. Infrequent individuals were also observed along roads, in a cinder deposit, along forest edges, and in open woodlands of the western slope. In the central survey region, Asiatic butterfly bush was not detected in transects nor vegetation plots, but a few individuals were observed off-transect in pastures dominated by alien grasses. A few plants were also found along the margins of the forested pit crater, but Asiatic butterfly bush was not found in the crater's interior. No plants of this species were found in the northwestern, southwestern, or eastern survey regions.

Asiatic butterfly bush is a shrub native to Asia and the Mariana Islands. In Hawai`i and the older section of HAVO individuals are found primarily in mesic to wet disturbed forest or on lava and cinder (Wagner et al. 1999). Dependence on disturbance in wet forest makes the presence of infestations relatively short-lived in intact forest, and plants are not currently controlled in the older HAVO unit.

A related species, smoke bush (*Buddleia madagascariensis*), was targeted for surveys in Kahuku, but was not encountered. Smoke bush is cultivated and sparingly naturalized in Hawai'i (Wagner et al. 1999; Staples and Herbst 2005). Another cultivated butterfly bush (*Buddleia davidii*) occurs in the adjacent HOVE community (Benitez 2004) but was not observed in Kahuku. This species is naturalized, at least on Kaua`i (Wagner et al. 1999).

Night Cestrum (Cestrum nocturnum L.)

Two night cestrum populations were discovered in the central Kahuku pastures: within a forested ravine near Pu'u 'Akihi at 810 m elevation; and in landscaped grounds near the ranch house buildings at 670 m elevation. Within the forested ravine, plants were growing under closed-canopy native 'ōhi'a/hāpu'u forest that contained numerous locally rare taxa. Fifty-nine individuals occupied an area approximately 100 m^2. Shrubs were highly branched and formed an exclusive monospecific stand. Extensive adventitious rooting was noted throughout the population. Three additional night cestrum were found planted in front of the Kahuku ranch house, and one apparently naturalized individual was found 15 m away in nearby forest. Plants were one to two-meters tall, and the three individuals near the ranch house were flowering in October 2005. No night cestrum was observed along vegetation plots and transects nor in the other survey areas.

Night cestrum is established in the Ka`ū Forest Reserve, downslope of the eastern survey region and beyond the park boundaries. The closest individual reported near the park was observed by a U. S. Geological Survey bird survey crew in mid-2005, in a closed-canopy 'ōhi'a forest 0.4 km south of the start of transect 3. Further downslope, night cestrum occurs in dense thickets within native forest at about 1,100 m elevation (Benitez pers. obs.).

Night cestrum is a white-berried shrub native to the Antilles and Central America (Wagner et al. 1999). Planted as an ornamental for its fragrant flowers, individuals have become naturalized in many tropical locations, including wet forest in Hawai'i (Wagner et al. 1999; Motooka et al. 2003). In the older part of HAVO, individuals were first detected in a rainforest SEA unit in 2001 and are presently being controlled to prevent further spread. Near Kahuku, night cestrum has escaped cultivation and become naturalized in

adjacent residential areas along Lorenzo road and within HOVE (Benitez pers. obs.). Individuals found in Kahuku are currently being treated twice yearly by the PIEPMT.

Lantana (Lantana camara L.)

Lantana was observed infrequently in the southwestern and central survey regions, where small thickets of approximately 20 m^2 occurred along roadsides and in a few pasture and woodland sites. Along survey lines in the southwestern survey area, lantana occurred at low abundance (<1% cover) in nine of 67 transect stations and in two vegetation plots., Lantana was not detected in vegetation plots or transect stations in the central survey region and was not observed above 1,430 m or in closed-canopy mesic and wet forests, including Pu'u 'Akihi and the pit crater. The shrub was not found in the northwestern, western, or eastern survey regions.

Lantana is perhaps native to the West Indies, and it is naturalized throughout the tropics and subtropics. In Hawai'i, lantana is one of the most serious weeds in dry to mesic environments (Smith 1985; Wagner et al. 1999). In older portions of HAVO, lantana is found principally in the coastal lowland and submontane zones below 1,000 m elevation, where removal is limited to SEAs.

Prickly Florida Blackberry (Rubus argutus Link)

Prickly Florida blackberry was found sparsely distributed (<1% cover) along transects and away from transects in the central pastures between 1,180 and 1,280 m elevation. Plants grew among alien grasses and along the edges of forest fragments. Inside a forested pit crater, blackberry was found growing in deep shade, where plants occupied less than one percent of the crater floor.

Native to the central and Eastern United States, Florida blackberry is a severe pest and forms dense thickets in wet and mesic forests in Hawai'i (Smith 1985). In older HAVO, plants occupy a wide range of habitats, but are most heavily concentrated in mesic koa forest and grasslands that were former pastures between 1,200 and 1,500 m elevation.

Because of the serious disruptive impacts of this species on forest regeneration, additional surveys for prickly Florida blackberry in the pastures and adjacent areas are recommended to fully map its occurrence in Kahuku.

Thimbleberry (Rubus rosifolius Sm.)

Thimbleberry was found in relatively low abundance (<1% cover) across a wide ecological range in Kahuku. Individuals were observed in forests, forest fragments, woodlands, and grasslands in all survey regions between 640 and 2,164 m. Along survey lines, thimbleberry was found in 23 of 647 transect stations and in eight of 177 vegetation plots.

Native to Asia, thimbleberry is a common weed in Hawai'i. Its distribution in the original section of HAVO is similar to the observed distribution in Kahuku, as it occurs across a variety of mesic to wet habitats. Thimbleberry possesses a number of highly invasive congeners (*R. argutus, R. ellipticus, R. glaucus*) in Hawai'i. Dense thickets are limited to recently disturbed habitats and are seldom encountered in deep shade. As a result, thimbleberry has been a low priority for management, and its control is limited to mesic and wet forest SEAs in HAVO. Nevertheless, because of the highly invasive

nature of this genus and its documented impacts in the Society Islands (Meyer 2000), this species may require monitoring to detect any changes in its invasiveness.

Sourbush (Pluchea carolinensis (Jacq.) G. Don)

Sourbush was found in disturbed habitats, grasslands, and woodlands between 640 and 1,920 m elevation throughout all survey areas in Kahuku. Sourbush was most frequent in the southwestern survey area, where its abundance was typically <1% plant cover. Sourbush was detected infrequently along transects (10 of 647 stations) and vegetation plots (two of 177 plots).

Sourbush is native to Mexico, the West Indies, and South America (Wagner et al. 1999), and the shrub is considered a pest of pastures and natural areas in Hawai'i (Motooka et al. 2003). In the original section of HAVO, sourbush is frequent primarily in grasslands, shrublands, and woodlands below 1,200 m elevation. Like thimbleberry, sourbush has not prompted an intensive management response, and it is not targeted for control outside of SEAs.

Prickly Pear (Opuntia ficus-indica (L.) Mill.)

One prickly pear cactus was found near transect 30 in Kahuku at 800 m elevation in the southwestern survey region. Two additional plants were found on an `ā'a lava flow approximately 700 m southeast of the first individual.

Prickly pear is a large, terrestrial cactus likely native to Mexico or Central America (Wagner et al. 1999). In Hawai'i, the species is naturalized in dry, disturbed habitats. In the older section of HAVO, individuals have been observed in the central coastal lowlands, and the cactus is sometimes associated with koa haole thickets. A formerly large population, now consisting of 35 plants, persists among scattered native and alien shrubs and alien grasses on Poliokeawe Pali (Benitez and Loh in prep).

Prickly pear formerly occupied a much larger range in HAVO. Between 1983 and 1985 Tunison and Stone (1992) documented dozens of individuals covering 19 ha at Poliokeawe Pali and six smaller populations extending to the coast. In 1985, two biocontrol agents, the moth *Cactoblastis cactorum* and the cochineal insect *Dactylopius opuntiae,* were released in HAVO. These insects have apparently caused the decline of prickly pear populations (Davis et al. 1992), and no additional control work has been performed.

Other Alien Shrubs

In addition to those discussed above, 27 shrub species were observed during the surveys. While many of these do not appear to pose a risk to Kahuku's native plant communities [*e.g*., hibiscus (*H. rosa-sinensis*), oleander (*Nerium oleander*), camellia (*Camellia japonica*)], several taxa warrant further consideration due to potentially invasive traits or known aggressive behavior elsewhere.

Two California privet shrubs (*Ligustrum ovalifolium*) were found near the ranch house, where they were likely planted. One individual was three meters tall and fruiting, the other was one-meter tall and sterile. A congeneric species (*L. sinense*) is naturalized in the original section of HAVO (Benitez and Loh in prep.) and is managed in rainforest units of the summit of Kīlauea (near 1,200 m elevation). Because of the potential to

become invasive, both California privets in Kahuku were cut and treated by the PIEPMT in 2006.

The shrub Apple of Sodom (*Solanum linneanum*) was observed primarily in actively used paddocks and corrals. This weed was not originally targeted for mapping, and little is known about its range extent or potential for spread. Apple of Sodom is abundant at nearby South Point and is known to infest dry forests and pastures (Motooka et al. 2003). Although it is not an invader of native forest, further surveys to map this species' distribution and abundance are recommended.

Pearl flower (*Heterocentron subtriplinervium*) was detected near the ranch house and controlled by the PIEPMT in March 2006. In HAVO, several populations of pearl flower have persisted for decades in rainforest and may be expanding their range (Tunison and Stone 1992, Benitez and Loh in prep.). Pearl flower is a member of the Melastomataceae, a highly invasive family in Hawai'i.

Seven invasive shrub species originally targeted for mapping were not found in Kahuku: plume poppy (*Bocconia frutescens*), smoke bush (*Buddleja madagascariensis*), Koster's curse (*Clidemia hirta*), firethorn (*Pyracantha koidzumii and P. crenatoserrata*), yellow Himalayan raspberry (*Rubus ellipticus*), Jerusalem cherry (*Solanum pseudocapsicum*), and tibouchina (*Tibouchina* spp.) These species are all capable of rapidly increasing their population sizes in natural areas of Hawai`i. For example, plume poppy, which is naturalized and well-established in the Ka`ū District, is bird dispersed and a prolific seeder. A single tree on Maui produced 300,308 seed capsules in one fruiting season (Chimera 2003). Koster's curse (*Clidemia hirta*) is a severe pest of wet forests in Hawai'i (Smith 1985; Wagner et al. 1999; Motooka et al. 2003). Seeds are highly dispersible, and infestations are notoriously difficult to eradicate. Both plume poppy and Koster's curse are present near Kahuku. Smoke bush and glory bush (*Tibouchina urvilleana*) were observed in cultivation in adjacent residential areas, although naturalized populations were not noted.

Subsequent to the survey, one individual of hill raspberry (*Rubus niveus*) appeared inside an exclosure constructed in the central pastures of Kahuku. This site, previously treated with herbicide and cleared, is being monitored by HAVO Resources Management personnel. The collected specimen was sterile, but the plant had apparently flowered at least once. Hill raspberry appears to have recently invaded Kahuku, possibly from infested sites in South Kona. The species has been present on the island for more than 40 years but is known from few sites (Wagner et al. 1999). Like most other introduced members of the genus *Rubus* in Hawai`i, this species may have the potential to be a pest in recovering pasturelands at Kahuku.

Invasive Alien Plant Species: Herbs and Vines

Approximately 120 alien herbaceous species (excluding Graminoids) were noted in Kahuku. All of the 17 invasive species targeted for mapping were located, except for the vine banana poka (*Passiflora tarminiana*). Two alien herb species were identified as encroaching, and two herbs of Polynesian introduction were found established within Kahuku.

Sisal (Agave sisalana Perrine), Mauritius Hemp (Furcraea foetida (L.) Haw.)

Near the Kahuku boundary, a population of sisal was observed along Highway 11 at 610 m elevation. This population had an estimated 100 plants distributed over one hectare of sparse `ōhi`a woodlands. Many plants were fertile, and abundant bulbils (bulb-like structures in the inflorescences) and seedlings were observed.

One small group of sterile Mauritius hemp was observed in Kahuku, at approximately 850 m elevation in alien grasses near the main ranch road. No additional sisal or Mauritius hemp were observed elsewhere in Kahuku.

Sisal and Mauritius hemp are large succulent rosette-forming herbs of the Agave Family; the two are native to tropical North and South America, respectively (Wagner et al. 1999). Both reproduce by bulbils. In the older section of HAVO, sisal has been documented in four lowland sites (Tunison and Stone 1992), and the population's spread is currently being contained (Benitez and Loh in prep.). Mauritius hemp is a pest in parts of its introduced range in Hawai'i, but the species has not been documented in the park until this survey (Fosberg 1966; Higashino et al. 1988).

Hāmākua Pāmakani (Ageratina riparia (Regel) R. King & H. Robinson)

The herbaceous subshrub Hāmākua pāmakani occurred frequently at low densities along transects located in the western, southwestern, and central survey regions between 792 and 1,874 m elevation. Hāmākua pāmakani was encountered only once in an eastern transect station. No plants were found in the northwestern survey area.

Hāmākua pāmakani was found in dry to mesic habitats receiving between 1,000 and 2,000 mm rainfall. In west and central regions, Hāmākua pāmakani was found in 17 of 88 vegetation plots. In the pastures, Hāmākua pāmakani was found where total vegetation cover generally exceeded 60% of the plot, the `ōhi`a/koa overstory was sparse, and the ground layer was dominated by alien grasses. Plants were found in 48% of transect stations sampled in the central pastures and in 24% of transect stations in the western and southwestern regions. Within transects and vegetation plots, Hāmākua pāmakani cover was typically <1% and was never greater than five percent. Dense, exclusive stands were not observed in Kahuku. Individual plants and small clusters (<5 m^2 area) were noted in woodlands, sparse woodlands, grasslands, and less frequently in forest. Several plants were observed off transect in the eastern survey region in closed-canopy, wet `ōhi`a forest at 1,800 m elevation..

Hāmākua pāmakani is native to Mexico and the West Indies (Wagner et al. 1999), and the species was formerly a major pest weed of pastures in Hawai'i. Biological control agents (Davis et al. 1992) may be responsible for maintaining this species at ecologically acceptable low levels in both native and exotic-dominated habitats in Kahuku and elsewhere in Hawai'i. In older HAVO, management of Hāmākua pāmakani in Kīpuka Puaulu SEA was discontinued in the early 1990s (Mattos, HAVO-RM pers. com. 2005).

Japanese Anemone (Anemone hupehensis var. japonica (Thunb.) Bowles & W. Stern)

A weedy perennial herb, Japanese anemone was very sparingly distributed in mesic to wet forests in west and east survey areas and lands adjacent to Kahuku. In the eastern region, five plant occurrences were noted along transects, and only one was within a vegetation plot. Plant sightings were primarily in closed-canopy `ōhi`a forest in

Kahuku and the adjacent Ka`ū Forest Reserve. Japanese anemone was most frequent in the vicinity of transect 3. Just outside the park on transect 3 was a 50-100 m^2 patch and several nearby similar sized clusters off-transect at approximately 1,580 m elevation. A single plant was found on transect 12 within Kahuku, and one plant was found on transect 15 in a dry streambed surrounded by `ōhi`a woodlands outside of the park.

In the western survey area, Japanese anemone was observed growing among alien grasses under `ōhi`a and koa trees. In the central pasture area, plants were found along the south edge of the forested pit crater, but the species was not noted along transects. Japanese anemone was not found in the northwest survey region.

This anemone is a cultivated variety of a species native to China (and takes its common name from the variety name). In Hawai'i, Japanese anemone is naturalized in disturbed wet habitats in the original section of HAVO and surrounding areas (Wagner et al. 1999). In the park, recent mapping (Benitez and Loh in prep.) has documented a range expansion since this species was first mapped in the 1980s (Resources Management Files 1980). Plants are found along fence lines, on trails and other disturbed habitats, and in forest at 900-1350 m elevation. Notable infestations occur in Thurston and `Ōla`a Rainforest SEA units. This species is not currently managed in HAVO.

Bull Thistle (Cirsium vulgare (Savi) Ten.)

Bull thistle was frequent at low densities across the northwestern, western and western survey regions, where plants were found in 10% (65/642) of transect stations and 13% (22/172) of vegetation plots between 700 and 2,347 m elevation. Plants were also observed in experimental restoration plots located in the central pastures (Loh pers. obs.). Throughout its range, bull thistle was observed at the lowest cover class (<1%), and dense infestations were not noted.

Bull thistle is a spiny biennial herb native to Eurasia that has become naturalized in dry to mesic areas of Hawai'i (Wagner et al. 1999), particularly in areas previously used to graze cattle. On Mauna Loa in the original section of HAVO, bull thistle is incidentally controlled in selected restoration sites located in mesic communities between 1,200 and 1,500 m elevation. Several species of thistle are notable as invaders in temperate and tropical grasslands and woodlands, and this group is intensively managed within the continental national parks for ecological and aesthetic reasons (Loope 1992). Continued monitoring will assist in determining whether this species poses a risk to plant communities in Kahuku.

Cape Ivy (Delairea odorata Lem.)

Two populations of cape ivy were found in the central survey region. A 20-m^2 patch was found growing among alien pasture grasses and climbing on `ōhi`a trees at 1,250 m elevation. A patch of vine with an area of 12 m^2 was found along a lava trench near the northern edge of the 1868 lava flow and the main ranch road at 730 m elevation. In the western survey area, cape ivy was observed growing on one transect located below the park boundary fence on The Nature Conservancy Hawai'i (TNCH) Honomolino Preserve.

Near Kahuku, plants are abundant in residential lots of HOVE subdivision, in native ‘ōhi’a forests of Manuka Natural Area Reserve (Benitez pers. obs.), and in koa forest of the TNCH Honomolino Preserve. Closest to the Kahuku western survey area was a dense infestation in a small, accessible pit crater in the Manuka NAR. Plants were abundant along the crater walls and floor, and vines were climbing native trees and shrubs.

Cape ivy is a fleshy, yellow-flowered vine native to South Africa (Staples and Herbst 2005); it is naturalized and highly invasive in Hawai’i (Wagner et al. 1999). Cape ivy (formerly known as *Senecio mikanioides*) is a serious pest of high-elevation forests on Mauna Loa, Mauna Kea, and Hualālai (Motooka et al. 2003). This species was noted as escaping the residential area in the original section of HAVO in 1943 (Fosberg 1966), but it appears to have been extirpated following control by park staff (Benitez and Loh in prep.).

English Ivy (Hedera helix L.)

Several English ivy vines totaling an area of 215 m^2 were encountered near the ranch house at Kahuku. Individuals were climbing native trees and growing in the forest behind the buildings. English ivy was not found beyond the house grounds and vicinity. Efforts to control the population were initiated by the PIEPMT in March 2006.

English ivy is a widely cultivated Eurasian climbing vine, sparingly naturalized in Hawai’i (Wagner et al. 1999). In the original section of HAVO small infestations occur between 910 and 1,220 m elevation in the vicinity of the `Āinahou Ranch House and the park’s residential area, where seedlings have been observed. Plants have been controlled at both sites since 1983 (Benitez and Loh in prep.).

Kahili Ginger (Hedychium gardnerianum Sheppard ex Ker-Gawl)

Systematic surveys encountered kahili ginger sparingly in the central pastures area, where several locally abundant infestations were noted in mesic forest and landscaped grounds between 640 and 950 m elevation. No plants were found on transects, and only two occurrences were noted in vegetation plots on the edges of native dominated forest fragments in the central pastures. Kahili ginger was not observed growing in open pasture conditions. Away from transect lines, infestations were discovered in a 7.8-ha forested ravine at 810 m elevation and in the Pu`u `Akihi ravine located upslope. At both sites, kahili ginger cover was estimated at 1-5%. Plants were growing among mostly native vegetation, including several rare species [e.g., hame (*Antidesma platyphyllum*); ha`iwale (*Cyrtandra menziesii*); olonā (*Touchardia latifolia*)]. A third infestation with an estimated area of 34 m^2 was found in the landscaped grounds of the ranch house and the surrounding forest. This population was treated by the PIEPMT in March 2006. Adjacent to Kahuku, plantings of kahili ginger were observed in residential lots located in the HOVE subdivision (Benitez 2004) and on Lorenzo Road near the southwestern and eastern boundaries of Kahuku.

Kahili ginger is a coarse herb with showy yellow and red flowers native to the Himalayan region (Wagner et al. 1999) and is regarded as one of the most disruptive pests of wet forests in Hawai`i (Smith 1985). In the original section of HAVO, kahili ginger infests over 3,000 ha of upland forest (Benitez and Loh in prep.) and dominates the understory in unmanaged areas near the Kīlauea summit. Intensive control efforts are underway to remove kahili ginger from much of its range in HAVO.

Stinking Everlasting (Helichrysum foetidum (L.) Cass)

In Kahuku, stinking everlasting was found between 1,670 and 2,350 m elevation in the northwestern (two transect stations, two vegetation plots) and western (two transect stations, two vegetation plots) survey regions. A maximum cover of 1-5% was noted in one 30-m radius vegetation plot located in a sparsely vegetated pūkiawe/`ōhelo shrubland of the western region. Stinking everlasting was occasionally observed in a recently burned kīpuka surveyed on the western slope. No additional stinking everlasting was noted elsewhere in Kahuku.

Stinking everlasting is a malodorous herb native to South Africa (Wagner et al. 1999). This species is not known from the original section of HAVO and thus represents a new addition to the park's flora. As little is known about its invasive potential, this taxon warrants further monitoring.

Japanese Mat Rush (Juncus effusus L.)

Japanese mat rush was found in wet forests, boggy areas, and inundated sites between 1,190 and 2,135 m elevation in the central and eastern survey regions. In the central pastures, Japanese mat rush was found in 18% (12/65) of transect stations, typically at 5-10% cover, where it grew in the open among alien pasture grasses and in forest fragments. In the eastern survey region, Japanese mat rush was found in 15% (48/321) of transect stations, most frequently at <1% cover, but occasionally at 10-25% cover. The moisture-loving rush was not observed in the northwestern, western, or southwestern survey regions, and it did not occur inside the forested pit crater. Two cogeneric, non-native species (*J. buffonis* and *J. ensifolius)* were noted infrequently in forest and wet habitats in the eastern survey region. Japanese mat rush is a perennial herb widely distributed in temperate regions (Wagner et al. 1999). Infestations occur in rain forests of older HAVO, but they are not targeted for control.

Air Plant (Kalanchoe pinnata (Lam.) Pers.)

Small, scattered roadside populations of air plant totaling a combined area of eight m^2 were encountered along Highway 11, spanning six km of roadsides from the Kahuku entrance to HOVE. No additional sightings of air plant were made along other ranch roads, along transects, in vegetation plots, or at the ranch house. Air plant along Highway 11 was controlled by the PIEPMT in March 2006. Five other species of Kalanchoe and related taxa were found cultivated near the main ranch house. These include felt bush (*Kalanchoe beharensis*), *Kalanchoe pumila,* panda plant (*Kalanchoe tomentosa*), an unidentified *Kalanchoe* sp., and jade plant (*Crassula ovata*). These species are not reported to be naturalized in Hawai'i (Wagner et al. 1999).

Outside Kahuku, air plant was commonly observed cultivated or naturalized along roadsides and vacant lots in HOVE (Benitez 2004). In Manuka State Park (Benitez pers. obs.) roadside plants were escaping into the dry forest.

Air plant is a succulent herb of unknown origin, naturalized and sometimes very abundant in low-elevation disturbed habitats on all the main islands except Ni`ihau and Kaho'olawe. This species and other succulents belonging to the Orpine Family (Crassulaceae) are not native to Polynesia (Wagner et al. 1999). Their popularity in the ornamental trade (Staples and Herbst 2005), ability to reproduce vegetatively, and adaptation to arid environments have contributed to their success in Hawai'i. In older

HAVO, air plant was mapped with five populations of 5-60 m^2 between 100 and 1,200 m elevation (Benitez and Loh in prep.); all infestations were subsequently controlled in 2003. A related species, chandelier plant (*Kalanchoe tubiflora*), is also naturalized and controlled in older HAVO. The ornamental *Kalanchoe waldheimii* is planted at `Āinahou Ranch but does not appear to be naturalized.

Neonotonia wightii (Wight & Arn.) Lackey

The vine *Neonotonia wightii* covered an area >100 m^2 overgrowing fences, smothering alien shrubs, and spreading into the adjacent forest near the Kahuku ranch house (670 m elevation). *Neonotonia wightii* was also observed growing within a corral along the main ranch road (near 730 m elevation). No additional *Neonotonia wightii* was detected during systematic surveys in Kahuku, but it probably persists in lower pastures that were not intensively surveyed. Systematic surveys and searches of ruderal habitats were limited, and additional surveys of livestock exclosures, pastures, and roadsides may locate new populations. Data from future surveys may allow managers to develop a comprehensive management plan for this species.

Although intentionally introduced to Hawai`i ranches, *Neonotonia wightii* is a potentially invasive weed. A forage crop of Neotropical origin (Wagner et al. 1999), plants are now naturalized in pastures, roadsides, and disturbed areas. Heavy vine cover can smother small plants and fences in Hawai'i (Motooka et al. 2003). In the original section of HAVO incipient *Neonotonia wightii* populations are establishing principally along Highway 11, and the vine has also been collected at `Āinahou Ranch. Large infestations occur beyond original HAVO's Ka`ū boundary. This species has not been controlled in HAVO.

Sweet Granadilla (Passiflora ligularis Juss.)

The vine sweet granadilla was observed off transect in mesic forest fragments and woodlands within the central survey region of Kahuku at 800-900 m elevation. Sweet granadilla was noted in several small (<0.5 ha) forest stands along transect 45 close to the Kahuku/Ka`ū Forest Reserve Boundary and near Pu`u `Akihi 1,300 m to the west-southwest, where several plants occupying five $m^2$ were climbing `ōhi`a trees. Individuals and larger patches (up to 30 $m^2$ area) were incidentally observed climbing `ōhi`a trees and hāpu‘u on a ranch road extending from Pu`u `Akihi to the Ka`ū Forest Reserve Boundary. Sweet granadilla was not detected in transects, vegetation plots, the forested pit crater, or elsewhere in Kahuku.

Sweet granadilla, native to the Andes of South America, is cultivated and naturalized in Hawai`i (Wagner et al. 1999). Major infestations occur on Hualālai and in TNCH Honomolino Preserve. In the older section of HAVO, individuals occur in rain forest and mesic forest but are not targeted for control.

A related taxon, purple granadilla or passion fruit (*Passiflora edulis* f. *edulis*) was noted in one transect station (tr 33 st 59) at 900 m elevation and one vegetation plot at 1,030 m in the central survey region. Both occurrences covered less than 1% (5 m^2) of the sampling unit; the former was on the edge of a forest fragment, the latter was found in a `ōhi`a/hāpu‘u forest on the eastern boundary of the pasture. Purple granadilla is abundant in disturbed mesic and wet forest in HAVO's East Rift. This species was targeted for control in the Luhi SEA units, but control was abandoned because purple

granadilla was too widespread, and it was unclear whether dense infestations would remain without continued disturbance.

Several other species of *Passiflora* are naturalized weeds in Hawai`i (Wagner et al. 1999). In HAVO and elsewhere in Hawai`i, banana poka (*Passiflora tarminiana*) is a serious weed in wet and mesic montane forests, and love-in-a-mist (*Passiflora foetida*) is abundant in dry coastal lowlands. Neither species was observed in Kahuku, although both were found in neighboring HOVE (Benitez 2004.).

Knotweed (Persicaria capitata (Buch.-Ham. ex D.Don) Masam.

The prostrate, invasive herb knotweed was found in disturbed areas, lava flows, pastures, native forests, and along roadsides between 640 and 2,070 m elevation. Knotweed was most frequently observed in the pastures of the central survey region, growing as small roadside populations of less than five m^2. Several larger infestations occurred: a population (250 m^2 in area) near a small trench on the northeast edge of the 1868 lava flow and one patch (40 m^2) near the ranch house. Additional large infestations were found along an abandoned airstrip at 2,200 m elevation and near a forestry planting area adjacent to the Ka`ū Forest Reserve at 975 m elevation. Knotweed was also found in both deep shade and exposed sites in the forested pit crater. In the west survey region, knotweed occurred along roadsides, on lava flows, and in several vegetated kīpukas. In this region, the highest elevation occurrence was on an `ā'a lava flow at 2,070 m elevation. Knotweed was found once growing as a two m^2 patch along the main road at 1,540 in the eastern survey region. Plants were not found in the northwestern or southwestern survey regions. Because of this species' broad ecological range, additional surveys are likely to result in new discoveries of infestations in Kahuku. In 2006, the PIEPMT initiated control efforts to remove infestations on lava flows and along roadsides in the western and eastern survey region.

Outside Kahuku, knotweed is abundant in adjacent HOVE, where surveys found the plant on 80% percent of roads (Benitez 2004). Roadside populations ranged in size from one square meter to 350 m^2, and several larger populations were noted inside vacant lots.

Knotweed is native to the Himalayas and western China (Wagner et al. 1999) and occurs in Hawai`i in a variety of habitats. The species was first collected in or near HAVO along Highway 11 and the Chain of Craters Road in the 1960s (Fosberg 1969). Today in the original section of HAVO, plants are found along roadsides, on lava fields, and in forests from 550 to 2,050 m elevation (Benitez and Loh in prep.). At sites outside the park, plants have been observed growing near sea level (Benitez pers. obs.). Knotweed has been intensively managed in original HAVO since 2002 along roadsides and in SEA units near the Kīlauea summit.

Madagascar Fireweed (Senecio madagascarensis Poir.)

Madagascar fireweed was found in Kahuku along roadsides, in disturbed areas, and within native shrublands between 640 and 2,470 m elevation in all survey regions. Systematic surveys encountered Madagascar fireweed most frequently along transects in the northwestern survey region between 2,240 and 2,470 m elevation. In this region, Madagascar fireweed was found in 21% (14/68) of transect stations and in two vegetation plots, where plants occurred in low abundance (<1% cover) on sparsely vegetated lava flows, in mixed grasslands, subalpine shrublands, and `ōhi`a-māmane

woodlands. In the central survey region, Madagascar fireweed was found in three percent (2/65) of transect stations between 640 and 1,560 m elevation in pastures and forest fragments. Plants occupying up to 35 m^2 were found in a vegetation plot at 1,560 m elevation in an `ōhi`a forest. In the central pastures, Madagascar fireweed was most commonly observed along roadsides and disturbed areas, where it was frequent and locally abundant. Because cover was not quantified in these areas, additional monitoring may be necessary to determine the distribution, abundance, and trends of Madagascar fireweed. Madagascar fireweed was found in five percent (16/321) of transect stations in the east survey region, and the species was only observed off transect in the southwest.

Adjacent to Kahuku, roadside occurrences of Madagascar fireweed were noted throughout HOVE (Benitez 2004) and along Highway 11 near the Kahuku ranch entrance.

Madagascar fireweed is a pasture weed native to Madagascar and Southern Africa. A phylogeographical analysis of Hawaiian Madagascar fireweed populations suggested these are most closely related to populations from the KwaZulu-Natal Region of South Africa (LeRoux et al. 2006). In Hawai`i, Madagascar fireweed is a relatively recent arrival and has spread rapidly across the Big Island. In addition to its potential for rapid spread, this species contains secondary compounds including pyrrolizidine alkaloids that are toxic to livestock (Motooka et al. 2003). Notable infestations now occur near Kamuela, along Saddle Road, and in the Ka`ū district. Madagascar fireweed is an incipient invader of the original section of HAVO (Benitez and Loh in prep.), where individuals were first observed in 2001 along Highway 11 between the Ka`ū park boundary and the Volcano golf course. These populations are currently being controlled, and roadsides in the park are monitored for new ingress of this weed.

Nasturtium (Tropaeolum majus L.)

At Kahuku, nasturtium covered an area of 200 m^2 on lawns and forest edges immediately south of the Kahuku ranch house at 670 m elevation. These plants were subsequently treated by the PIEPMT in Spring 2006. No additional plants were detected in Kahuku.

Nasturtium is a vine with round leaves and showy yellow-red flowers; it is native to montane regions of Mexico to Central Chile. In Hawai'i, plants are naturalized in mesic, disturbed areas on Kaua`i, Moloka'i, Maui, and Hawai'i between 850 and 1,350 m elevation. In the original section of HAVO, nasturtium occurs in mesic forests and pastures between 1,200 and 1,300 m elevation on Mauna Loa, where the species has been managed to prevent its spread since 1979.

Common Mullein (Verbascum thapsus L.)

Common mullein, a wooly biennial, was the most frequently encountered broadleaf invader at upper elevations in Kahuku. Individuals occurred in native plant communities on barren lava flows and in disturbed areas along the northwestern and western survey regions between 1,760 and 2,500 m elevation.

Common mullein was most abundant in the northwest, where plants were observed in 88% (60/68) of transect stations and 75% (12/16) of vegetation plots. Individuals were distributed at <1% cover throughout the sampling unit (ca. 1,250 ha) on sparsely vegetated lava flows, in heavily browsed alien grassland, native shrublands, and

woodlands of māmane, naio and `ōhi`a. The effect of browsing along the central stalks of common mullein and on surrounding vegetation was observed throughout the region. In the western survey area, plants were clustered in two burned kīpukas (area = 109 ha), on adjacent ‘ā’a lava flows, and on flow edges (area = 80 ha) at a maximum elevation of 1,900 m. Individuals grew with alien grasses, sparsely distributed shrubs, and native trees on exposed rock and soil.

Two common mullein plants were found and removed along the principal road bisecting the eastern survey area near transect 3. No additional common mullein was observed in the eastern region, pastures, or southwest. Adjacent to Kahuku, common mullein was abundant and reached densities of up to 1,600 individuals/ha along roadsides in the HOVE subdivision (Benitez 2004).

Native to Eurasia, common mullein was introduced to Hawai’i in the early 1900s. Large populations are currently established on the slopes and saddle area of Hualālai, Mauna Loa, and Mauna Kea Volcanoes between 1,600 m and 3,300 m elevation (Juvik and Juvik 1992). In HAVO, common mullein is found primarily on ‘ā’a flows between 1,520 m and 2,140 m elevation on Mauna Loa (Loh et al. 2000), and the weed is targeted in an intensive containment program. Based on its distribution along elevation and rainfall gradients on Mauna Kea on the Big Island, mullein has the potential to expand its range substantially in both Kahuku and the original portion of HAVO.

Other Alien Herbs and Vines

Among the 123 alien herbaceous (non-graminoid) species found in Kahuku, 31 appear to be cultivated taxa. Six of these cultivated species were observed naturalized beyond plantings in Kahuku. These included three highly invasive species (kahili ginger, Mauritius hemp, nasturtium) that are currently being controlled by park staff. Three additional species, butterfly orchid (*Epidendrum* x *obrienianum*), white ginger (*Hedychium coronarium*), and day flower (*Commelina* sp.) were found naturalized only in disturbed sites. The ginger and orchid may warrant further monitoring due to their potential to expand their range in Kahuku and for their observed invasiveness in older HAVO and elsewhere in the Islands.

Among the herbs found in Kahuku, 21 are cited as weeds of Hawai’i’s pastures and natural areas (Motooka et al. 2003). Thirteen of these were included as target species for surveys and were discussed in the previous section. The remaining eight taxa are: tropic ageratum (*Ageratum conyzoides*), spiny amaranth (*Amaranthus spinosus*), hairy beggartick (*Bidens pilosa*), red spiderling (*Boerhavia coccineus*), elephant’s foot (*Elephantopus mollis*), white ginger (*Hedychium coronarium*), Japanese honeysuckle (*Lonicera japonica*), and sensitive plant (*Mimosa pudica*). Additional surveys may be required to adequately describe the occurrence and assess invasiveness of these species in Kahuku.

Banana poka (*Passiflora tarminiana*, formerly *P. mollissima*), considered one of Hawai’i's worst pests of mesic and wet forests (Wagner et al. 1999), was the only invasive herbaceous or viny species on the target list not found in Kahuku. Dense infestations are capable of smothering and physically damaging native plants. Banana poka is intensively managed in mesic and wet forest SEA units in older HAVO.

Invasive Alien Plant Species: Ferns

Eleven alien fern species were encounterd in Kahuku. The majority of ferns were located in the pasture survey region, and only three taxa were common. Asian swordfern (*Nephrolepis multiflora*) was the most widespread alien fern species in Kahuku. Plants were not targeted for systematic surveys, but were found in forest, woodlands, shrublands, and pasture in the southwestern and central survey regions between 694 and 1,268 m elevation. In pasture plots, swordfern was found at <5% cover growing with kikuyu and other alien grasses under sparse (<25%) `ōhi`a canopy, and the fern was found infrequently along the margins and within the forested pit crater. Plants were also found growing in forest along the eastern Kahuku/Ka`ū Forest Reserve boundary. In the southwestern survey area, swordfern was found in four vegetation plots on the 1868 lava flow, in a Christmasberry shrubland at 670 m, and in an `ōhi`a woodland along Kahuku's eastern boundary with HOVE.

In the older section of HAVO, large areas of disturbed mesic and transitional dry to mesic forest have been invaded by Asian swordfern. The fern forms thick 1-2 m high swards that dominate the understory. The dried rachis, papery fronds, and litter that accumulate within the swards are capable of supporting large wildfires, and the species is currently being investigated for its ability to alter fire regimes and successional trajectories in invaded areas (Ainsworth 2007).

Two other ferns, *Deparia petersenii* and *Christella dentata*, were frequently found in open areas of the pasture survey region. A related species, *C. parasitica*, was less common.

Invasive Alien Plant Species: Grasses

Thirty-eight alien grass species, including 10 target species, were encountered in Kahuku. The greatest diversity of alien grasses was noted in the pastures of the central survey region Alien grasses were dominant vegetation components throughout most of Kahuku, the exception being deeply shaded forest, pioneer communities, and high-elevation (>2,000 m) communities. Alien grasses, particularly kikuyu, dominated the pastures, and kikuyu and meadow ricegrass were co-dominants in the understory of formerly logged koa-`ōhi`a forests (1,500-1,900 m elevation) in the western survey region of Kahuku. These two species were the principal grasses in the northwestern survey region as well, although they were less abundant here than in wetter central and eastern Kahuku. In the southwest survey region, a suite of fire-adapted grasses (bush beardgrass, broomsedge, and barbwire grass) were established in the understory of `ōhi`a woodlands. In contrast, pioneer communities on lava flows and upper elevation communities in the west and east were relatively free of alien grasses. Localized populations of the highly invasive fountain grass were found principally on lava flows below 800 m elevation and along Highway 11 and nearby roadsides within Kahuku.

Broomsedge (Andropogon virginicus L.)

The invasive bunchgrass broomsedge was widespread in woodlands and grasslands across western, southwestern, eastern, and central survey regions between 640 and 2,150 m elevation. Broomsedge was most abundant in the understory of dry `ōhi`a woodlands of the southwest, where a maximum cover of 10-25% was noted in transect stations east of the 1887 lava flow. Throughout the southwest, broomsedge was found in 22% (15/67) of transect stations and 39% (7/18) of vegetation plots, where it grew among other exotic grasses, principally bush beardgrass (*Schizachyrium*

condensatum) and barbwire grass, in the understory of dry `ōhi`a woodlands. In the more sparsely vegetated areas west of the 1887 lava flow, broomsedge was found at very low abundance (<1% cover) in 28% (2/7) of vegetation plots and was not observed in transect stations. Broomsedge was found in 26% (17/65) of central region transect stations. Cover was < 5%, with the densest infestations concentrated at lower elevations near the park entrance, along roadsides, and in paddocks that were dominated by alien kikuyu grass. Populations were also established on recent lava flows (e.g., 1868). In the eastern survey area, broomsedge was observed on seven of eight transects. Along transects, small infestations (<1% cover) occurred primarily in `ōhi`a woodlands in an ecological zone that transitioned between wet-mesic closed-canopy forest and subalpine shrublands at 1,645-2,300 m elevation. Plants were growing with native bunchgrass *Deschampsia nubigena*, the sedge *Morelotia gahniiformis,* alien grasses such as sweet vernal grass and sheepgrass (*Eragrostis brownei*)*,* and native shrubs `a`ali`i and pūkiawe. In the western survey region, broomsedge was seen only sparingly, and it was not observed in the northwestern area.

Broomsedge, native to southeastern United States, is a highly invasive fire-adapted grass. Fire-regimes are altered where invasions occur in HAVO's mesic and dry `ōhi`a woodlands (Smith and Tunison 1992).

Barbwire Grass (Cymbopogon refractus (R. Br.) A. Camus)

Barbwire grass was found frequently in dry `ōhi`a woodlands of the southwest and less commonly in central survey regions between 640-1,500 m elevation. Although occasionally noted at 50-75% cover, infestations generally occurred at <10% cover in transect stations and vegetation plots. Barbwire grass was a principal ground cover in kīpukas infested by Christmasberry in the southwestern region, particularly at lower elevations. Sparse infestations were seen in the western portion of this survey region, where individuals were found in all 30 stations located along transect 30. In the central pastures, small populations were noted along roadsides, and one plant was found in an `ōhi`a woodland dominated by kikuyu grass at 1,500 m elevation.

Barbwire grass is native to Australia. In Hawai'i, the species occurs in pastures, roadsides, and dry disturbed sites from sea level to 1,110 m elevation (Wagner et al. 1999). In the original section of HAVO, this grass occurs along the southwestern boundary with Kapāpala Ranch, although its distribution has never been mapped. A congeneric species, lemon grass (*Cymbopogon citratus*) was found in cultivation at the Kahuku ranch house; it does not appear to be naturalized.

Meadow Ricegrass (Ehrharta stipoides Labill.)

Meadow ricegrass was encountered in all survey regions: in forest, woodlands, shrublands, and grasslands between 760 and 2,450 m elevation. Meadow ricegrass was one of two principal grasses found in the northwestern and western survey areas. The species was most frequent in the northwest, where it was found in 63% (43/68) of transect stations and 14/16 (88%) of vegetation plots, occupying 25-50% cover in woodlands dominated by naio, māmame or `ōhi`a, shrublands dominated by pūkiawe and `a`ali`i, and mixed native/alien grasslands. Meadow ricegrass was occasional in sparsely vegetated māmane woodland communities with <10 % total vegetation cover. In the western survey region, meadow ricegrass was found in seven of 44 vegetation plots and occurred principally in `ōhi`a/koa woodlands, where it formed the dominant ground cover (60-100%). In the southwest, meadow ricegrass abundance decreased

along rainfall gradients from east to west. To the east of the 1887 lava flow, a maximum cover of 10-25% was observed in vegetation plots in `ōhi`a woodlands. West of this flow, where the vegetation was generally sparse, meadow ricegrass occurred in the lowest cover classes (<1%) in vegetation plots and was not detected along transects. In the eastern survey region, meadow ricegrass was sparse (<1% cover) and occurred principally in forests and transitional woodlands below 1,940 m elevation. Meadow ricegrass was also found in the central region growing among other alien grasses in pastures, forest fragments, woodlands, forest, and under tall-stature closed `ōhi`a canopy within the forested pit crater. Small infestations (1-5% cover) occurred in 11/65 (17%) of transect stations and 4/15 (27%) of vegetation plots in the central survey region.

Meadow ricegrass is commonly found under koa in abandoned pastures on Mauna Loa between 1,200 and 2,000 m elevation in the original section of HAVO, and the grass is abundant in the TNCH Honomolino Preserve adjacent to Kahuku. The species is the focus of several studies examining impacts of alien grasses on forest regeneration in abandoned pastures in Hawai'i (Denslow et al. 2006).

Thatching Grass (Hyparrhenia rufa (Nees) Stapf)

Thatching grass appears to be an incipient invader in Kahuku. Infestations were observed along roadsides from the park entrance to the ranch house between 640 and 670 m elevation. No thatching grass was encountered elsewhere in Kahuku during systematic surveys or in off-transect searches. Additional surveys of roadsides and other disturbed areas within and adjacent to Kahuku may assist in delineating the extent of the invasion.

An intentional introduction to pastures in Hawai'i, thatching grass is now naturalized and common along roadsides and cultivated fields between 10 and 660 m elevation on Kaua`i, O`ahu, Moloka`i, Maui and Hawai'i (Wagner et al. 1999). In HAVO, thatching grass is a dominant grass in coastal lowlands, but it is controlled along roadsides to prevent its spread into new areas.

Molasses Grass (Melinus minutiflora P. Beauv.)

Molasses grass was detected sparingly in systematic searches and along transects between 710 and 1,500 m elevation. Small infestations (<1% cover) were found in one vegetation plot in the southwest and single transect stations in the northwestern and central survey regions. Additional surveys within the central and southwestern areas and disturbed areas may locate additional infestations.

In Hawai'i, molasses grass is common in dry to mesic disturbed, open areas on all the main islands except Ni'ihau (Wagner et al. 1999). Considered a serious pest, the grass is capable of choking out or preventing native plant growth (Smith 1985; Motooka et al. 2003).

Guinea grass (Panicum maximum Jacq.)

Guinea grass was observed only along roadsides from the park entrance to the ranch house between 640 and 670 m elevation. Several clumps (total area of 40 m^2) noted in the vicinity of the house were subsequently controlled by the PIEPMT in March 2006. Small populations remain along the main road to the park entrance. Plants were not encountered elsewhere during systematic searches of Kahuku. However, because of

Kahuku's ranching history and numerous forage grass introductions, additional undetected Guinea grass populations may occur on the former ranch.

Near Kahuku, Guinea grass grows abundantly along portions of Highway 11 in the Ka`ū district, where it is nearly continuously distributed. Small roadside populations occur in vegetated areas within HOVE.

Guinea grass is an African forage grass that is widely naturalized throughout the tropics (Wagner et al. 1999). In Hawai'i, Guinea grass occurs in a broad ecological range between sea level and 850 m (Motooka et al. 2003). Dense infestations up to approximately one ha occur in koa haole groves in coastal lowlands in HAVO, and several smaller, recently established populations (<20 m²) surround these infestations. Small incipient populations also occur along Highway 11, and these populations are controlled to prevent Guinea grass establishment in adjacent `ōhi`a woodlands. Guinea grass is sensitive to Glyphosate (Motooka et al. 2003). In HAVO a 5% Roundup solution in water applied to foliage of mature plants did not produce a complete kill, and the effectiveness of higher concentrations is being evaluated.

Kikuyu (Pennisetum clandestinum Chiov.)

Kikuyu was observed in forests, woodlands, shrublands, and grasslands throughout all survey areas between 640-2,420 m elevation, except for the eastern survey region where the grass was not detected east of transect 3.

In the western survey region, kikuyu was the principal grass growing in the open and one of two grasses (with meadow ricegrass) growing under `ōhi`a and koa. In the central survey region, kikuyu was found in 94% (61/65) of transect stations and 63% (12/19) of vegetation plots. The grass formed a near dominant ground cover (>60%) in the open pasture, but it was less abundant under `ōhi`a (<25%). Plants were rarely seen in the deep shade. Only a few infestations were found in the mesic forest understory within a ravine, and no plants were found in wet forest inside the pit crater or along the Ka`ū Forest Reserve.

In the northwestern survey region, kikuyu was found in 41% (28/68) of transect stations with cover between 1-50%. Plants were most abundant in vegetated kīpukas that contained mixed native (e.g., `ōhi`a, māmane, naio) woodlands and were least abundant in sparsely vegetated areas that had little soil development. In the southwest, kikuyu was abundant (>25% cover) in vegetation plots and transect stations in `ōhi`a woodlands above 1,130 m elevation. Kikuyu was not found in lower elevation woodlands below 910 m elevation. In the eastern survey region, kikuyu was found primarily in areas closest to the central pastures, and no plants were detected in transects or vegetation plots east of transect 3.

Introduced for cattle grazing, kikuyu is a tenacious weed in Hawai'i (Wagner et al. 1999). The grass smothers native vegetation and prevents seedling establishment. In the original HAVO unit, kikuyu is broadly distributed between 1,000 and 2,000 m elevation. Highest concentrations are in formerly grazed koa forest on the Mauna Loa Strip Road.

Fountain Grass (Pennisetum setaceum (Forssk.) Chiov.)

Fountain grass was observed between 610 and 1,750 m elevation on young lava flows, disturbed habitats in pastures, and in southwestern and western survey regions. Populations were discrete and localized, except for a population that stretched along Highway 11. Fountain grass was not detected in other areas of Kahuku.

Three discrete populations of fountain grass were found in the central survey region. The largest population consisted of 370 individuals distributed across 3.3 ha located 600 m north of Highway 11 near the Kahuku-HOVE boundary. Individuals were growing in sparse, primarily native shrubland with alien barbwire grass on shallow soil and ʻāʼa. Three smaller populations were located in disturbed, roadside habitats within Kahuku. Among these were 31 plants, which possibly included the congener *P. polystachion,* growing among a suite of alien weeds (e.g., bush beardgrass, Cape ivy, castor bean, kikuyu grass, and knotweed). These plants were near a lava trench on the northern edge of the 1868 lava flow. Another population of 21 plants was found along Kahuku's former airstrip at 670 m elevation. Individuals were growing in pavement cracks and on the adjacent lava flows. An additional plant was found along a spur road near the park's eastern entrance and Highway 11, where it was growing among other alien herbaceous species on loose soil and aggregates.

One roadside population, spanning the central and southwestern survey regions, was found distributed along the 8.3 km stretch of Highway 11 that lies within and adjacent to Kahuku's southern boundary. This population contained 193 individuals. Fountain grass has been observed sparingly distributed beyond the park boundary downslope of Highway 11, and it appears to be in the early stages of invasion in this region (Benitez pers. obs.).

Two separate individual plants were identified in the western region. A single plant was sighted and removed in 2004 by Tim Tunison along a logging road (1,750 m elevation), and a second plant was removed near Pu'u `Ōhohia during off-transect rare plant surveys. GPS data were not collected for these sightings, but approximate locations were drawn on a map. No additional plants were located in surveys of the areas surrounding known populations or from aerial sweeps of the lava flows in the western, southwestern, and central pastures. Adjacent to Kahuku, fountain grass is established along roadsides and in a few residential lots of HOVE (Benitez 2004).

Native to Africa, fountain grass is a highly disruptive fire-adapted species (Smith 1985; Wagner et al. 1999) that has increased fire frequency in invaded lowland ecosystems in Hawai'i. Considerable resources are devoted to preventing the build-up of high densities of fountain grass in the original section of HAVO (Tunison et al. 1994). In Kahuku, search and removal efforts to eradicate infestations were begun in 2004, and the park is currently partnering with the HOVE community to contain the spread of fountain grass in their neighborhood.

Bush Beardgrass (Schizachyrium condensatum (Kunth) Nees)

The tall bunchgrass bush beardgrass was found in woodlands, shrublands, and grasslands between 640 and 2,150 m elevation. The species was most abundant in dry `ōhi`a woodlands located in the southwest survey region east of the 1887 lava flow and below 910 m elevation. Plants (with a maximum of 25-50% cover) were encountered in 46% (17/37) of transect stations and co-occurred with barbwire grass, broomsedge,

alien swordfern, and native shrubs. Bush beardgrass was less frequent in the more sparsely vegetated woodlands west of the 1887 lava flow, where plants were encountered only twice along the survey transect near 870 m elevation. In the eastern survey region, bush beardgrass was frequently found growing at low abundance (<1%) in transitional `ōhi`a woodlands and subalpine native shrublands up to 2,270 m elevation. Plants were found along all eight transects and in 50% (321/642) of transect stations and in 19% (15/78) of vegetation plots of the eastern survey region. Vegetation plots containing bush beardgrass had co-occurring species such as exotic broomsedge, sheepgrass, sweet vernal grass, rattail grass, velvet grass, and the native hairgrass (*Deschampsia nubigena*). Bush beardgrass was infrequent in the pastures of the central survey region, occurring with <1% cover in only eight of 65 transect stations. It was also noted along roadsides and disturbed habitats along the central pastures, but was absent from shaded environments such as forest and the pit crater's interior. No bush beardgrass was encountered in the northwestern survey region.

Bush beardgrass is a C4 grass (Rundel 1980) native to tropical and subtropical America (Wagner et al. 1999). The grass is widespread on Hawai`i Island, and plants have been recently documented in roadside locations and natural areas near the Ko'olau range on O'ahu. In the older section of HAVO, bush beardgrass is abundant in dry `ōhi`a woodlands, where it has altered fire regimes in heavily invaded areas.

Rattail Grass (Sporobolus africanus (Poir.) Robyns & Tournay)

Rattail grass was found in woodlands, shrublands, and grasslands in all survey regions within Kahuku between 850 and 2,350 m elevation, but the species was most abundant at the upper end of its elevational distribution.

Rattail grass was most frequent in the eastern survey region, where it was growing in transitional woodlands and subalpine shrublands up to 2,350 m elevation. Rattail grass was found in 16% (104/642) of transect stations and grew most abundantly (10-75% cover) along transects located west of the 1950 lava flow (Transects 3, 6, 9). In the central survey region, rattail grass was most abundant (to 25-50% cover in transect stations) at upper elevations (>1,400 m) growing among alien grasses in sparse `ōhi`a woodlands (10-25 % canopy cover) and alien grasslands. At lower elevations (820-1,060 m) rattail grass was encountered frequently at very low abundance (<1% cover). In the western, northwestern, and southwestern survey region, rattail grass was not found in transect stations at greater than 10% cover.

Rattail grass is native to Africa (Wagner et al. 1999) and is naturalized in disturbed areas and poor pasturelands in Hawai'i. It occurs in the older section of HAVO, where it is not controlled.

Other Alien Grasses

In addition to the 10 species described above, 28 additional alien grass species were identified in Kahuku. Four of these were considered widespread because they were found in at least four of five survey regions. These are sweet vernal grass, narrow-leaved carpet grass, velvet grass (*Holcus lanatus*), and sheepgrass. The majority of alien grasses were concentrated in the central pastures and adjacent areas within the western and southwestern survey regions below 1,500 m elevation. Apart from the species targeted for systematic mapping, only four grass species were found in

vegetation plots above 2,000 m elevation. In order of decreasing abundance, these were sweet vernal grass, sheepgrass, velvet grass, and brome fescue (*Vulpia bromoides*).

Three grass species were unique to the ranch house surroundings. These were cultivated lemon grass, pitted beardgrass (*Bothriochloa pertusa*), and wiregrass (*Eleusine indica*). Both pitted beardgrass and wiregrass appeared to be naturalized.

Two aggressive grass invaders, elephant grass (*Pennisetum purpureum*) and palmgrass (*Setaria palmifolia*), were not found in Kahuku. Elephant grass was not originally targeted for mapping, but it was noted encroaching along the eastern boundary of Kahuku. Native to Northern Africa, this species was originally cultivated and became naturalized in mesic and wet habitats in Hawai'i (Wagner et al. 1999). The highly invasive palmgrass was originally targeted for mapping but was not observed within Kahuku during the inventory. Native to Asia, it is naturalized in Hawai'i in mesic valleys, wet forest and streams on O`ahu, Lāna`i, Maui, and Hawai`i (Wagner et al. 1999). In older HAVO, palmgrass infests portions of wet forest on Kīlauea summit and in 'Ōla'a, where it can form a continuous ground cover (Benitez and Loh in prep.). Future surveys throughout the pastures and adjacent forests may provide more information on the distribution of these two species in Kahuku.

Management Considerations for Invasive Alien Plant Species at Kahuku

Invasive alien plants have devastating effects upon the native flora in Hawai'i (Smith 1985; Vitousek and Walker 1989). Many of the invasive species identified in this inventory have reduced native plant diversity and abundance and altered vegetation structure in invaded plant communities in the islands. At their very worst, certain invasive species (e.g., faya tree, fountain grass, strawberry guava) have been able to completely displace native vegetation and disrupt ecosystem processes by altering water and fire regimes or nutrient cycles (Vitousek 1990).

In the older section of HAVO, two thirds of 915 plant species present (Higashino et al. 1988) are alien, with 100 invasive species considered highly disruptive to native ecosystems (Smith 1985; Tunison and Stone 1992; Benitez and Loh in prep.). Roughly half of the species appear to be at an early stage of invasion with small localized populations, and parkwide control to eradicate or contain populations is being implemented. The remaining species are widespread, and management actions are limited to containment at the invasion front and/or exclusion from high priority management units (SEAs). In some cases no feasible management plan has been identified (e.g., bush beardgrass, broomsedge), and no actions have been taken.

In Kahuku, approximately 50 species have been identified as highly aggressive invaders based on their distribution and impacts to native communities in Kahuku or elsewhere in the islands (e.g., alien grasses, Christmasberry, faya tree, kahili ginger, strawberry guava). Other species were found that have characteristics typically associated with invasive species, such as rapid growth, high reproductive rates, easily dispersible propagules, or congeners that are documented as invasive in tropical island systems (e.g., Monterey pine, pepper tree, thimbleberry). For both categories of species, formulating the appropriate management strategies will require additional field surveys to map the extent of infestations, identify satellite populations, and monitor the rate and spread of infestations across Kahuku.

Highly invasive weeds with apparently limited distribution at Kahuku include silk oak, sisal, and fountain grass in dry habitats; kahili ginger, strawberry guava, rose apple, and night cestrum in mesic and wet forest fragments; and faya tree and common mullein at higher elevations. Site-led management to eradicate these populations is underway, but additional surveys are needed to ensure that species are detected and controlled across their entire range in Kahuku. For example, the wide (3 km) spacing of transects in the eastern survey region excluded large areas from sampling, and these may contain invasive weed populations. More intensive (i.e., closely spaced) foot surveys may be needed to address spatial gaps.

Aerial surveys proved to be an effective method for locating additional invasive populations not identified during foot surveys. For example, a single aerial survey enabled us to systematically sweep large tracts of forest to detect faya tree emergent in the forest canopy. Aerial surveys also proved effective in identifying emergent individuals of silk oak, Monterey pine, and rose apple in forest, woodland, and grasslands, and fountain grass on open lava flows. Aerial surveys can be conducted periodically across large tracts of open terrain (e.g., lava flows, alien grasslands, open shrublands) to detect new individuals and monitor populations. These surveys also have the potential to locate some conspicuous rare plant populations or to identify suitable rare plant habitat for additional surveys.

Other areas in need of additional surveys (foot and/or aerial) include the central survey region, which has been the site of numerous plant introductions for forage, ornamental, horticultural and silvicultural purposes; and disturbed areas (roadsides, fencelines, clearings), which serve as corridors for establishment of ruderal, weedy species (Forcella and Harvey 1983; Tyser and Worley 1992; Forman and Alexander 1998). Human activities along these corridors serve as vectors for the transport of weed propagules. Monitoring of these corridors may be cost-effective if individuals can be detected and removed before they spread into natural areas

Future re-monitoring will provide information on the changing distribution and spread of infestations and the establishment of new species in Kahuku. There were several species with limited distributions (e.g., apple of Sodom, pearl flower) or sparse occurrences across a wide area (e.g., sour bush, thimbleberry) for which the invasive potential is unknown. Many share characteristics or are congeners of documented pest species in Hawai'i. Because species initially thought to be innocuous can rapidly expand their ranges following an invasion time lag (Sakai et al. 2001), continued monitoring may be necessary.

Several highly invasive species discovered near the park have the potential to establish in Kahuku. These encroaching species underscore the need for frequent monitoring so that individuals can be detected and a timely management response initiated. Encroaching species include dryland invaders kāhili flower, plume poppy, loquat, and Victorian box. Banana poka, an aggressive weed of mesic to wet habitats, was also found in unoccupied lots in HOVE, and its seeds are highly dispersible. A highly aggressive invasive shrub, Koster's curse, is known to occur in the Ka`ū district but was not found in Kahuku. Yellow Himalayan raspberry is a major pest in pastures of the Volcano area (Stratton 1996). Although not known from the Ka`ū district, its seeds are easily dispersed long distances by birds. There were nine additional species identified as encroaching whose invasive potential is currently unknown because little information exists on their distribution and impacts to natural areas.

Without management intervention, many of the invasive species will continue to spread unchecked and result in the displacement of additional native species and communities in Kahuku. Measures to remove small localized infestations now before they become widespread are both feasible and cost effective (Tunison and Stone 1992), and this strategy is an integral part of the park's Resources Management program. Candidates for eradication are species with small localized distributions at Kahuku and include species planted for forestry (e.g., *Eucalyptus* spp., tropical ash, *Pinus* spp.), ornamental species (e.g., African olive, night cestrum), and other species that arrived incidentally or deliberately and become sparingly naturalized on the ranch, such as silk oak, fountain grass, and rose apple.

For widespread species, alternatives such as local eradication or containment may prove more realistic than Kahuku-wide eradication. For example, common mullein is found primarily on young lava flows and in several kīpukas within the northwestern and western survey regions. The build-up of large infestations makes the cost of treatment prohibitive in kīpukas and in the northwestern survey areas. However, eradication of small populations from lava flows in order to contain the spread of infestations in the west survey area appears promising based on recent control work performed by the PIEPMT. Such a site-based approach to managing widespread disruptive weeds (e.g., weed management in Special Ecological Areas) has been highly successful in the original section of HAVO.

There are some widespread invasive species for which there may be no feasible control action. Kikuyu grass, meadow ricegrass, bush beardgrass, and other alien grasses dominate former koa and `ōhi`a forest in the actively used pastures of the central survey region and are common in the southwestern, western, and northwestern survey regions. Thick infestations of Christmasberry dominate portions of low-elevation pastures and `ōhi`a woodland communities. For these highly infested areas, an experimental approach may be needed to develop new eradication techniques (e.g., bulldozing) and restore native species diversity by re-introduction.

Actions to eradicate or control the spread of disruptive weeds currently in Kahuku might be best accompanied by additional measures to prevent the introduction and establishment of new species. Such measures would include decontamination of vehicles, field equipment and gear used by park staff and visitors entering Kahuku, routine inspection of frequently used roads, trails, and facilities that provide avenues for propagules to establish and disperse into natural areas, and the planting of native species as an alternative to non-native species for landscaping around buildings and facilities. Removal of non-native feral pigs, goats, mouflon, and cattle will reduce the creation of site conditions that facilitate weed establishment. Introduced ungulates are major modifiers of native Hawaiian plant communities and ecosystems (Stone and Taylor 1984; Stone 1985). Through trampling, rooting and feeding, ungulates have selectively depleted native plant species and promoted the dispersal and establishment of weedy plants throughout native plant communities in the Hawaiian Islands.

Rare Native Plant Species

The term “rare plant” is used here to describe native Hawaiian plants federally listed as endangered, threatened, candidate endangered, or species of concern, and native plant species that are rare or uncommon within the survey area, but have no designated

federal status. Five endangered, one threatened, a candidate endangered, and seven species of concern (SOC) were documented within the Kahuku addition of HAVO during the course of this study (Figure 9). New records for the park included two endangered plants (`ōhā, *Clermontia lindseyana* and hāhā, *Cyanea stictophylla*), one candidate endangered species (makou or *Ranunculus hawaiensis*), and two SOC (ha`iwale or *Cyrtandra menziesii* and *Sanicula sandwicensis*). The Ka`ū silversword (*Argyroxiphium kauense*) has long been known from Kahuku, and has been planted in the Mauna Loa Strip, but it is an addition to the naturally-occurring flora of HAVO. Another two SOC (`ōhelo papa or *Fragaria chiloensis* ssp. *sandwicensis* and ho`awa, *Pittosporum hawaiiense*) and a relatively rare lobelioid (`ōhā wai or *Clermontia clermontioides*) formerly reported from HAVO with little supporting evidence were found in Kahuku; these are now confirmed as part of the park's flora. An additional 26 native species were mapped as rare or uncommon at Kahuku; four of these were new records for the park.

Species known in herbaria from earlier collections at Kahuku, but not found during this survey, were included in the checklist of vascular plants (Appendix A). Most of these species are described in the section "Historical Records of Rare Plants at Kahuku," and details from collection labels are presented in Appendix B.

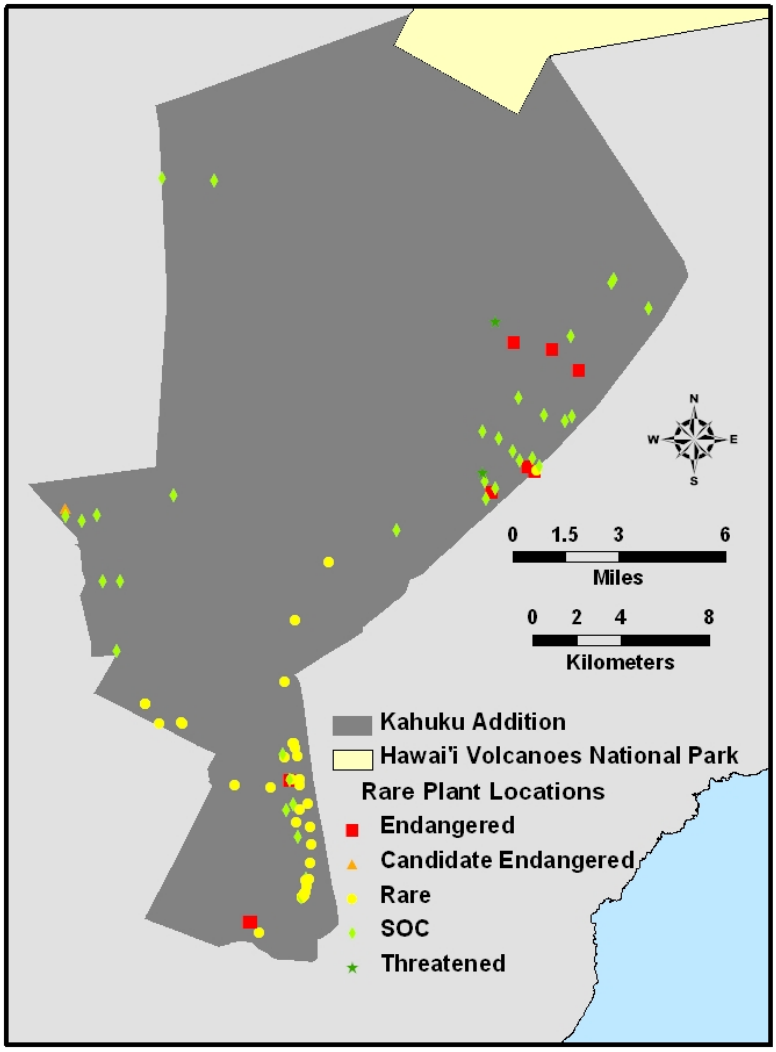

Figure 9 Locations of rare plants in the Kahuku addition to Hawai'i Volcanoes National Park.

Rare Native Plants: Endangered Species

Ka'ū silversword (Argyroxiphium kauense (Rock & M. Neal) Degener & I. Degener)

Kahuku contains one of only three naturally occurring populations of Ka'ū silversword in Hawai'i. No new occurrences of Ka'ū silversword were found during this survey. However, future surveys may result in additional sightings of persistent populations.

Individuals were first documented at Kahuku in the 1950s and were originally named *A. sandwicense* var. *kauense*. The named variety was elevated to its own species in 1957 (Degener and Degener 1957) and listed as endangered in 1993. The current distribution of Ka'ū silversword at Kahuku is limited to ca. 730 individuals within a few

hectares on old weathered ‘ā‘a dating at 200 to 750 years old in open ‘ōhi‘a woodland at 1,900 m elevation in Kahuku’s eastern survey region.

Surveys conducted by Jacobi and Warshauer in the 1970s indicated there were more plants present 30 years ago than there are today. Jacobi estimated the extent of Ka‘ū silversword occurrence to be at least 10 times the current range at Kahuku (James Jacobi, USGS, pers. comm. 2006). Photos of the Keopohina area from the earlier survey show large plants uprooted and damaged by pig activity. Ka‘ū silversword populations are particularly vulnerable to browsing from goats, sheep, and mouflon, because they are highly palatable, obligate outcrossers, and typically flower only once before they die (Carr 1985).

The Kahuku population was fenced by the ranch in the late 1970s to protect it from animal damage. The State of Hawai`i rebuilt the fence in the 1990s, and HAVO upgraded the fenced exclosure in 2004. Following the discovery of two individuals located outside the exclosure in 2004, a second 0.4 ha exclosure was constructed approximately 0.4 km from the original population. Three hundred and sixty-two nursery-propagated individuals were planted into the exclosure in 2005. This exclosure was expanded to 10 ha in 2006 to accommodate future plantings required for recovery of the species.

Asplenium peruvianum Desv. var. insulare (C.V. Morton) D.D. Palmer (No common name)

Asplenium peruvianum var. *insulare* is an endangered fern found in high-elevation lava tube entrances. The fern may be found growing as far as the light line within lava tubes, where it is generally epiphytic on side walls, and occasionally on the lava tube floors. Prior to the Kahuku surveys, this fern was known from five sites in the park above 1,800 m elevation within the upper Mauna Loa SEA. Four new sites for this species were documented at Kahuku during the survey. The ferns occurred in the eastern survey region on pāhoehoe lava flows dated at 1,500-3,000 years old.

Known populations of *Aslpenium peruvianum* var. *insulare* are protected from feral animal activity by natural topography and the plant’s epilithic growth habit. Even though the endangered fern *A. peruvianum* var. *insulare* was found in only four lava tube openings at Kahuku, a large expanse of high-elevation subalpine habitat with numerous unsurveyed lava tubes remains in Kahuku, and these tubes may provide suitable habitat for this small fern. The relatively brief survey of Kahuku found the species in almost as many sites as are known in the older section of HAVO. The endangered fern is currently known from only 10-12 populations on Hawai`i and Maui (U.S. Fish and Wildlife Service 2006).

‘Ōhā wai, ‘ōhā (Clermontia lindseyana Rock)

‘Ōhā wai was documented in three sites at Kahuku. These were in mesic to wet ‘ōhi‘a forest in the eastern survey region along the park boundary with the Ka`ū Forest Reserve at 1,800 m to 1,900 m elevation. The observed plants were large and growing epiphytically on large-diameter ‘ōhi‘a. One plant had seedlings which were also epiphytic. ‘Ōhā wai is a new endangered species record for the park.

‘Ōhā wai has a wide distribution on Hawai`i Island, where it has been reported from eastern Mauna Kea and eastern, southeastern, and southwestern Mauna Loa at

elevations above 1,311 m (U.S. Fish and Wildlife Service 1996). Currently the species is protected within ungulate-free exclosures only within Hakalau Forest, Kūlani, and Kīlauea Forest in the eastern section of the species' range. The areas of Kahuku where ʻōhā wai were observed had extensive damage from pig activity and either feral cattle or mouflon browsing; and no terrestrial individuals were observed. Protection of the Kahuku/Ka`ū Forest population is important to the conservation of this species in the southernmost portion of its range.

Hāhā (Cyanea stictophylla Rock)

Hāhā was found in a large, unnamed pit crater in the central survey region in Kahuku at 1,000 m elevation. The surrounding forest was montane wet ʻōhiʻa/hāpuʻu with soil over large rock rubble substrate 1,500 to 3,000 years old. Two large plants with fruit were observed; hāhā was not found elsewhere in Kahuku. This is a new documented endangered species for HAVO.

Hāhā had a relatively wide range on Hawai`i Island in the past, but was recently estimated to persist with fewer than 20 natural individuals in three populations (U. S. Fish and Wildlife Service 1996). Like many lobeliads, hāhā plants are highly vulnerable to herbivory by large ungulates. Even though only two individuals were found in the deep and inaccessible pit crater, these plants represent an important contribution to the genetic diversity of this species.

Laukahi kuahiwi (Plantago hawaiensis (A. Gray) Pilg.)

Laukahi kuahiwi was observed at Kahuku in a scattered population of 73 plants at six sites along transect 24 above 1,800 m elevation. These sites were in subalpine ʻōhiʻa woodland on pāhoehoe lava flows dated 1,500-3,000 years old. In the older section of HAVO, two populations of laukahi kuahiwi have been documented above 1,800 m elevation in the upper Mauna Loa SEA growing in a similar habitat.

The relatively small numbers of laukahi kuahiwi individuals observed at Kahuku are only a tiny proportion of the more than 5,000 individuals thought to be present in at least eight populations on Hawai`i Island. The largest known population of the species was reported from Kapāpala adjacent to Kahuku on the east (U. S. Fish and Wildlife Service 1996), so it is possible that more laukahi kuahiwi plants will be discovered with additional surveys in the eastern reaches of Kahuku. High numbers alone, however, are not enough to prevent the loss of entire populations, as demonstrated by the disappearance of most of a population of 300 plants in Kīpuka Kulalio of HAVO's Mauna Loa Strip; the cause of the loss was unknown but may have been due to heavy winter rains (Belfield and Pratt 2002). While the plants at Kahuku did not show any sign of browsing, there was observed pig damage from rooting and digging throughout its habitat. A few plants appeared to be damaged by this activity.

Rare Native Plants: Candidate Endangered Species

Makou (Ranunculus hawaiiensis A. Gray)

A single population of eight makou plants was located along a roadside in Kahuku's western survey region. These plants were found in mesic koa/ʻōhiʻa forest at 1,870 m elevation on substrate of soil over `ā`a 1,500-3,000 years old. Much of the potential habitat available for makou in this area of Kahuku is dominated by the invasive alien meadow ricegrass. The makou plants were found growing in an open rocky area within the road corridor. This is a new candidate endangered species for the park. There

is also a recent historical specimen of makou from the east side of Kahuku (St. John 26820, BISH), which was collected 13 km northeast of the “Nene Cabin” in 1971, far removed from the current sighting.

The candidate endangered species makou is one of the rarest plants found at Kahuku. It is likewise rare throughout its range of Hawai`i and Maui, where the species is known from only five populations of <300 plants on both islands (U.S. Fish and Wildlife Service 2006). This species is particularly vulnerable to browsing and grazing from feral ungulates and from loss of habitat through alien plant invasion, primarily from alien grasses. Even though only one small population of this herbaceous species was found at Kahuku, these few plants are a significant addition to the very few plants recently observed in Ka`ū and Kona Districts. With protection, there are many potential sites at Kahuku for restoration or re-introduction of makou.

Rare Native Plants: Threatened Species

Hawaiian catchfly (Silene hawaiiensis Sherff)

A single Hawaiian catchfly was sighted in Kahuku’s eastern survey region, along transect 18 in subalpine ‘ōhi‘a woodland at 2,250 m elevation on old pāhoehoe substrate dating from 1,500-3,000 years old. Two other plants were reported at Kahuku, one from the area of transect 18 and another from within the silversword exclosure. None of the plants reported was observed bearing flowers or fruit. On a subsequent visit to the exclosure the plant could not be relocated, and we have incomplete information on the other sighting; these sightings were therefore not mapped.

The low number of sites supporting Hawaiian catchfly at Kahuku was surprising, since suitable habitat apparently was extensive throughout the subalpine zone of the eastern survey region. However, signs of long-term ungulate browsing were evident throughout this region, and mouflon sheep are known to seek out this plant. The plant located during the survey appeared to be re-sprouting leaf growth after having been browsed by mouflon sheep. In the older section of the park, mouflon sheep jumped the boundary fence and reduced one Hawaiian catchfly population to half its original size over a three-year period (Belfield and Pratt 2002).

The older sections of HAVO include important habitat for Hawaiian catchfly that are protected from goats and mouflon by fences. A large population of perhaps 5,000 plants is known from the Kīlauea caldera area, and a scattered population of ca. 1,500-2,000 plants has been reported within the Mauna Loa SEA (Belfield and Pratt 2002). Protection of subalpine habitat by fencing at Kahuku may result in the reappearance of Hawaiian catchfly there. If natural recovery does not occur, there will be many potential sites for re-introduction of this species to Kahuku. A small out-planting of this species is currently underway within the new silversword exclosure; the seed source was the Mauna Loa population of Hawaiian catchfly.

Rare Native Plants: Species of Concern

Ha`iwale (Cyrtandra menziesii Hook. & Arnott.)

This species of ha`iwale, a new SOC record for the park, was found at three Kahuku sites in ‘ōhi‘a/hāpu‘u forest between 800 and 1,000 m elevation. Individuals were present within the large unnamed pit crater on soils over large rock rubble substrate 1,500 to 3,000 years old. The species was also sighted within the smaller crater of Pu`u `Akihi

and in an adjacent forested ravine on soils over rock rubble substrate 3,000 to 5,000 years old. Pu`u `Akihi and the forested ravine had >10 to 50 individuals at each site. Plants ranged in height from 20 cm to 2.5 m, and most were observed with flowers and fruit in July. The varied class heights indicated reproduction was taking place. The pit crater and Pu`u `Akihi are not accessible to feral ungulates, but the forested ravine exhibited signs of pig activity and also encroachment by invasive weeds, particularly kahili ginger and strawberry guava.

ʻŌhelo papa (Fragaria chiloensis (L.) Duchesne subsp. sandwicensis Decne.)

ʻŌhelo papa, the native Hawaiian strawberry, was observed at 21 sites throughout Kahuku's eastern survey region. Plants were found on transects 3, 15, 18, and 21, where 567 plants were counted. The transect 3 site supported few plants in `ōhi`a woodland on substrates aged from 750 to 1,500 years old. ʻŌhelo papa was most abundant along transects 15, 18, and 21, where it was found growing on substrates 1,500 to 3,000 years old along the edges of old weathered ʻāʻa flows, on shallow soils over old pāhoehoe flows, and in lava tube entrances. A number of plants were located in open `ōhi`a woodland. This species did not seem to be a preferred browse plant for ungulates, but plants and habitat damaged by pig activity were noted. While ʻōhelo papa was listed in previous checklists of plants in the park, there were no collections or recent observations within the Mauna Loa Strip of the older section of HAVO, so Kahuku plants represent the only extant populations known from HAVO.

Hōʻawa (Pittosporum hawaiiense Hillebr.)

This relatively rare species of hōʻawa was located at eight sites in Kahuku in the eastern and central survey regions. Four sites spanned 12 km and elevations from 1,600 to 1,800 m in mesic to wet ʻōhiʻa forests and woodlands. These occurrences were on substrates ranging from weathered `ā`a aged 200 to 750 years (transect 3) to old weathered pāhoehoe (transects 9 and 12). Four additional hōʻawa were found in a forested ravine below Pu`u `Akihi at 850 m elevation in mesic to wet ʻōhiʻa/hāpuʻu forest on soils over rock rubble aged at 3,000 to 5,000 years. At two of these sites, young saplings and seedlings were present. Hō`awa is known from the `Ōla`a Forest Reserve adjacent to the `Ōla`a section of HAVO and possibly from the `Āinahou Ranch in HAVO, although evidence for the latter locality is a very incomplete specimen.

ʻĀkala (Rubus macraei A. Gray)

ʻĀkala was located at eight sites in Kahuku's eastern survey region, along transects 3, 9, and 15. Seven of these occurrences were on substrates of weathered `ā`a aged from 200 to 750 years, and one site was along an intermittent stream channel in an older pāhoehoe flow. All sites were within ʻōhiʻa woodland and forest, and all exhibited signs of feral pig disturbance. Plants taller than 20 cm were seldom observed, and no plant exhibited flowers, fruits, or sign of reproduction from seed. There was extensive potential habitat for this `ākala over the 12 km distance between transects 3 to 15, but no additional plants were observed during off-transect searches, or elsewhere in Kahuku. `Ākala was previously reported from the older section of HAVO along the Mauna Loa Strip (Fosberg 1966) in the 1960s but has not been observed there recently. A congeneric species, also known as ʻākala (*R. hawaiensis*), was encountered more commonly in forest and woodlands in Kahuku, and this also occurs in the older section of the park along the Mauna Loa Strip and within `Ōla`a Forest.

Sanicula sandwicensis A. Gray (No common name)

A small population of *Sanicula sandwicensis*, an herb with no common name, was found in Kahuku's western survey region. Less than 20 plants were found in native subalpine shrubland along the edge of a small kīpuka at 1,850 m elevation, on soil substrate over old pāhoehoe. Fruits were observed on some plants, indicating some level of reproduction. However, browsing pressure by mouflon sheep was high in this area, and plants were growing only within the cover of pūkiawe patches or in rocky areas where animals could not reach them. No additional plants were observed elsewhere in Kahuku. *Sanicula sandwicensis* was not known previously from Kahuku or from the older section of HAVO, and it is a new addition to the list of HAVO species of concern.

Mauʻu lāʻili (Sisyrinchium acre H. Mann)

This herb belonging to the Iris Family was found in most areas of Kahuku except the lower pasture lands and dry forest types. Mauʻu lāʻili was observed at 125 sites in Kahuku's western and eastern survey regions along transects 9, 12, 15, 21, 24, 36, and 42. The plant ranged from 1,780 m to 2,500 m elevation. Mau`u la`ili was found growing in varied substrates from old weathered ʻāʻa and pāhoehoe flows to meadows with developed soils; plants also grew along disturbed road corridors. Individual sites contained from one to 113 individuals. An off-transect search in Kahuku's eastern survey region found mau`u la`ili plants in many clumps of >20, totaling 1,540. Many plants were observed with flowers and fruits, and very few plants exhibited any browsing damage. Mauʻu lāʻili was previously known from the older section of HAVO in the upper Mauna Loa SEA.

Koli`i (Trematolobelia grandifolia (Rock) Degener)

A single koli`i was found growing on the floor of a large unnamed pit crater in the central Kahuku pastures at 1,000 m elevation. The forest type was ʻōhiʻa/hāpuʻu forest with soils over large rock rubble substrate 1,500 to 3,000 years old. Koli`i was also reported from forest in Kahuku's eastern survey region by the Forest Bird Survey team. However, no specific location record of that site is available, and the plant may have been beyond Kahuku's boundary in the Ka`ū Forest Reserve. Koli`i is distributed in the older section of HAVO in forests of ʻŌla`a, Kīlauea Crater Rim, and Kīlauea's East Rift.

Uncommon and Rare Plant Species

Hame (Antidesma platyphyllum H. Mann)

Hame was located in Kahuku's central region in a forested ravine below Pu`u `Akihi. Its habitat was mesic to wet ʻōhiʻa/hāpuʻu forest on substrate of soil over rock rubble. Eight trees were observed at the site; these ranged in height from 0.6-12 m and in diameter from 1-20 cm. All but one tree had heights lower than 2.5 m. The largest was a 12-m tall tree bearing flowers. The height and diameter ranges of this small population indicate some level of reproduction. This species of hame occurs in the `Ōla`a Forest and Kīlauea East Rift sections of older HAVO, where it is uncommon. Near Kahuku, hame is known from the Manuka Natural Area Reserve.

Paini`u (Astelia menziesiana Sm.)

At least 66 paini`u plants were sighted at nine sites on transects 9, 15, 18 in Kahuku's' eastern survey region from 1,900 to 2,200 m elevation. Plants were also noted on transect 33 in Kahuku's western survey region at 1,300 m, as well as within a large pit crater in central Kahuku at 1,000 m and in the silversword exclosure at 1,600 m

elevation. Extensive habitat of ‘ōhi‘a mesic to wet forest is available for paini`u from transect 9 to transect 18, particularly near the park boundary with Ka`ū Forest Reserve and at transect 33 in ‘ōhi‘a/hāpu‘u wet forest. All paini`u were growing epiphytically or were located within lava tubes, pit craters, or exclosures not accessible to feral ungulates. By contrast, paini`u grows terrestrially within the silversword exclosure, where ungulates have been excluded since the late 1970’s..

Paini`u is an important host plant for a rare native Hawaiian damselfly species (*Megalagrion koelense*), which utilizes water-filled leaf axils in its reproductive and life cycles. In the older section of HAVO, paini`u is a relatively common species in areas that have been fenced to exclude feral pigs and where alien plants are controlled, such as the Small Tract and Koa Unit sections of `Ōla`a Forest and forests of the Kīlauea summit.

Pāpala (Charpentiera obovata Gaud.)

Pāpala was rare at Kahuku. Only 12 large trees with diameters ranging from eight cm to 42 cm were found in a forested ravine below Pu‘u ‘Akihi in Kahuku’s central survey region, growing in wet to mesic ‘ōhi‘a forest on soils over rock rubble dated at 3,000 to 5,000 years old. Elevation of the population is 800 to 850 m. The presence of seedlings, saplings, and young trees indicates that this population has been reproducing despite pig activity observed in the area. In the original section of HAVO, pāpala is known from ‘Ōla`a Forest and Kīpuka Puaulu. The species has been out-planted in restoration projects at Kīpuka Kī, in mesic forests above Kīpuka Kī, and in the Soapberry bend area along the Mauna Loa Strip Road.

‘Ōhā wai (Clermontia clermontioides (Gaud.) A. Heller subsp. clermontioides)

‘Ōhā wai was seen in eastern Kahuku at five sites on transects 5 and 33, within the large unnamed pit crater, and in forest maintained for watershed protected by a fence from cattle grazing. The transect 5 site was mesic to wet ‘ōhi‘a forest; all other plants were in ‘ōhi‘a/hāpu‘u forest. Elevations for these sites ranged from 900 to 1,700 m on substrates 750-1,500 to 1,500-3,000 years old. Plant heights ranged from two to three meters, and flowering and fruiting were observed during the spring and summer. No seedlings or small plants were seen. All `ōhā wai were in sites not easily accessed by feral ungulates (e.g., fenced watershed, epiphytic on trees, pit crater). This species appeared on earlier plant checklists of the older section of HAVO (Fosberg 1966) under the synonym *C. coerulea* , but no herbarium or living specimens have been found to confirm the plant’s presence, and we consider Kahuku’s ‘ōhā wai to be a new addition to the park’s flora.

‘Ōhā or ‘Ōhā wai (Clermontia montis-loa Rock)

This species of ‘ōhā was documented in Kahuku’s eastern survey region at five sites on transects 15 and 33, as well as at two off-transect sites. All but one sighting occurred within ‘ōhi‘a/hāpu‘u forest; the exceptional transect 15 site was in mesic to wet ‘ōhi‘a forest. Elevations for these sites ranged from 900 to 1,800 m on substrates 1,500-5,000 years old. Plant heights ranged from 2.5 to 4 m. Plants were observed in flower and fruit and were primarily epiphytic. As with other *Clemontia* species in Kahuku, all ‘ōhā were in sites relatively inaccessible to feral ungulates.

Hāhā (Cyanea pilosa A. Gray subsp. unknown)

Hāhā was found growing on the floor of a large unnamed pit crater located in Kahuku's central survey region, surrounded by pasturelands at 1,000 m elevation. The forest type was ʻōhiʻa/hāpuʻu with soils over large rock rubble substrate 1,500 to 3,000 years old. Numerous plants (50-100) were observed, and many bore flowers. No voucher collection was made, and the subspecies remains undetermined. If pit crater plants represent subsp. *pilosa*, this is a new record for Kaʻū District (Jon Price, USGS, pers. comm., 2005). *Cyanea pilosa* subsp. *longipedunculata* occurs in the older section of HAVO at ʻŌlaʻa Forest and formerly was found in the vicinity of the Thurston Lava Tube. No additional hāhā was observed elsewhere in Kahuku during the inventory.

Heau (Exocarpos menziesii Stauffer)

Heau was observed in Kahuku's eastern survey region along transects 3 and 9 on weathered pāhoehoe substrates dated 1,500 to 3,000 years old. The plant's habitat was subalpine ʻōhiʻa woodland at 1,800 m elevation. Over 200 plants were observed at these sites; more than half the plants were flowering or fruiting. Basal diameters ranged from four to 26 cm. As these are slow growing plants, basal diameters in this range indicate significant longevity. At one plant, the rare native koa bug (*Coleotichus blackburniae*) was seen feeding on flowers. Scattered individuals and small groups of plants were noted in the central survey region of Kahuku along the boundary with HOVE on the same age substrate and forest type. The western population extended into HOVE to 1,524 m elevation. Though bark girdling was observed on some plants, this species did not appear to be a preferred browse plant of ungulates. Damaged fruits were noted at some plants, suggesting rat predation may be a problem for heau.

Heau is rare in the older section of HAVO, where only 11 individuals are known from the Mauna Loa SEA. At Kahuku the numbers of heau are more robust and the plant seems well distributed locally in some subalpine woodland and shrubland communities.

Nohoanu, hinahina (Geranium cuneatum Hook. subsp. cuneatum, G. cuneatum subsp. hypoleucum (A. Gray) Carlq. & Bissing)

Two subspecies of nohoanu or native geranium were observed at Kahuku. Subspecies *cuneatum* was found rarely in Kahuku's western survey region, whereas subspecies *hypoluecum* was more frequently noted in the eastern survey region. Subsp. *hypoleucum* occurred at 43 sites along transects 9, 18, 21, 24, and 42 in ʻōhiʻa woodland on substrates of old weathered ʻāʻa and pāhoehoe dating from 750 to 3,000 years old. No plant taller than 10 cm was observed along the survey transects. Both subspecies appeared to be aggressively browsed by mouflon sheep. This species was also present in the silversword exclosure where it was observed growing to its full height, flowering, fruiting, and reproducing. This suggests that intense browsing pressure is limiting populations of nohoanu in Kahuku's ʻōhiʻa woodlands and subalpine communities. The subspecies *hypoleucum* is known from the Mauna Loa Strip of HAVO, but subsp. *cuneatum* is an addition to the flora of HAVO.

Manono (Kadua affinis DC, formerly Hedyotis terminalis)

Manono, normally a common tree species, was located at Kahuku at only four sites. Three sites were within a forested ravine below Puʻu ʻAkihi at 800-850 m elevation. Trees were growing on a substrate of soil over weathered rock rubble aged 3,000 to 5,000 years old within a mesic to wet ōhiʻa/hāpuʻu forest. Another tree was found at 1,200 m elevation in ʻōhiʻa/koa woodland on a substrate of soil over weathered ʻāʻa

aged 1,500 to 3,000 years. Trees ranged in heights from two to six m, and two trees were observed flowering. Manono is known from the older section of HAVO at Kīlauea's East Rift, `Ōla`a, Kīpuka Kī, and Kīpuka Puaulu. Only two natural individuals persist at Kīpuka Kī and Puaulu, sites with a former grazing history.

Hesperocnide sandwicensis (Wedd.) Wedd. (No common name)

Hesperocnide sandwicensis was seen at two sites in Kahuku's northwestern survey region. One small population of >10 plants occurred in ʻōhiʻa woodland forest at 2,000 m elevation on a substrate aged 3,000 to 5,000 years. The other site was in ʻōhiʻa woodland at 2,500 m elevation (transect 42) on a substrate aged 1,500 to 3,000 years. Both sites were heavily impacted by sheep browsing. *Hesperocnide sandwicensis* is an annual or semi-annual which produces a large quantity of seed, and its numbers may fluctuate seasonally. Belonging to the Nettle Family (Urticaceae), individuals are armed with stinging hairs on leaves; these may be a deterrent to browsing by animals present in the area. This species was not known from the older section of HAVO and is an addition to the park's flora.

Pala (Marattia douglasii (C. Presl) Baker)

Pala fern was observed at four sites in Kahuku's central survey area: in the large unnamed pit crater, a lava tube, at the Pu`u `Akihi crater, and within a forested ravine below Pu`u `Akihi. All sites were located in ʻōhiʻa/hāpuʻu forest with well-developed soils over large rock rubble. Elevations ranged between 900 m and 1,200 m elevation. Plants were growing on steep slopes in the ravine and in craters protected from feral ungulates and domestic cattle. Frond heights measured greater than 2.5 m. At the lava tube site and Pu`u `Akihi more than 20 individual pala ferns were noted in multiple height classes, indicating reproduction. Pala is known from the older section of HAVO within`Ōla`a Rainforest, where it is uncommon but conspicuous in exclosures protected from ungulates.

Alani (Melicope clusiifolia A. Gray)

Alani (*Melicope clusiifolia*) was located at two sites along transect 33 in Kahuku's central survey region. Its habitat was ʻōhiʻa/hāpuʻu forest at 900-950 m elevation on soil over pāhoehoe aged 1,500 to 3,000 years. One fertile tree measured five m in height and 16 cm in diameter. HAVO Resources Management personnel reported more than 10 additional trees in the central pastures, where their capsular fruit was collected for restoration projects at Kahuku. Alani is common in the Kīlauea section of HAVO, particularly in Kīlauea's East Rift forests.

Alani (Melicope radiata St. John)

This species of alani was found at a single site in the central survey region in a forested ravine below Pu`u `Akihi at 860 m elevation. Vegetation here was wet to mesic ʻōhiʻa forest on soils over old rock rubble (3,000 to 5,000 years). The tree had a height of four m and a diameter of four cm and was bearing flowers. This alani was also observed along the Kahuku boundary with Manuka Natural Area Reserve. The species is locally common in the older section of HAVO at Kīpuka Puaulu, Kīpuka Alani, and in forests of the Kīlauea's East Rift.

Kōlea (Myrsine lanaiensis Hillebr.)

This species of kōlea was documented at three sites in the southwestern survey region between 650 m and 667 m elevation. The tree's habitat was dry ʻōhiʻa woodland

on `ā`a substrate dating 1,500 to 3,000 years old. There were 36 trees ranging in height from four cm to eight m, and old fruit was observed on some of the larger trees. The largest tree diameter measured 26 cm. Presence of small height classes at these sites indicated reproduction. Some of the larger trees exhibited evidence of past bark girdling by feral ungulates. This species was previously known from the older section of HAVO at a single population downslope of the `Āinahou Ranch house.

Phyllostegia ambigua (A. Gray) Hillebr. (No common name)

Phyllostegia ambigua was only found growing within a large unnamed pit crater in Kahuku's Central survey region at 1,000 m elevation. Another unidentified *Phyllostegia* sp. was also collected in the pit crater. The forest type here is ʻōhiʻa/hāpuʻu with soils over large rock rubble substrate 1,500 to 3,000 years old. Numerous plants were observed in flower and fruit. *Phyllostegia ambigua* is known from the older section of HAVO at only one site in `Ōla`a Rainforest.

Pōpolo kū mai (Phytolacca sandwicensis Endl.)

Pōpolo kū mai was observed at three sites along transect 33 in the eastern survey region of Kahuku between 1,100 m and 1,300 m elevation. Its habitat was ʻōhiʻa/hāpuʻu forest on substrates 1,500 to 3,000 years old. Plants ranged in width from 2.5 m to five m. Two plants were in vegetated or elevated areas relatively protected from cattle and feral ungulates; seedlings were observed at these sites. One plant appeared severely grazed and was in poor condition. Where pōpolu kū mai grew epiphytically and within a thicket of blackberry, it had no browsing damage and was reproducing with flowers and fruits. Terrestrial plants were heavily browsed and lacked flowers, fruit, or seedlings. Pōpolo kū mai has been found rarely in the older section of HAVO in several units of `Ōla`a Rainforest and in mesic forest of Kīpuka Aiea and Kīpuka Kī.

Hōʻawa (Pittosporum confertiflorum A. Gray)

Hōʻawa was found at a single site along the upper area of transect 24, above 1,800 m elevation in subalpine ʻōhiʻa woodland on an old pāhoehoe lava flow. The plant was observed with fruit. Hōʻawa has been previously documented in HAVO's older section above 1,800 m elevation in the upper Mauna Loa SEA in a similar habitat, and more recently has been observed in lowland mesic forest below the East Rift SEA (McDaniel, HAVO-RM, pers. comm., 2005). At Kahuku, extensive subalpine habitat exists for species recovery should ungulates be excluded.

Hōʻawa (Pittosporum hosmeri Rock)

Hōʻawa was documented at six sites, each with a single tree. Two trees were located off transect in a small kīpuka at 1,600 m elevation in koa/ʻōhiʻa woodland forest on soil over old `ā`a (3,000 to 10,000 years). Four trees were seen along transect 33 at 1,300 to 1,350 m elevation in ʻōhiʻa/hāpuʻu forest on substrates of soil over pāhoehoe (1,500 to 3,000 years). Trees ranged in height from five to nine m with diameters of five to nine cm. All trees were observed with fruit, and one in koa/ʻōhiʻa forest had both fruit and flowers. Hō`awa fruits exhibited severe seed predation from rats, with most capsules eaten through and completely devoid of seeds. Wagner et al. (1999) noted that *P. hosmeri* and *P hawaiiense* are very closely related, differing in the less conspicuous reticulate leaf venation and the larger tomentose (covered with matted hairs) capsules of the former. The species apparently hybridize where they grow together, and some of the trees at Kahuku may prove to be hybrids.

Hō‘awa (Pittosporum terminalioides Planch. ex A. Gray)

Only one hō‘awa of this species was seen in Kahuku in the southwestern survey region at 659 m elevation in dry ‘ōhi‘a woodland on weathered `ā`a substrate (1,500 to 3,000 years old). The tree was five m in height, and no flowers or fruits were observed. Hō‘awa is known from the older section of HAVO at numerous sites along the western boundary adjacent to Kapāpala Ranch, and trees have also been observed in the eastern lowlands near Paliuli.

Pāwale (Rumex giganteus W.T. Aiton)

Only five pāwale plants were located at four sites in Kahuku. Four plants were growing along transect 33 at 1,400 m elevation in Kahuku’s central survey region, and one plant, exhibiting browse damage, was found on transect 31, two km away. The eastern plants were in wet ‘ōhi‘a/hāpu‘u forest, and the western plants were in mesic ‘ōhi‘a/koa woodland. Both sites have soil over pāhoehoe aged 1,500 to 3,000 years. Plant lengths ranged from two to 15 m, and all plants bore old fruit. The site on transect 33 supported more than 10 seedlings beneath one plant. This species of pāwale is uncommon in the older section of HAVO at `Ōla`a Forest, Kīpuka Aiea, Mauna Loa SEA, and woodlands near Pu`u Puai.

‘Iliahi or Sandalwood (Santalum paniculatum Hook. & Arnott. var. pilgeri (Rock) Stemmermann and S. paniculatum var. paniculatum)

One large `iliahi population (> 50 trees) and nine smaller groups were found in Kahuku. Two varieties were represented; *Santalum paniculatum* var. *pilgeri* occurred at seven sites in western and southwestern Kahuku, and *Santalum paniculatum* var. *paniculatum* was located at the remaining three sites in eastern Kahuku.

Kahuku’s largest ‘iliahi population was found during off-transect surveys along the Kahuku/Ka`ū Forest Reserve boundary. This population of over 50 mature trees grew in mesic ‘ōhi‘a forest near transect 3. These were also the largest ‘iliahi trees observed in Kahuku. ‘Iliahi was located at two additional sites in eastern Kahuku along transect 3 at 1,680 and 1,780 m elevation in ‘ōhi‘a/pūkiawe subalpine woodland and closed-canopy, transitional ‘ōhi‘a forest. These sites had substrates of weathered pāhoehoe dating at 200-3,000 years old. At the lower-elevation woodland site, seven trees were counted, with heights ranging from four to six m. Flowers and fruit were observed, as was old bark girdling from feral ungulates and recent damage to seeds by rat predation. This ‘iliahi variety occurs in several habitats in the older section of the park, from dry lowlands to subalpine forest and woodlands.

In the western survey region, four ‘iliahi sites were near 660 m elevation in dry ‘ōhi‘a woodland on `ā`a substrate. One site was in dry ‘ōhi‘a/`a`ali`i woodland at 840 m elevation (transect 31) on `ā`a substrate, and two sites were at Pu`u `Ōhohia near 1,680 m in a substrate of cinder over soil. All western sites were on substrates dated at 1,500 to 3,000 years. Trees were four to six m in height, and most had flowers and young fruit. The Pu`u `Ōhohia site is adjacent to the boundary of the Manuka Natural Area Reserve, within which an additional 10 young trees and seedlings were sighted. *Santalum paniculatum* var. *pilgeri* is a new record for HAVO.

‘Iliahi, also known as sandalwood, may have been formerly more abundant in Kahuku. Seeds and saplings are heavily predated by rats and browsed by ungulates. Historical records indicate sandalwood trees were taken for commercial purposes in

Kahuku between 1790 and1840, although precise numbers and locations are unknown (Avery 2006).

Naupaka kuahiwi (Scaevola chamissoniana Gaud.)

Naupaka kuahiwi was documented at five sites in Kahuku. Seven plants were noted on the edge of Pu`u `Akihi Crater on elevated rocky outcrops below the hill and at the edge of a forested ravine below Pu`u `Akihi. The shrub species occupied a transitional forest type of ʻōhiʻa/uluhe on soil over cinder and rocky substrates aged 3,000 to 5,000 years. Plants measured 1.5 to 3.0 m in height and had both flowers and fruits. Naupaka kuahiwi is common in the Kīlauea section of HAVO, where it occurs in forest of the East Rift and east of the park along Highway 11. At Kahuku the species appears to be restricted to the Pu`u `Akihi area. Several plants were observed with browsed leaves, but most were protected from feral ungulates by inaccessible habitat.

ʻOhe (Tetraplasandra hawaiensis A. Gray)

Six `ohe trees were found within 100 m of each other, east of Pu`u `Akihi in pastureland with scattered stands of ʻōhiʻa and hāpuʻu on soil over old pāhoehoe at 900 m elevation. Tree heights ranged from eight to 12 m, and diameters were large (32-60 cm) indicating great age. All the trees exhibited robust flowering and fruiting. No seedlings or saplings were observed at these grassy sites. Bark girdling by feral ungulates and cattle was apparent at the base of all the trees. Wagner et al. (1999) reported the elevation range of *T. hawaiensis* at 150 to 800 m, which would place the Kahuku trees at their upper elevational limit.

In the older section of HAVO, this species of `ohe is found rarely in forests of Kīlauea`s East Rift, and trees formerly occurred near Nāulu. Many areas that formerly supported the tree have been covered by recent lava flows or affected by wildfires generated from Mauna Ulu and Pu`u `Ō`ō eruptions.

Olonā (Touchardia latifolia Gaud.)

Olonā was observed in a single site in a forested ravine below Pu`u `Akihi at 800 m elevation on a substrate of soil over weathered rock rubble aged 3,000 to 5,000 years old. Vegetation here was mesic to wet ʻōhiʻa/hāpuʻu forest. This large patch of olonā had more than 100 stems (in an area approximately 25 m^2). Male flowers were noted on plants, which are likely reproducing and expanding through vegetative growth. This site was also invaded by the weedy night cestrum, which has since been controlled.

Olonā is uncommon in the older section of HAVO, where it is known from `Ōla`a Rainforest. At Kahuku this species exhibits exceptionally large, broad leaves. Wagner et al. (1999) noted that plants in the Kīlauea area have narrowly elliptic to elliptic-lanceolate leaves, a form that was described as *T. angusta* by St. John. There are parallel morphological patterns between olonā and ōpuhe (*Urera gl*abra) at Kahuku, and the species are similar in appearance.

Ōpuhe (Urera glabra (Hook. & Arnott.) Wedd)

Only one ōpuhe plant was found growing within a large unnamed pit crater located in the central Kahuku pasturelands. The forest type here is ʻōhiʻa/hāpuʻu with soils over large rock rubble substrate. Ōpuhe is uncommon in the park at ʻŌla`a and in forests of Kīlauea's East Rift; the tree is extremely rare in mesic forests of Kīpuka Puaulu, Kīpuka Kī, and Kīpuka Aiea.

Historical Records of Rare Plants at Kahuku

At least three endangered plants, two SOCs and eight other rare or uncommon species occurred in or near Kahuku in the past, but were not found during the present inventory. Our knowledge of the past distribution of rare plant species is based on herbarium specimens and published accounts. A search of specimen records at Bishop Museum Herbarium in Honolulu (locality=Kahuku) carried out at the request of the NPS Inventory and Monitoring Program provided us with locality information placing specimens near or within Kahuku.

Neraudia ovata, an endangered shrub in the Nettle Family, was collected once at Kahuku on an `ā`a flow at 457 m elevation (L. W. Bryan, sn, 1956, BISH). Because of the lack of detail on the specimen label, it is not certain that the plant was actually growing within the Kahuku addition of HAVO. If the elevation recorded on the label is accurate, than the specimen was collected downslope of Highway 11 and outside of the park. Nonetheless, there remains much suitable habitat for this species at Kahuku. Similarly, the endangered halapepe tree (*Pleomele hawaiiensis*) has been observed several times near Kahuku. One specimen at the National Museum of Natural History was collected at Pu`u Kamaoa, 6.4 km west of Kahuku and 0.8 km east of HOVE King Kamehameha Ave (Meinecke, sn, 1975, USNM). This site was probably outside the current boundary of the Kahuku addition; however, appropriate habitat for this species exists in kīpukas near the 1887 flow within the lower central portion of Kahuku. A third endangered species documented from Kahuku is the mint *Stenogyne angustifolia*. This herbaceous vine was collected by A. Meebold (#20866, BISH) in 1935 at an unspecified location on the ranch. Natural populations of this mint are currently restricted to relatively high elevation sites at Pohakuloa Training Area, but it was clearly more widely distributed in the past. The mint was also collected in 1868 at a site between Kīlauea and Kapāpala (Sherff 1935). The proximity to the park of that 1868 collection led park managers to introduce the species to the Mauna Loa Strip of HAVO.

Kauila (*Alphitonia ponderosa*), is a rare dry forest tree now considered a SOC. This tree was collected in or near Kahuku at least five times between 1946 and 1974. St. John (#22445, 1946, BISH) made a specimen of kauila on the 1887 lava flow, and Herbst and Ishikawa (#5066, 1974, BISH) later collected it at HOVE adjacent to the park. This tree may persist within unsurveyed dry woodlands of Kahuku, and natural plants occur in adjacent HOVE. Also reported from the 1887 lava flow at Kahuku was the SOC *Portulaca villosa* or `ihi, which was collected in 1946 by D. P. Rogers (sn, BISH). Because this herb is typically a coastal species and the 1887 lava flow extends to the sea, this record of *P. villlosa* may actually be from a site far outside the Kahuku addition.

Other rare or uncommon plants formerly collected in or near Kahuku but not observed on this survey include four trees or shrubs typical of dry forests. Maua (*Xylosma hawaiiense*) was noted at Kahuku by Joseph Rock in 1917, and a`ai`a (*Streblus pendulinus*) was found by Meebold in 1935. Locality information is lacking to place either tree at a specific site, but a roadside maua has been found recently in a subdivision below HOVE, Hawaiian Ranchos (Benitez pers. obs). `Ala`a (*Pouteria sandwicensis*) was collected twice (1935, 1964) at Pu`u Kamaoa just south of the southeastern corner of HOVE near the current boundary of the Kahuku addition. Naupaka kuahiwi (*Scaevola gaudichaudii*), an uncommon shrub of dry to mesic woodlands, was collected on an `ā`a flow at Kahuku by L. W. Bryan in 1956; the label

elevation of ~457 m places the site downslope of Highway 11 just outside the Kahuku addition.

Two rare species of upper elevation bogs have been reported from Kahuku. Laukahi kuahiwi (*Plantago pachyphylla*), a terrestrial herb very uncommon on Hawai`i Island, was collected in 1966 by Carlquist (#2106, BISH) at 1,525 m elevation on the southwestern slope of Mauna Loa at Kahuku. There are only three specimens of this laukahi species from Hawai`i Island in the Bishop Museum Herbarium (Wagner et al. 1999). On the eastern side of Kahuku, at 1,830 m elevation above Wood Valley, F. R. Warshauer made a specimen of the endemic violet *Viola maviensis* during the Hawai`i Forest Bird Survey in the late 1970s. These populations were not relocated during the inventory, and additional field surveys that focus on these specialized bog communities may be needed to determine if these species persist in the park.

A few apparently uncommon species of the upper eastern slopes of Kahuku are documented by specimens at the Bishop Museum Herbarium but were not seen during the current survey. One of these is *Vaccinium dentatum* or `ōhelo; this shrub was collected at Kahuku above 1,966 m elevation in 1928 (G. W. Russ, sn, BISH). Although not generally considered to be a rare or uncommon species (Wagner et al. 1999), this `ōhelo is not widely distributed on the island and has not previously been observed in HAVO. One relatively uncommon fern, *Dryopteris sandwicensis*, collected at 1,829 elevation in eastern Kahuku near the "Nene Cabin" by St. John in 1971 is also a potential addition to the park's flora. The fact that these uncommon plants, as well as several common fern species, were formerly present in eastern Kahuku (Appendix B) but were not encountered during field surveys indicates that more intensive work here would likely result in a larger species list for the addition.

New Park Records

New records of native plants for HAVO include three endangered and six SOC or rare species encountered during the survey and discussed above. Six of the historical herbarium collections detailed in the previous section also represent additions to the known flora of the Park (*Streblus pendulinus*, *Scaevola gaudichaudii*, *Vaccinium dentatum*, *Dryopteris sandwicensis*, *Plantago pachyphylla,* and *Viola maviensis*); it is possible they are no longer extant within Kahuku. In addition to these, five native species found at Kahuku during this survey are also new or confirmed records for HAVO. Ka`upu fern (*Polystichum hillebrandii*) was observed in koa woodlands within kīpuka on the west side of Kahuku. This fern was formerly known from HAVO only as an historical record from an uncertain locality. Other records for the Park are an endemic annual panicgrass (*Panicum konaense*); a parasitic hulumoa (*Korthalsella remyana*) collected on a host `ōhi`a tree in a kīpuka near the 1887 flow; pāmoho (*Asplenium excisum*), an indigenous terrestrial fern sighted only within the deep pit crater of the central pasturelands; and lastly, *Carex meyenii*, an indigenous sedge found growing in large clumps within the eastern central pastures of Kahuku.

Discussion of Rare Native Plants at Kahuku

Despite more than 100 years as a cattle ranch, Kahuku provides habitat for at least six endangered or threatened species, as well as a candidate endangered plant, seven species of concern, and numerous species rare in the park or on the island. The distribution of rare plants occurred throughout all vegetation zones and in many different habitat types from low elevation dry forest to high-elevation subalpine woodlands. Rare

plants were documented on 15 of the 21 transects surveyed. Of the 399 records for rare plants made during this survey, 171 or 43% were located off transects. High areas of rare plant diversity were those protected from feral ungulates due to their natural topography, such as the large unnamed pit crater located in central Kahuku and the interior crater of Pu`u `Akihi. Although only partially protected by topography, an associated ravine near Pu`u `Akihi also contained a high number of rare tree species. Other areas of diversity were high-elevation subalpine woodlands in the remote areas of east Kahuku where *Apslenium peruvianum*, `ōhelo papa, laukahi kuahiwi, Hawaiian catchfly, and mauʻu lāʻili were found.

Invasive animals and plants continue to jeopardize the long-term presence of native plants and communities in Kahuku. Domestic cattle and feral mouflon, goats, and pigs, browse, graze, bark strip, uproot, and trample plants. Native species which are particularly palatable to ungulates may be extirpated becuase of intense browsing pressure, and other native species may not have adaptations that allow them to recover from trampling and bark stripping. These disturbances may facilitate the invasion of alien plants, which in turn may alter soil chemistry, water availability, and fire regimes (Smith 1985). The introduction of alien insects is also a serious concern and may lead to additional losses of native flora and fauna, as alien insects can be significant vectors of bird diseases and plant pathogens. The combined impacts of alien ungulates, invasive plants, and introduced insects represent significant potential limiting factors for native plants, as well as the native birds and insects that depend on them.

Feral ungulate damage was ubiquitous throughout all survey regions. During the inventory, a diverse set of habitat types was visited, and no area or habitat was without signs of animal activity except inaccessible pit craters, interior craters of tephra cones, deep cracks, fissures, and lava tubes.

Rats are known to be a significant limiting factor to native plants in Hawai`i (Stone 1985), and their impacts to native plants were noted in Kahuku. Rats were first introduced to Hawai`i by Polynesians and later by Europeans. There are three species of rat present in Hawai`i: the black rat (*Rattus rattus*), the Polynesian rat (*R. exulans*), and the Norway rat (*R. norvegicus*). Studies of rats conducted in Hawaiian rainforests indicate that the black rat appears to be the most abundant species, followed by the Polynesian rat, and finally the Norway rat (Lindsey et al. 1999). Rats are pervasive in all habitats and ecological zones in Hawai'i and are known to damage a wide range of native plant species. Rats limit reproduction of plants by consumption of mature fruit and seed and through girdling stems and branches, an activity which can cause the direct mortality of seedlings and saplings and reduce the ability of mature plants to produce flowers and fruit. Rats were not the focus of this inventory, but incidental observations of rodent damage to the seeds and fruit of rare plants, such as ho`awa species, sandalwood, and heau, indicate that rodent depredation is a topic for future monitoring and management.

Sixty-seven percent of the rare species present at Kahuku occurred with less than fifty known individuals. Some species were even rarer; makou (eight individuals) and Hawaiian catchfly (three individuals) had fewer than 10 representatives, and two species of hō`awa (*Pittosporum confertiflorum* and *P. termnalioides*) were found as single individuals. Natural reproduction of these species also appeared to be limited. Only 31%, or 13 of the 42 rare plant species, were observed with seedlings and saplings, were represented by more than one size class, or appeared to be reproducing vegetatively.

With one exception, no rare plant species at Kahuku was documented with more than 20 seedlings or five saplings. The lone exception was the widespread herb mauʻu lāʻili, which had large numbers of seedlings present.

There are seven rare native species, which herbarium records indicate occurred at Kahuku but were not located during our botanical survey: *Neraudia ovata*, halapepe (*Pleomele hawaiiensis*) and *Stenogyne angustifolia* (endangered); kauila (*Alphitonia ponderosa*) and `ihi (*Portulaca villosa*) (SOCs); and maua (*Xylosma hawaiiense)* and a`ai`a (*Streblus pendulinus*) (locally rare with no formal listing). All of these species are known to be susceptible to ungulate activity and could be eliminated over time under intense browsing pressure, displaced by invasive alien plants, or destroyed by human alteration of their habitats (e.g., forest conversion, road building).

Management Considerations for Rare Native Plant Species

This plant inventory represents a first look into the native plant resources in Kahuku. Additional surveys may be needed to more accurately determine the presence of rare species, including their range extents and population structure in the area. Priority for these more intensive surveys would best be given to diversity "hotspots," areas with high biological diversity, and to habitats that share similar characteristics (e.g., substrate age and type, rainfall, elevation, vegetation type) to those where rare plants were located. This information, combined with concurrent inventories for birds, insects and invasive plants and animals, can provide the framework for identifying high priority areas in urgent need of management based on their high biological diversity, rarity, and immediate risk from alien species, as part of a comprehensive management strategy for protecting biological resources in Kahuku.

While information on biological resources continues to be gathered, there are management actions that can be taken now that will assist the long-term persistence of native plants and communities in Kahuku. Such actions are suggested based on the results from this current plant inventory, recovery efforts ongoing in the older section of HAVO, and reported successes in management of state and private conservation lands facing similar issues in Hawaii. These actions include:

- Cessation of cattle ranching in the near future
- Fence construction and removal of feral and domestic ungulates
- Selective control of invasive alien plants
- Reintroduction or augmentation of key native plant species
- Rare plant restoration
- Visitor access, interpretation, and educational programs.

At lower elevations, domestic cattle, feral mouflon, and pigs continue to erode the forest fragments remaining in the paddock system. These fragments provide important habitat for rare native plants and, along with relictual native trees present in the pasture, serve as important source material for future forest regeneration. Because of edge effects and continued browsing pressures, the persistence of these fragments is precarious.

HAVO has a successful long-standing program of fencing and ungulate removal and control since the 1970s. Parkwide eradication of feral goats, which began in 1970 and was followed by exclusion of feral pigs in the 1980s, has allowed for the recovery of koa

forest and selected rainforest, montane, subalpine and lowland habitats. In the 1980s the Special Ecological Area (SEA) concept was adopted by Hawai`i Volcanoes National Park as a strategy for focusing feral animal and invasive alien plant control on the most intact ecosystems remaining in the park. Areas were selected on the basis of the rarity and exemplary nature of the vegetation type, vegetation intactness, plant species diversity and richness, manageability of alien plants and animals, presence of rare and endangered species, preserve design considerations, immediacy of threats from alien plants, research potential, and interpretive values (Tunison and Stone 1992).

Beginning in 2001 through 2006, four large-scale restoration projects have been completed in the original park: koa forest restoration in the "Soapberry Bend" area between Kīpuka Puaulu and Kīpuka Kī, restoration of burned areas along the lower Mauna Loa Strip Road, Pānau Iki in the East Rift, and Pepeiau in the southwest lowlands of the park. These projects utilize common native species as out-plantings and broadcast seed, and they have been highly successful in restoring common native species to degraded and burned areas. Since 2001, the park has also successfully propagated and out-planted over 60 rare native species in coastal strand communities, dryland, mesic forest and woodland, subalpine, and rainforest habitats. Many of the restoration techniques utilized in these projects are applicable in Kahuku.

Several projects have already been completed or are on-going at Kahuku which suggest the potential success of large-scale vegetation recovery if ungulates are removed. In 2003, a 16-km-long barrier fence was constructed along the western Kahuku park boundary, and an aggressive feral ungulate removal program was initiated. A koa recovery study conducted in this area in 2002-2005 indicated that koa was recovering in the study area, and an increase of woody native shrubs and trees was also noted (Loh et al. 2005). In central Kahuku, an on-going project is testing several treatment strategies for converting pastureland back to forest in ungulate-proof fenced exclosures. Within the exclosures, natural regeneration of native forest species is augmented by direct out-planting and seed broadcast of native species in combination with site manipulations to temporarily suppress pasture grasses (by herbicide application or soil scarification). In scarified plots, abundant regeneration of koa seedlings from the natural soil seed bank appears in less than six months following ungulate exclusion (McDaniel, HAVO-RM, unpublished data.).

Until ungulates can be removed throughout Kahuku, preserving genetic source material of vulnerable native species must remain a concern for managers. Refugia provided by small fenced exclosures, such as the silversword exclosures and those located in the central pastures, may be considered for out-planting of rare species with critically low numbers (e.g., *Cyanea* spp., *Phyllostegia* spp., *Clermontia* spp.). Currently, five rare species are under propagation at the park's nursery for out-planting into exclosures: hāhā, makou, *Phyllostegia ambigua*, Hawaiian catchfly, and mauʻu lāʻili. Exclosure out-planting would be an interim measure until large areas can be fenced and ungulates removed from Kahuku.

Within the central Kahuku region, there are two sites, which because of their biological diversity, rarity, and minimal requirements to exclude invasive species, could already function as Special Ecological Areas. Located in lower eastern and central Kahuku, both sites are easily accessible and would allow for a high degree of interpretation through local educational programs and field programs for visitors. The first is the interior of Pu`u `Akihi crater and the large associated ravine. This site has a

high level of rare plant diversity of species found in wet to mesic type forests. Cattle are not able to access the crater or ravine, but pig damage is widely evident and appears to be limiting regeneration of some native species. Strategic placement of fence segments to cut off feral pig access to the ravine and crater, along with selective removal of kahili ginger, will stabilize the area from further deterioration by invasive species. The second potential SEA is a dry forest habitat. Located in the lower southwest part of central Kahuku, the area supports a relictual dry `ōhi`a-lama forest and the only stands of dryland kolea and ho`awa found at Kahuku. It is also an ideal site for restoration of those dry forest species now thought to be locally extinct at Kahuku, such as halapepe and *Neraudia ovata*. In lieu of larger-scale fencing projects, these potential SEA projects would achieve much for rare plant stabilization and re-introduction in the short term by providing sources of seed and propagation material for future larger-scale projects.

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APPENDIX A. CHECKLIST OF VASCULAR PLANTS OF THE KAHUKU ADDITION, HAWAI`I VOLCANOES NATIONAL PARK

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
FERNS													
ASPLENIACEAE	*Asplenium adiantum-nigrum* L.	`Iwa`iwa	I		C	Fern		x	x				
ASPLENIACEAE	*Asplenium excisum* C. Presl	Pamoho	I	RARE	R	Fern	x						
ASPLENIACEAE	*Asplenium peruvianum* Desv. var. *insulare* (C. V. Morton) D. D. Palmer	None	E	END	R	Fern		x					
ASPLENIACEAE	*Asplenium polyodon* G. Forst.	Punana manu	I		U	Fern	x	x		x			
ASPLENIACEAE	*Asplenium trichomanes* L. subsp. *densum* (Brack.) W. H. Wagner	`Oali`i	E		C	Fern		x	x				
ASPLENIACEAE	*Asplenium* sp.	Unknown	I?		R	Fern				x			
ATHYRIACEAE	*Athyrium microphyllum* (Sm.) Alston	`Akolea	E		C	Fern	x	x		x			
ATHYRIACEAE	*Deparia petersenii* (Kuntze) M. Kato	None	A		U	Fern		x		x			
ATHYRIACEAE	*Diplazium sandwichianum* (C. Presl) Diels	Ho`i`o	E		U	Fern	x	x		x			
BLECHNACEAE	*Blechnum appendiculatum* Willd.	None	A		U	Fern				x			
BLECHNACEAE	*Sadleria cyatheoides* Kaulf.	`Ama`u	E		C	Fern	x	x		x			

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
BLECHNACEAE	*Sadleria pallida* Hook. & Arn.	`Ama`u	E		C	Fern	x	x		x			
BLECHNACEAE	*Sadleria souleyetiana* (Gaudich.) T. Moore	`Ama`u	E		U	Tree		x		x			
DENNSTAEDTIACEAE	*Hypolepis hawaiiensis* Brownsey var. *hawaiiensis*	Olua	E	RARE	R	Fern		x					
DENNSTAEDTIACEAE	*Microlepia speluncae* (L.) T. Moore	Palapalai	I	RARE	R	Fern	x			x			
DENNSTAEDTIACEAE	*Microlepia strigosa* (Thunb.) C. Presl.	Palapalai	I		U	Fern	x	x	x	x			
DENNSTAEDTIACEAE	*Pteridium aquilinum* (L.) Kuhn var. *decompositum* (Gaudich.) R. M. Tryon	Kilau, bracken fern	E		A	Fern		x	x	x	x		
DICKSONIACEAE	*Cibotium glaucum* (Sm.) Hook & Arn.	Haupu`u pulu	E		A	Tree	x	x	x	x			
DICKSONIACEAE	*Cibotium menziesii* Hook.	Haupu`u `i`i	E		C	Tree	x	x		x			
DRYOPTERIDACEAE	*Cyrtomium falcatum* (L. f.) C. Presl	Holly fern	A		U	Fern				x			
DRYOPTERIDACEAE	*Dryopteris fusco-atra* (Hillebr.)	`I`i	E		U	Fern	x	x		x			
DRYOPTERIDACEAE	*Dryopteris glabra* (Brack.) Kunze var. *glabra*	Kilau	E		U	Fern	x			x			
DRYOPTERIDACEAE	*Dryopteris hawaiiensis* (Hillebr.) W. J. Rob.	Kilau	E		U	Fern	x		x	x	x		
DRYOPTERIDACEAE	*Dryopteris sandwicensis* (Hook. & Arn.) C. Chr.	None	E		UNK	Fern		x					

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
DRYOPTERIDACEAE	*Dryopteris unidentata* (Hook. & Arn.) C. Chr.var. *paleacea* (Hillebr.) Herat ex Fraser-Jenk.	`Akole	E	RARE	R	Fern		x					
DRYOPTERIDACEAE	*Dryopteris wallichiana* (Spreng.) Hyl.	Lau kahi	I		C	Fern	x	x	x	x			
DRYOPTERIDACEAE	*Nothoparanema rubiginosa* (Brack.) A. R. Sm. & D. D. Palmer	None	E		U	Fern	x	x					
DRYOPTERIDACEAE	*Polystichum hillebrandii* Carruth.	Ka`upu	E	RARE	R	Fern			x				
GLEICHENIACEAE	*Dicranopteris linearis* (Burm. F.) Underw.	Uluhe	I		A	Fern	x	x		x			
GLEICHENIACEAE	*Sticherus owhyhensis* (Hook.) Ching	Uluhe	E		R	Fern	x	x					
GRAMMITIDACEAE	*Adenophorus tripinnatifidus* Gaudich.	None	E		UNK	Fern		x					
GRAMMITIDACEAE	*Grammitis hookeri* (Brack.) Copel.	Maku`e lau li`i	I		U	Fern	x	x					
GRAMMITIDACEAE	*Grammitis tenella* Kaulf.	Kolokolo	E		U	Fern		x		x			
HYMENOPHYLLACEAE	*Callistopteris baldwinii* (D.C. Eaton) Copel.	None	E		R	Fern				x			
HYMENOPHYLLACEAE	*Mecodium recurvum* (Gaudich.) Copel.	`Ohi`a ku	E		R	Fern	x			x			
HYMENOPHYLLACEAE	*Sphaerocionium lanceolatum* (Hook. & Am.) Copel.	Palai hinahina	E		R	Fern	x						

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
HYMENOPHYLLACEAE	*Vandenboschia davallioides* (Gaudich.) Copel.	Palai hihi, kilau	E		U	Fern	x			x			
LOMARIOPSIDACEAE	*Elaphoglossum paleaceum* (Hook. & Grev.) Sledge	Maku`e	I		C	Fern	x	x					
LOMARIOPSIDACEAE	*Elaphoglossum wawrae* (Luerss.) C. Chr.	Laukahi, `ekaha	E		C	Fern		x					
LINDSAEACEAE	*Sphenomeris chinensis* (L.) Maxon	Pala`a	I		C	Fern	x			x			
LYCOPODIACEAE	*Huperzia erosa* Beitel & w. H. Wagner	Wawae`iole	E	RARE	UNK	Fern		(x)					
LYCOPODIACEAE	*Lycopodiella cernua* (L.) Pic. Serm.	Wawae`iole	I		C	Fern				x			
LYCOPODIACEAE	*Lycopodium venustulum* Gaudich. var. *verticale* W. H. Wagner	Wawae`iole	E		C	Fern	x	x					
MARATTIACEAE	*Marattia douglasii* (C. Presl) Baker	Pala	E	RARE	R	Fern	x	x		x			
NEPHROLEPIDACEAE	*Nephrolepis cordifolia* (L.) C. Presl	Narrow swordfern	I		C	Fern	x	x		x			
NEPHROLEPIDACEAE	*Nephrolepis exaltata* (L.) Schott subsp. hawaiiensis W. H. Wagner	Ni`ani`au, okupukupu	E		C	Fern		x		x			
NEPHROLEPIDACEAE	*Nephrolepis multiflora* (Roxb.) F. M. Jarrett ex. C. V. Morton	Asian swordfern	A		C	Fern	x			x	x		
POLYPODIACEAE	*Lepisorus thunbergianus* (Kaulf.) Ching	`Ekaha akolea	I		U	Fern	x	x	x				

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
POLYPODIACEAE	*Phlebodium aureum* (L.) J. Sm.	Golden polypody	A		U	Fern				x		x	x
POLYPODIACEAE	*Polypodium pellucidum* Kaulf. var. *vulcanicum* Skottsb.	`Ae	E		C	Fern			x				
POLYPODIACEAE	*Polypodium pellucidum* Kaulf. var. *pellucidum*	`Ae	E		U	Fern		x					
PSILOTACEAE	*Psilotum complanatum* Sw.	Moa	I		U	Fern				x			
PSILOTACEAE	*Psilotum nudum* L.	Moa	I		U	Fern	x	x	x	x	x		
PTERIDACEAE	*Adiantum hispidulum* Sw	Rough maidenhair fern	A		U	Fern				x			
PTERIDACEAE	*Adiantum raddianum* C. Presl	Maidenhair fern	A		R	Fern				x			
PTERIDACEAE	*Coniogramme pilosa* (Brack.) Hieron.	Lo`ulu	E		R	Fern	x	x					
PTERIDACEAE	*Dorypteris decipiens* (Hook.) J. Sm. X D. decora Brack.	`Iwa`iwa	E		UNK	Fern					x		
PTERIDACEAE	*Doryopteris decora* Brack.	`Iwa`iwa	E		U	Fern			x				
PTERIDACEAE	*Pellaea ternifolia* (Cav.) Link	Kalamoho lau li`i	I		C	Fern		x	x				
PTERIDACEAE	*Pityrogramma austroamericana* Domin	Gold fern	A		C	Fern				x			
PTERIDACEAE	*Pteris cretica* L.	Cretan brake	I		C	Fern	x	x	x	x			
PTERIDACEAE	*Pteris excelsa* Gaudich.	Waimaka nui	E		U	Fern	x	x					

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
THELYPTERIDACEAE	*Amauropelta globulifera* (Brack.) Holttum	Palapalai a Kamapua`a	E		C	Fern		x		x			
THELYPTERIDACEAE	*Christella dentata* (Forssk.) Brownsey & Jermy	Pai`i`iha	A		C	Fern				x			
THELYPTERIDACEAE	*Christella parasitica* (L.) L. Lev.	None	A		U	Fern				x			
THELYPTERIDACEAE	*Macrothelypteris torresiana* (Gaudich.) Ching	None	A		U	Fern				x			
THELYPTERIDACEAE	*Pneumatopteris sandwicensis* (Brack.) Holttum	Ho`i`o kula	E		C	Fern	x	x					
THELYPTERIDACEAE	*Pseudophegopteris keraudreniana* (Gaudich.) Holttum	Waimaka nui	E		U	Fern	x	x		x			
GYMNOSPERMS													
ARAUCARIACEAE	*Araucaria columnaris* (G. Forster) J. D. Hooker	Cook-pine	A		U	Tree				x			
CUPRESSACEAE	*Cupressus macrocarpa* Gordon	Monterey cypress	A		R	Tree				x			
PINACEAE	*Pinus caribaea* Morelet	Caribbean pine	A		U	Tree				x			
PINACEAE	*Pinus radiata* D. Don	Monterey pine	A		R	Tree		x					
PINACEAE	*Pinus* sp. 1 (long leaf)	Pine	A		U	Tree				x		x	
PINACEAE	*Pinus* sp. 2 (short leaf)	Pine	A		U	Tree				x			
PODOCARPACEAE	*Nageia falcatus* (Thunberg) Kuntze	Yellow wood	A		R	Tree						x	

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
FLOWERING PLANTS/DICOTS													
ACANTHACEAE	*Justicia carnea* Lindley	Flamingo flower	A		R	Shrub						x	
AMARANTHACEAE	*Amaranthus spinosus* L.	Spiny amaranth	A		U	Herb				x			
AMARANTHACEAE	*Charpentiera obovata* Gaud.	Papala	E	RARE	R	Tree				x			
ANACARDIACEAE	*Mangifera indica* L.	Mango	A		R	Tree					x		
ANACARDIACEAE	*Schinus molle* L.	Pepper tree	A		R	Tree						x	
ANACARDIACEAE	*Schinus terebinthifolius* Raddi	Christmas berry	A		A	Tree			x	x	x		
APIACEAE	*Hydrocotyle bowlesioides* Mathias & Constance	Pennywort	A		U	Herb				x		x	
APIACEAE	*Sanicula sandwicensis* A. Gray	Snakeroot	E	SOC	R	Herb			x				
APOCYNACEAE	*Alyxia stellata* (J. R. Forster & G. Forster) Roemer & Schultes	Maile	E		C	Vine	x	x					
APOCYNACEAE	*Catharanthus roseus* (L.) G. Don	Madagascar periwinkle	A		En	Herb							x
APOCYNACEAE	*Nerium oleander* L.	Oleander	A		En	Shrub							x
APOCYNACEAE	*Thevetia peruviana* (Persoon) K. Schumann	Be still tree, yellow oleander	A		En	Shrub							x
AQUIFOLIACEAE	*Ilex anomala* Hook. & Arnott	Kawa`u, Hawaiian holly	I		C	Tree	x	x		x			
ARALIACEAE	*Cheirodendron trigynum* (Gaud.) A. Heller subsp. trigynum	`Olapa	E		C	Tree	x	x		x			

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
ARALIACEAE	*Hedera helix* L.	English ivy	A		U	Vine						x	
ARALIACEAE	*Schefflera actinophylla* (Endl.) Harms	Octopus tree	A		R	Tree				x		x	x
ARALIACEAE	*Schefflera arboricola* (Hayata) Hayata	Dwarf octopus tree	A		R	Tree						x	
ARALIACEAE	*Tetraplasandra* hawaiensis A. Gray	`Ohe	E		R	Tree				x			
ASCLEPIADACEAE	*Asclepias physocarpa* (E. Mey) Schlechter	Balloon plant	A		U	Herb/Shrub			x	x			
ASTERACEAE	*Ageratina riparia* (Regel) R. King & H. Robinson	Hamakua pamakani	A		U	Herb	x		x	x			
ASTERACEAE	*Ageratum conyzoides* L.	Maile hohono	A		C	Herb		x	x		x		
ASTERACEAE	*Argyroxiphium kauense* (Rock & Neal) Degener & I. Degener	Mauna Loa silversword, Ka`u silversword	E	END	R	Herb		x					
ASTERACEAE	*Cirsium vulgare* (Savi) Ten.	Bull thistle	A		C	Herb	x	x	x	x			
ASTERACEAE	*Conyza bonariensis* (L.) Cronq.	Hairy horseweed	A		U	Herb			x				
ASTERACEAE	*Conyza canadensis* (L.) Cronq.var. *canadensis*	Horseweed	A		R	Herb				x			
ASTERACEAE	*Conyza canadensis* (L.) Cronq.var. *pusilla* (Nutt.) Cronq.	Horseweed	A		U	Herb			x		x		
ASTERACEAE	*Crassocephalum crepidioides* (Benth.) S. Moore	None	A		U	Herb	x		x				
ASTERACEAE	*Delairea odorata* Lem.	Cape ivy	A		R	Vine			x	x			x

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ASTERACEAE	*Dubautia ciliolata* (DC) D. Keck subsp. ciliolata	Na`ena`e	E		U	Shrub		x	x				
ASTERACEAE	*Dubautia ciliolata* (DC) D. Keck subsp. ciliolata x Dubautia scabra (DC) D. Keck subsp.scabra	Na`ena`e	E		R	Shrub		x					
ASTERACEAE	*Dubautia scabra* (DC) D. Keck subsp. leiophylla (A. Gray) G. Carr	Kupaoa	E		R	Shrub			x				
ASTERACEAE	*Dubautia scabra* (DC) D. Keck subsp. scabra	Kupaoa	E		C	Shrub	x	x	x				
ASTERACEAE	*Elephantopus mollis* Kunth	Elephant's foot	A		U	Herb				x			
ASTERACEAE	*Emilia fosbergii* Nicolson	Flora's paintbrush, pualele	A		U	Herb			x				
ASTERACEAE	*Erechtites valerianaefolia* (Wolf.) DC	Fireweed	A		U	Herb	x			x			
ASTERACEAE	*Euchiton sphaericus* (Willd.) A. Anderb.	Cudweed	A		C	Herb		x	x	x	x		
ASTERACEAE	*Gamochaeta purpurea* (L.) Cabrera	Purple cudweed	A		C	Herb		x		x	x		
ASTERACEAE	*Gazania rigens* (L.) Gaertn.	Gazania	A		R	Herb						x	
ASTERACEAE	*Helichrysum foetidum* (L.) Cass.	Stinking everlasting	A		U	Herb			x				
ASTERACEAE	*Hypochoeris radicata* L.	Gosmore	A		C	Herb	x	x	x	x	x		
ASTERACEAE	*Lapsana communis* L.	Nipplewort	A		U	Herb			x				

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ASTERACEAE	*Montanoa hibiscifolia* Benth.	Tree daisy	A		En	Shrub							x
ASTERACEAE	*Picris hieracioides* L.	Hawkweed	A		R	Herb			x				
ASTERACEAE	*Pluchea carolinensis* (Jacq.) G. Don	Sourbush	A		U	Shrub		x	x	x	x		
ASTERACEAE	*Pseudognaphalium sandwicensium* (Gaud.) A. Anderb. var. *hawaiiense* (O. Deg. & Sherff) W. L. Wagner	`Ena`ena	E		U	Herb			x				
ASTERACEAE	*Pseudognaphalium sandwicensium* (Gaud.) A. Anderb. var. *kilaueanum* (O. Deg. & Sherff) W. L. Wagner	`Ena`ena	E		C	Herb		x	x	x	x		
ASTERACEAE	*Senecio madagascarensis* Poir.	Madagascar fireweed	A		U	Herb			x	x			
ASTERACEAE	*Senecio sylvaticus* L.	Wood groundsel	A		U	Herb		x					
ASTERACEAE	*Siegesbeckia orientalis* L.	Small yellow crown-beard	A		U	Herb				x			
ASTERACEAE	*Taraxacum officinale* W. W. Weber	Common dandelion	A		U	Herb				x			
ASTERACEAE	*Tetramolopium humile* (A. Gray) Hillebr. subsp. humile	None	E		U	Herb		x	x				
ASTERACEAE	*Youngia japonica* (L.) DC.	Oriental hawksbeard	A		U	Herb	x	x		x			
BALSAMINACEAE	*Impatiens wallerana* J. D. Hooker	Impatiens	A		U	Herb						x	

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BEGONIACEAE	*Begonia semperflorens - cultorum*	Wax begonia	A		R	Herb						x	
BIGNONIACEAE	*Jacaranda mimosifolia* D. Don	Jacaranda	A		U	Tree				x			x
BORAGINACEAE	*Cynoglossum amabile* Staf & J. R. Drumm.	Chinese forget-me-not	A		C	Herb			x				
BORAGINACEAE	*Heliotropium amplexicaule* Vahl	Heliotrope	A		R	Herb				x			
BRASSICACEAE	*Cardamine flexuosa* With.	Bittercress	A		C	Herb		x	x	x			
BRASSICACEAE	*Lepidium* sp. (*hyssopifolium* or *virginicum*)	Pepperwort	A		R	Herb						x	
BUDDLEJACEAE	*Buddleia asiatica* Lour.	Asiatic butterfly bush	A		C	Shrub	x		x	x		x	
CACTACEAE	*Opuntia ficus-indica* (L.) Mill.	Prickly pear, panini	A		R	Shrub					x		x
CACTACEAE	*Hylocereus undatus* (Haw.) Britton & Rose	Night-blooming cereus	A		En								x
CAMPANULACEAE	*Clermontia clermontioides* (Gaud.) A. Heller subsp. clermontioides	`Oha	E	RARE	U	Shrub	x	x		x			
CAMPANULACEAE	*Clermontia lindseyana* Rock	`Oha	E	END	R	Shrub/Tree		x					
CAMPANULACEAE	*Clermontia montis-loa* Rock	`Oha	E		R	Tree		x					
CAMPANULACEAE	*Cyanea pilosa* A. Gray subsp. ?	Haha	E	RARE	R	Shrub	x						

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CAMPANULACEAE	*Cyanea stictophylla* Rock	Haha	E	END	R	Shrub	x						
CAMPANULACEAE	*Trematolobelia grandifolia* (Rock) Degener	Koli`i	E	SOC	R	Shrub	x	x					
CAMPANULACEAE	*Wahlenbergia gracilis* (G. Forster) A. DC	None	A		U	Herb			x	x			
CAPRIFOLIACEAE	*Lonicera japonica* Thunb.	Japanese honeysuckle	A		U	Vine				x			
CAPRIFOLIACEAE	*Sambucus mexicana* K. Presl ex DC	Mexican elder	A		En	Shrub							x
CARYOPHYLLACEAE	*Cerastium fontanum* Baumg. subsp. *triviale* (Link) Jalas	Larger mouseear chickweed	A		C	Herb		x		x			
CARYOPHYLLACEAE	*Drymaria cordata* (L.) Willd. Ex. Roem. & Schult.	Pipili	A		C	Herb				x			
CARYOPHYLLACEAE	*Polycarpon tetraphyllum* (L.) L.	None	A		U	Herb		x	x	x			
CARYOPHYLLACEAE	*Silene hawaiiensis* Sherff	Hawaiian catchfly	E	THR	R	Shrub		x					
CARYOPHYLLACEAE	*Stellaria media* (L.) Vill.	Common chickweed	A		U	Herb			x				
CASUARINACEAE	*Casuarina equisetifolia* L.	Common ironwood	A		En	Tree							x
CASUARINACEAE	*Casuarina glauca* Sprengl	Long-leaf ironwood	A		U	Tree				x			
CELASTRACEAE	*Perrottetia sandwicensis* A. Gray	Olomea	E		U	Tree	x	x		x			

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CHENOPODIACEAE	*Chenopodium ambrosioides* L.	Mexican tea, wormwood	A		C	Herb			x				
CLUSIACEAE	*Clusia rosea* Jacq.	Autograph tree	A		En	Tree							x
CONVOLVULACEAE	*Ipomoea indica* (J. Burm.) Merr.	Koali `awa	I		U	Vine				x		x	
CRASSULACEAE	*Crassula ovata* (P.Miller) Druce	Jade plant	A		R	Herb						x	x
CRASSULACEAE	*Kalanchoe beharensis* Drake	Felt bush	A		R	Herb						x	
CRASSULACEAE	*Kalanchoe pinnata* (Lam.) Pers.	Air plant	A		R	Herb					x		
CRASSULACEAE	*Kalanchoe pumila* J. G. Baker	None	A		R	Herb						x	
CRASSULACEAE	*Kalanchoe tomentosa* J. G. Baker	Panda plant	A		R	Herb						x	
CRASSULACEAE	*Kalanchoe* sp.	None	A		R	Herb						x	
CUCURBITACEAE	*Benicasa hispida* (Thunberg) Cogniaux	Chinese pickling melon	A		R	Vine						x	
CUCURBITACEAE	*Momordica charantia* L.	Balsam pear	A		R	Vine		x					
CUCURBITACEAE	*Sechium edule* (N. Jacquin) Swartz	Chayote, pipinella	A		R	Vine						x	
EBENACEAE	*Diospyros sandwicensis* (A. DC) Fosb.	Lama	E		R	Tree					x		
ERICACEAE	*Leptecophylla tameiameiae* (Cham.& Schltdl.) C. M.Weiller	Pukiawe	I		C	Shrub	x	x	x	x	x		
ERICACEAE	*Vaccinium calycinum* Sm.	`Ohelo kau la`au	E		C	Shrub	x	x		x			

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ERICACEAE	*Vaccinium dentatum* Sm.	`Ohelo	E		UNK	Shrub		(?)					
ERICACEAE	*Vaccinium reticulatum* Sm.	`Ohelo	E		C	Shrub			x	x	x		
ERICACEAE	*Vaccinium reticulatum* Sm.x V. calycinum Sm.	`Ohelo	E		C	Shrub		x					
EUPHORBIACEAE	*Aleurites moluccana* (L.) Willd.	Kukui	P		R	Tree						x	
EUPHORBIACEAE	*Antidesma platyphyllum* H. Mann	Hame	E		R	Tree				x			
EUPHORBIACEAE	*Chamaecyse prostrata* (Aiton) Small	Prostrate spurge	A		U	Herb				x			
EUPHORBIACEAE	*Euphorbia cotinifolia* L.	Herba mala	A		En	Shrub							x
EUPHORBIACEAE	*Euphorbia peplus* L.	Petty spurge	A		U	Herb			x				
EUPHORBIACEAE	*Macaranga mappa* (L.) Mull.-Arg.	Bingabing	A		En	Tree							x
EUPHORBIACEAE	*Riccinus communis* L.	Castor bean	A		U	Tree						x	
FABACEAE	Ac*acia confusa* Merr.	Formosa koa	A		U	Tree				x			
FABACEAE	*Acacia koa* A. Gray	Koa	E		C	Tree		x	x	x			
FABACEAE	*Acacia mearnsii* De Wild.	Black wattle	A		En	Tree							x
FABACEAE	*Chamaechrista nictitans* (L.) Moench *subsp. patellaria* (DC ex Collad) H. Irwin & Barneby var. *glabrata* (Vogel) H. Irwin & Barneby	Partridge pea	A		U	Shrub				x			
FABACEAE	*Crotaria incana* L.	Fuzzy rattlepod	A		R	Shrub						x	
FABACEAE	*Crotalaria pallida* Aiton	Rattlebox	A		C	Shrub				x			

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FABACEAE	*Crotalaria micans* Link	Rattlebox	A		C	Shrub				x			
FABACEAE	*Desmodium intortum* (Mill.) Urb.	Tick trefoil	A		U	Vine/Shrub				x		x	
FABACEAE	*Desmodium sandwicense* E. Mey.	Spanish clover	A		C	Herb/Shrub				x			
FABACEAE	*Desmodium triflorum* (L.) DC	Tick trefoil	A		U	Herb			x	x			
FABACEAE	*Indigofera suffruticosa* Mill.	Indigo	A		U	Shrub				x			
FABACEAE	*Leucaena leucocephala* (Lam.) de Wit	Koa haole, ekoa	A		R	Shrub					x		
FABACEAE	*Lotus subbiflorus* Lag.	Trefoil	A		U	Herb				x			
FABACEAE	*Lotus uliginosus* Schkuhr	Trefoil	A		U	Herb				x			
FABACEAE	*Macroptilium atropurpureum* (DC) Urb.	None	A		U	Herb				x		x	
FABACEAE	*Medicago lupulina* L.	Black medick	A		U	Herb				x			
FABACEAE	*Mimosa pudica* L. var. *unijuga* (Duchass. & Walp.) Griseb.	Sleeping grass	A		U	Herb						x	
FABACEAE	*Neonotonia wightii* (Wight & Arn.) Lackey	ncn	A		U	Herb/Vine				x		x	
FABACEAE	*Senna septemtrionalis* (Viv.) H. Irwin & Barneby	Kolomona	A		U	Shrub				x			
FABACEAE	*Sophora chrysophylla* (Salisb.) Seem.	Mamane	E		U	Tree			x		x		
FABACEAE	*Trifolium dubium* Sibth.	Small hop-clover	A		U	Herb				x			

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FABACEAE	*Trifolium pratense* L. var. *sativum* Schreb.	Red clover	A		U	Herb			x				
FABACEAE	*Trifolium repens* L. var repens	White clover	A		C	Herb			x	x			
FLACOURTIACEAE	*Xylosma hawaiiense* Seem.	Maua	E	RARE	UNK	Tree			(?)				
GENTIANACEAE	*Centaurium erythraea* Raf. subsp. *erythraea*	Bitter herb	A		C	Herb		x	x				
GERANIACEAE	*Geranium cuneatum* Hook. subsp. *cuneatum*	Nohoanu	E	RARE	R	Shrub			x				
GERANIACEAE	*Geranium cuneatum* Hook. subsp. *hypoleucum* (A. Gray) Carlq. & Bissing	Nohoanu	E	RARE	U	Shrub		x					
GERANIACEAE	*Geranium homeanum* Turcz.	Crane's bill	A		C	Herb	x	x	x	x	x		
GERANIACEAE	*Pelargonium* x *hortorum* L. H. Bailey	Geranium	A		R	Herb						x	
GESNERIACEAE	*Cyrtandra platyphylla* A. Gray	`Ilihia	E		U	Shrub	x	x					
GESNERIACEAE	*Cyrtandra lysiosepala* (A. Gray) C. B. Clarke	Ha`iwale	E		R	Shrub	x						
GESNERIACEAE	*Cyrtandra menziesii* Hook. & Arnott	Ha`iwale	E	SOC	R	Shrub	x			x			
GOODENIACEAE	*Scaevola chamissoniana* Gaud.	Naupaka kuahiwi	E		R	Shrub				x			
GOODENIACEAE	*Scaevola gaudichaudii* Hook. & Arnott	Naupaka kuahiwi	E	RARE	UNK	Shrub					(?)		

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GOODENIACEAE	*Scaevola taccada* (Gaertn.) Roxb.	Naupaka kahakai	I		R	Shrub				x			
HYDRANGACEAE	*Broussaisia arguta* Gaud.	Kanawao	E		C	Shrub	x			x			
LAMIACEAE	*Hyptis pectinata* (L.) Poir.	Comb hyptis	A		U	Shrub				x			
LAMIACEAE	*Marrubium vulgare* L.	C horehound	A		C	Herb			x				
LAMIACEAE	*Phyllostegia ambigua* (A. Gray) Hillebr.	None	E	RARE	R	Vine	x						
LAMIACEAE	*Phyllostegia* sp.	None	E		R	Vine	x						
LAMIACEAE	*Prunella vulgaris* L.	Selfheal	A		C	Herb		x	x	x			
LAMIACEAE	*Solenostemon scutellarioides* (L.) Codd.	Coleus	A		R	Herb						x	
LAMIACEAE	*Stenogyne angustifolia* A. Gray	None	E	END	UNK	Vine		(x)					
LAMIACEAE	*Stenogyne calaminthoides* A. Gray	None	E		R	Vine		x					
LAMIACEAE	*Stenogyne rugosa* Benth.	Ma`ohi`ohi	E		R	Vine	x		x	x			
LAMIACEAE	*Stenogyne sessilis* Benth.	None	E	RARE	U	Vine		x	x				
LAURACEAE	*Persea americana* Mill.	Avocado	A		U	Tree				x		x	
LOGANIACEAE	*Labordia hedyosmifolia* Baill.	Kamakahala	E	RARE	R	Shrub		x					
LYTHRACEAE	*Cuphea carthagenensis* (Jacq.) Macbr.	Tarweed	A		C	Herb		x		x			
LYTHRACEAE	*Lythrum maritimum* Kunth	Pukamole	A		C	Shrub			x				

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MALVACEAE	*Abutilon grandifolium* (Willd.) Sweet	Hairy abutilon	A		U	Shrub				x			
MALVACEAE	*Hibiscus rosa-sinensis* L.	Chinese hibiscus	A		R	Shrub						x	x
MALVACEAE	*Malvastrum coromandelianum* (L.) Garcke subsp. *coromandelianum*	False mallow	A		R	Shrub				x			
MALVACEAE	*Sida rhombifolia* L.	None	A		U	Shrub						x	
MELASTOMATACEAE	*Heterocentron subtriplinervium* (Link. & Otto) A. Braun & C. Bouche	Pearl flower	A		R, lc	Shrub						x	
MENISPERMACEAE	*Cocculus orbiculatis* (L.) DC	Huehue	E		C	Vine			x		x		
MORACEAE	*Ficus microcarpa* L. fil.	Chinese banyan	A		En	Tree							x
MORACEAE	*Streblus pendulinus* (Endl.) F. V. Muell.	A`ia`i	I	RARE	UNK; R	Tree				(?)			
MYOPORACEAE	*Myoporum sandwicensis* A. Gray	Naio	I		U	Tree			x	x	x		
MYRICACEAE	*Morella faya* (Aiton) Wilbur	Faya, firetree	A		U	Tree		x					
MYRSINACEAE	*Myrsine lessertiana* A. DC	Kolea lau nui	E		C	Tree	x	x	x	x			
MYRSINACEAE	*Myrsine lanaiensis* Hillebr.	Kolea	E	RARE	R	Tree			x		x		
MYRSINACEAE	*Myrsine sandwicensis* A. DC	Kolea lau li`i	E		R	Tree		x					

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MYRTACEAE	*Eucalyptus robusta* Sm.	Swamp mahogany	A		U	Tree				x			x
MYRTACEAE	*Eucalyptus saligna* J. E. Smith	Blue gum	A		U	Tree				x			
MYRTACEAE	*Metrosideros polymorpha* Gaud. var. *glaberrima* (H. Lev.) St. John	`Ohi`a lehua	E		C	Tree		x	x				
MYRTACEAE	*Metrosideros polymorpha* Gaud. var. *incana* (H. Lev.) St. John	`Ohi`a lehua	E		C	Tree	x	x	x	x	x		
MYRTACEAE	*Metrosideros polymorpha* Gaud. var. *polymorpha*	`Ohi`a lehua	E		A	Tree		x	x	x			
MYRTACEAE	*Myrciaria cauliflora* (A.P. de Candolle) O. Berg.	Jaboticaba	A		R, lc	Tree						x	
MYRTACEAE	*Psidium cattleianum* Sabine	Waiawi, strawberry guava	A		C	Tree				x			
MYRTACEAE	*Psidium guajava* L.	C guava	A		U	Tree				x		x	
MYRTACEAE	*Syzygium jambos* (L.) Alston	Rose apple	A		C, lc	Tree				x			
OLEACEAE	*Fraxinus uhdei* (Wenzig) Lingelsh.	Tropical ash	A		U	Tree				x			
OLEACEAE	*Ligustrum ovalifolium* Hassk.	California privet	A		R, lc	Tree				x		x	
OLEACEAE	*Olea europaea* L. subsp. *cuspidata* (Wall. ex. G. Don) Cif.	African olive	A		R,lc	Tree				x		x	x

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
ONAGRACEAE	*Epilobium billardierianum* Ser. subsp. *cinereum* (A. Rich.) Raven & Engelhorn	Willow herb	A		C	Herb		x	x	x	x		
ONAGRACEAE	*Epilobium ciliatum* Raf.	Willow herb	A		R	Herb		x					
ONAGRACEAE	*Ludwigia palustris* (L.) Elliott	Marsh purslane	A		U	Herb				x			
ONAGRACEAE	*Oenothera laciniata* J. Hill.	Cut-leaf evening primrose	A		U	Herb				x			
ONAGRACEAE	*Oenothera stricta* Ledeb. Ex. Link	Evening primrose	A		U	Herb				x			
OXALIDACEAE	*Oxalis corniculata* L.	`Ihi	P		C	Herb	x		x	x			
OXALIDACEAE	*Oxalis debilis* Kunth var. *corymbosa* (A. DC) Lourteig	Pink wood sorrel	A		R, Ic	Herb						x	
PAPAVERACEAE	*Argemone glauca* (Nutt. Ex Prain) Pope var. *decipiens* Ownbey	Pua kala	E	RARE	R	Herb				x			
PAPAVERACEAE	*Bocconia frutescens* L.	Plume poppy	A		En	Shrub							x
PAPAVERACEAE	*Eschscholzia californica* Cham.	California poppy	A		En	Herb							x
PAPAVERACEAE	*Hunnemannia fumariifolia* Sweet	Mexican tulip poppy	A		En	Herb							x
PASSIFLORACEAE	*Passiflora edulis* Sims f. edulis	Liliko`i	A		U	Vine				x			
PASSIFLORACEAE	*Passiflora ligularis* Juss.	Sweet granadilla	A		U	Vine				x			
PHYTOLACCACEAE	*Phytolacca sandwicensis* Endl.	Popolo ku mai	E	RARE	R	Herb/Shrub				x			

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PIPERACEAE	*Peperomia cookiana* C. DC	`Ala`alawainui	E		R	Herb	x			x			
PIPERACEAE	*Peperomia hypoleuca* Miq.	`Ala`alawainui	E		R	Herb	x						
PIPERACEAE	*Peperomia macraeana* C. DC	`Ala`alawainui	E		R	Herb	x			x			
PIPERACEAE	*Peperomia* sp.	`Ala`alawainui	E		R	Herb			x				
PITTOSPORACEAE	*Pittosporum* cf. *confertiflorum* A. Gray	Ho`awa	E	RARE	R	Tree		x					
PITTOSPORACEAE	*Pittosporum hawaiiense* Hillebr.	Ho`awa	E	SOC	U	Tree	x	x		x			
PITTOSPORACEAE	*Pittosporum hosmeri* Rock	Ho`awa	E	RARE	R	Tree	?			x			
PITTOSPORACEAE	*Pittosporum terminalioides* Planch. ex. A.Gray	Ho`awa	E		R	Tree				x	x?		
PITTOSPORACEAE	*Pittosporum undulatum* Venten.	Victorian box	A		En	Tree							x
PLANTAGINACEAE	*Linaria canadensis* (L.) Dum. Cours.	Toad flax	A		U	Herb				x			
PLANTAGINACEAE	*Plantago australis* Lam.	Dwarf plantain	A		U	Herb				x			
PLANTAGINACEAE	*Plantago hawaiensis* (A. Gray) Pilger	Laukahi kuahiwi	E	END	R	Herb		x					
PLANTAGINACEAE	*Plantago lanceolata* L.	Narrow-leaved plantain	A		U	Herb		x		x			
PLANTAGINACEAE	*Plantago major* L.	C plantain	A		U	Herb				x			
PLANTAGINACEAE	*Plantago pachyphylla* A. Gray	Laukahi kuahiwi	E	RARE	UNK	Herb			x				

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PLANTAGINACEAE	*Veronica plebeia* R. Br.	C speedwell	A		C	Herb	x	x	x	x	x		
PLANTAGINACEAE	*Veronica serpyllifolia* L.	Thyme-leaved speedwell	A		C	Herb		x	x	x	x		
POLYGALACEAE	*Polygala paniculata* L.	Polygala	A		U	Herb				x			
POLYGONACEAE	*Persicaria capitata* (Buch.-Ham. ex D.Don) Masam.	Knotweed	A		U	Herb	x		x			x	
POLYGONACEAE	*Persicaria punctata* (Elliott) Small	Smartweed	A		U	Herb		x					
POLYGONACEAE	*Rumex acetosella* L.	Sheep sorrel	A		C	Herb		x	x	x			
POLYGONACEAE	*Rumex giganteus* W. T. Aiton	Pawale	E	RARE	R	Shrub	x			x			
POLYGONACEAE	*Rumex skottsbergii* Degener & I. Degener	Pawale	E		U	Shrub			x				
PORTULACACEAE	*Portulaca oleracea* L.	Pigweed	A		U	Herb				x			
PORTULACACEAE	*Portulaca pilosa* L.	None	A		U	Herb			x	x			
PORTULACACEAE	*Portulaca villosa* Cham.	`Ihi	E	SOC	UNK	Herb							x
PRIMULACEAE	*Anagallis arvensis* L.	Scarlet pimpernel	A		U	Herb		x		x		x	
PROTEACEAE	*Grevillea banksii* R. Br.	Kahili flower	A		En	Tree							x
PROTEACEAE	*Grevillea robusta* A. Cunn. ex. R. Br.	Silky oak	A		U	Tree			x	x			
PROTEACEAE	*Macadamia integrifolia* Maidena & Betche	Macadamia nut	A		R, Ic	Tree						x	

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RANUNCULACEAE	*Anemone hupehensis* Lemoine var. *japonica* (Thung.) Bowles & W. Stern	Japanese anemone	A		U	Herb	x	x		x			
RANUNCULACEAE	*Ranunculus hawaiensis* A. Gray	Makou	E	CAN	R	Herb		x	x				
RANUNCULACEAE	*Ranunculus plebeius* R. Br. Ex DC	Common Australian buttercup	A		UNK	Herb		x					
RHAMNACEAE	*Alphitonia ponderosa* Hillebr.	Kauila	E	SOC	UNK	Tree					(x)		x
ROSACEAE	*Acaena* sp.	Unknown	A		U	Herb			x				
ROSACEAE	*Eriobotrya japonica* (thunb.) Lindl.	Loquat	A		En	Tree							x
ROSACEAE	*Fragaria chiloensis* (L.) Duchesne subsp. *sandwicensis* (Decne.) Staudt.	`Ohelo papa	E	SOC	U	Herb		x					
ROSACEAE	*Fragaria vesca* L.	European strawberry	A		C	Herb		x		x			
ROSACEAE	*Osteomeles anthyllidifolia* (Sm.) Lindl.	`Ulei	I		U	Shrub			x	x	x		
ROSACEAE	*Prunus persica* (L.) Batsch.	Peach	A		U	Tree				x			
ROSACEAE	*Prunus cerasifera* Ehrh. x salicina Lindl.	Methley plum	A		U, lc	Tree		x					
ROSACEAE	*Prunus* sp.		A		R	Tree		x					
ROSACEAE	*Rubus argutus* Link	Prickly blackberry	A		C	Shrub	x		x	x			

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ROSACEAE	*Rubus hawaiensis* A. Gray	`Akala	E		U	Shrub	x	x	x	x			
ROSACEAE	*Rubus macraei* A. Gray	`Akala	E	SOC	R	Shrub		x					
ROSACEAE	*Rubus niveus* Thunb.	Hill raspberry	A		R	Shrub				x			
ROSACEAE	*Rubus rosifolius* Sm.	Thimbleberry	A		C	Shrub	x		x	x	x		
RUBIACEAE	*Coprosma ernodeoides* A. Gray	Kukae nene	E		C	Shrub	x	x	x				
RUBIACEAE	*Coprosma montana* Hillebr.	Pilo	E		C	Tree	x	x					
RUBIACEAE	*Coprosma ochracea* W. Oliver	Pilo	E		C	Tree	x	x		x			
RUBIACEAE	*Coprosma rhynchocarpa* A. Gray	Pilo	E		U	Tree	x	x	x				
RUBIACEAE	*Coprosma pubens* A. Gray	Pilo	E		U	Tree				x			
RUBIACEAE	*Galium* sp.	Bedstraw	A		R	Herb				x			
RUBIACEAE	*Hedyotis corymbosa* (L.) Lam.	None	A		U	Herb				x			
RUBIACEAE	*Kadua affinis* DC	Manono	E		R	Tree	x			x			
RUBIACEAE	*Kadua centranthoides* Hook. & Arnott	None	E		U	Shrub	x	x					
RUBIACEAE	*Richardia brasiliensis* Gomes	None	A		U	Herb				x			
RUBIACEAE	*Psychotria hawaiiensis* (A. Gray) Fosb.var. *hawaiiensis*	Kopiko `ula	E		R	Tree	x			x			

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RUBIACEAE	*Psychotria hawaiiensis* (A. Gray) Fosb.var. *hillebrandii* (Rock) Fosb.	Kopiko `ula	E		R	Tree	x						
RUBIACEAE	*Psydrax odorata* (G. Forst.) A. C. Sm. & S. P. Darwin	Alahe`e	I		U	Tree			x	x	x		
RUBIACEAE	*Spermacoce exilis* (L. O. Williams) C. Adams	None	A		U	Herb				x			
RUBIACEAE	*Unknown herbaceous* plant	None	A		R	Herb						x	
RUTACEAE	x *Citrofortunella microcarpa* (Bunge) Wijnands	Calamondin	A		R. Lc	Tree						x	
RUTACEAE	*Melicope clusiifolia* (A. Gray) T. Hartley & B. Stone	Alani	E		U	Tree		x		x			
RUTACEAE	*Melicope radiata* (St. John) T. Hartley & B. Stone	Alani	E		U	Tree	x	x	x	x?			
SANTALACEAE	*Exocarpos menziesii* Stauffer	Heau	E	RARE	R	Shrub		x	x				
SANTALACEAE	*Santalum paniculatum* Hook. & Arnott var. *paniculatum*	`Iliahi, sandalwood	E		R	Tree			x				
SANTALACEAE	*Santalum paniculatum* Hook. & Arnott var. *pilgeri* (Rock) Stemmermann	`Iliahi, sandalwood	E	RARE	R	Tree			x		x		
SAPINDACEAE	*Dodonea viscosa* Jacq.	`A`ali`i	I		C	Shrub		x	x		x		

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SAPOTACEAE	*Pouteria sandwicensis* (A. Gray) Baehni & Degener	`Ala`a	E	RARE	UNK	Tree					(x)		x
SCROPHULARIACEAE	*Linaria canadensis* (l.) Dum. Cours. var. *texana* (Scheele) Pennell	Blue toadflax	A		U	Herb			x	x			
SCROPHULARIACEAE	*Lophospermum erubescens* D. Don	Larger roving sailor	A		R	Vine					x		
SCROPHULARIACEAE	*Parentucellia viscosa* (L.) Caruel	None	A		UNK	Herb		x					
SCROPHULARIACEAE	*Verbascum thapsus* L.	C mullein	A		U	Herb			x				x
SOLANACEAE	*Brugmansia x candida* Pers.	Angel's trumpet	A		R	Shrub						x	
SOLANACEAE	*Cestrum nocturnum* L.	Night-blooming jasmine	A		R	Shrub				x		x	
SOLANACEAE	*Physalis peruviana* L.	Poha	A		U	Shrub	x			x		x	
SOLANACEAE	*Solanum americanum* Mill.	Popolo	I		U	Shrub			x	x			
SOLANACEAE	*Solanum linneanum* Hepper & P. Jaeger	Apple of Sodom	A		U	Shrub				x		x	
SOLANACEAE	*Solanum lycopersicum* L. var. *cerasiforme* (Dunal) D. M. Spooner, G. J. Anderson & R. K. Jansen	Tomato	A		R	Herb				x			
STERCULIACEAE	*Waltheria indica* L.	`Uhaloa	I		R	Shrub					x		
THEACEAE	*Camellia japonica* L.	Camellia	A		R, lc	Shrub						x	
THEACEAE	*Eurya sandwicensis* A. Gray	`Anini	E	SOC	R	Tree		x					

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THYMELAEACEAE	*Wikstroemia phillyreifolia* A. Gray	`Akia	E		U	Shrub			x		x		
TROPAEOLACEAE	*Tropaeolum majus* L.	Nasturtium	A		R	Vine						x	
URTICACEAE	*Hesperocnide sandwicensis* (Wedd.) Wedd.	None	E	RARE	R	Herb			x				
URTICACEAE	*Neraudia ovata* Gaud.	None	E	END	UNK, R	Shrub					(?)		
URTICACEAE	*Pilea nummulariifolia* (Swartz) Weddell	Creeping charlie	A		R, lc	Herb						x	
URTICACEAE	*Pipturus albidus* (Hook. & Arnott) A. Gray	Mamaki	E		C	Shrub	x	x		x			
URTICACEAE	*Touchardia latifolia* Gaud.	Olona	E	RARE	R	Shrub				x			
URTICACEAE	*Urera glabra* (Hook. & Arnott) Wedd.	Opuhe	E	RARE	R	Tree	x						
VERBENACEAE	*Holmskioldia sanquinea* Retzius	Cup-and-saucer plant	A		R, lc	Shrub						x	
VERBENACEAE	*Lantana camara* L.	Lantana	A		U, lc	Shrub					x		
VERBENACEAE	*Stachytarpheta australis* Moldenke	Vervain	A		C	Shrub				x	x		
VERBENACEAE	*Verbena litoralis* Kunth	Oi	A		C	Shrub			x	x	x		
VIOLACEAE	*Viola maviensis* H. Mann	Pamakani, violet	E	RARE	R	Herb			(x)				
VISCACEAE	*Korthalsella complanata* (Tiegh.) Engl.	Hulumoa	E		R	Herb			x				
VISCACEAE	*Korthalsella remyana* Tiegh.	Hulumoa	E		R	Herb					x		

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FLOWERING PLANTS/MONOCOTS													
AGAVACEAE	*Agave sisalana* Perrine	Sisal	A		U	Herb					x		x
AGAVACEAE	*Cordyline fruticosa* (L.) A. Chev.	Ki, ti	P		U	Shrub				x			
AGAVACEAE	*Dracaena fragrans* (L.) Ker Gawler	Fragrant dracaena	A		R	Shrub						x	
AGAVACEAE	*Dracaena marginata* Lamarck	Money tree	A		R	Shrub						x	
AGAVACEAE	*Furcraea foetida* (L.) Haw.	Mauritius hemp	A		R	Herb				x			
AGAVACEAE	*Sansevieria trifasciata* Prain	Bowstring hemp	A		R	Herb						x	
ARACEAE	*Calocasia esculenta* (L.) Schott	Kalo, taro	P		U	Herb				x		x	
ARACEAE	*Monstera deliciosa* Liebmann	Monstera	A		R,lc	Vine						x	x
ARACEAE	*Philodendron* cf. *scandens* K. Kock & Sello	Heart-leaf philodendron	A		R,lc	Vine						x	
ARACEAE	*Syngonium podophyllum* Schott	Syngonium	A		R,lc	Vine						x	
ARECACEAE	*Cocos nucifera* L.	Coconut palm	P		R,lc	Tree						x	
ARECACEAE	*Phoenix roebelinii* O'Brien	Dwarf date palm	A		R,lc	Tree						x	
ASTELIACEAE	*Astelia menziesiana* Sm.	Pa`iniu	E		R	Herb	x	x		x			
COMMELINACEAE	*Commelina diffusa* N. L. Burm.	Dayflower, honohono	A		C	Herb				x			

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COMMELINACEAE	*Commelina* sp.	Unknown	A		R, lc	Herb						x	
COMMELINACEAE	*Dichorisandra thyrsiflora* J. C. Mikan	Blue ginger	A		R, lc	Herb						x	
COMMELINACEAE	*Tradescantia zebrina* Bosse	Wandering-jew	A		R, lc	Herb						x	
CYPERACEAE	*Bulbostylis capillaris* (L.) C. B. Clarke	None	A		C	Sedge			x	x	x		
CYPERACEAE	*Carex alligata* Boott	None	E		C	Sedge		x	x				
CYPERACEAE	*Carex macloviana* Dum. D`Urv.	None	I		U	Sedge			x				
CYPERACEAE	*Carex meyenii* Nees	None	I		U	Sedge				x			
CYPERACEAE	*Carex wahuensis* C. A. Mey subsp. *wahuensis*	None	E		U	Sedge			x	x			
CYPERACEAE	*Carex wahuensis* C.A. Mey subsp. rubiginosa (R. Brown) T. Koyama	None	E		C	Sedge			x	x	x		
CYPERACEAE	*Cyperus difformis* L.	None	A		U	Sedge				x			
CYPERACEAE	*Cyperus haspan* L.	None	A		U	Sedge				x			
CYPERACEAE	*Cyperus hillebrandii* Boeck. subsp. *hillebrandii*	None	E		U	Sedge	x		x		x		
CYPERACEAE	*Cyperus polystachyos* Rottb.	None	I		C	Sedge	x			x	x		
CYPERACEAE	*Cyperus sanquinolentus* (Vahl) Nees	None	A		C	Sedge				x			
CYPERACEAE	*Fimbristylis dichotoma* (L.) Vahl	None	I		U	Sedge				x			

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CYPERACEAE	*Kyllinga brevifolia* Rottb.	Kili`o`opu	A		U	Sedge				x	x		
CYPERACEAE	*Machaerina angustifolia* (Gaud.) T. Koyama	`Uki	I		U	Sedge	x			x			
CYPERACEAE	*Morelotia gahniiformis* (Gaud.) A. Heller	None	E		A	Sedge		x	x	x	x		
CYPERACEAE	*Oreobolus furcatus* H. Mann	None	E		U	Sedge		x					
CYPERACEAE	*Rhynchospora rugosa* (Vahl) Gale subsp. lavarum (Gaud.) T. Koyama	Pu`uko`a	I		U	Sedge		x		x			
CYPERACEAE	*Uncinia uncinata* (L.f.) Kukenth.	None	I		C	Sedge	x	x					
HEMERO-CALLIDACEAE	*Dianella sandwicensis* Hook. & Arnott	`Uki`uki	I		U	Herb		x	x				
IRIDACEAE	*Sisyrinchium acre* H. Mann.	Mau`u la`ili	E	SOC	U	Herb		x	x				
IRIDACEAE	*Sisyrinchium exile* E. P. Bicknell	None	A		U	Herb				x			
JUNCACEAE	*Juncus bufonius* L.	C rush	A		U	Rush				x			
JUNCACEAE	*Juncus effusus* L.	Japanese mat rush	A		C	Rush		x		x			
JUNCACEAE	*Juncus ensifolius* Wikstrom	None	A		U	Rush		x					
JUNCACEAE	*Juncus tenuis* Willd.	Rush	A		U	Rush		x	x				
JUNCACEAE	*Luzula hawaiiensis* Buchenau var. *hawaiiensis*	None	E		C	Rush	x	x	x				

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LILIACEAE	*Agapanthus praecox* Willdenow subsp. *orientalis* (F. M. Leighton) F. M. Leighton	African lily, agapanthus	A		R, lc	Herb				x			
LILIACEAE	*Asparagus macowanii* Baker	Regal fern	A		R,lc	Vine						x	
LILIACEAE	*Clivia miniata* (Lindley) Bosse	Clivia	A		R,lc	Herb						x	
LILIACEAE	*Chlorophytum comosum* (Thunberg) Jacques	Spider plant	A		R,lc	Herb						x	
LILIACEAE	*Crinum pedunculatum* R. Brown	Swamp lily	A		R,lc	Herb						x	
LILIACEAE	*Ophiopogon japonicus* (L. f.) Ker Gawler	Dwarf Mondo-grass	A		R,lc	Herb						x	
ORCHIDACEAE	*Arundina graminifolia* (D. Don) Hochr.	Bamboo orchid	A			Herb				x			
ORCHIDACEAE	*Epidendrum* x *obrienianum* Rolfe	Butterfly orchid	A		R,lc	Herb						x	x
ORCHIDACEAE	*Phaius tankarvilleae* (Banks ex. L'Her) Blume	Chinese ground orchid	A		U	Herb	x	x		x			
ORCHIDACEAE	*Spathoglottis plicata* Blume	Malaysian ground orchid	A		U	Herb				x			
PANDANACEAE	*Freycinetia arborea* Gaud.	`le`ie	I		U	Vine	x	x		x			
POACEAE	*Agrostis avenacea* J. F. Gmelin	He`upueo	I		C	Grass	x	x	x	x	x		
POACEAE	*Agrostis sandwicensis* Hillebr.	Hawaiian bentgrass	E		R	Grass			x				
POACEAE	*Andropogon virginicus* L.	Broomsedge	A		C	Grass		x		x	x		

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POACEAE	*Anthoxanthum odoratum* L.	Sweet vernal grass	A		A	Grass	x	x	x	x			
POACEAE	*Axonopus fissifolius* (Raddi) Kuhlm.	Narrow leaved carpetgrass	A		C	Grass	x	x	x	x	x		
POACEAE	*Bothriochloa barbinodis* (Lag.) Herter	Fuzzy top	A		C, lc	Grass				x			
POACEAE	*Bothriochloa pertusa* (L.) A. Camus	Pitted beardgrass	A		R	Grass						x	
POACEAE	*Briza minor* L.	Little quaking grass	A		R	Grass			x				
POACEAE	*Chloris gayana* Kunth	Rhodes grass	A		U	Grass				x			
POACEAE	*Cymbopogon citratus* (C. Nees) Stapf	Lemon grass	A		R	Grass						x	
POACEAE	*Cymbopogon refractus* (R. Br.) A. Camus	Barbwire grass	A		A	Grass			x	x	x		
POACEAE	*Dactylis glomerata* L.	Cock's foot, orchard grass	A		U	Grass			x				
POACEAE	*Deschampsia nubigena* Hillebr.	Hairgrass	E		C	Grass		x	x				
POACEAE	*Digitaria ciliaris* (Retz) Koeler	Henry's crabgrass	A		U	Grass				x			
POACEAE	*Digitaria eriantha* Steud.	Pangola grass	A		U	Grass				x			
POACEAE	*Digitaria setigera* Roth	Kukaepua`a	I		R	Grass						x	
POACEAE	*Digitaria violascens* Link	Smooth crabgrass	A		U	Grass			x	x			
POACEAE	*Ehrharta stipoides* Labill.	Meadow ricegrass	A		A	Grass	x	x	x	x	x		

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
POACEAE	*Eleusine indica* (L.) Gaertn.	Wiregrass	A		R	Grass						x	
POACEAE	*Eragrostis brownei* (Kunth) Nees ex. Steud.	Sheepgrass	A		C	Grass		x	x	x	x		
POACEAE	*Eragrostis elongata* (Willd.) Jacq.		A		U	Grass				x			
POACEAE	*Eragrostis pectinacea* (Michx.) Nees	Carolina lovegrass	A		U	Grass				x		x	
POACEAE	*Eragrostis variabilis* (Gaud.) Steud.	Emoloa	E		R	Grass			x				
POACEAE	*Festuca arundinacea* Schreber	Fescue	A		C	Grass			x	x			
POACEAE	*Holcus lanatus* L.	Velvet grass	A		C	Grass		x	x	x	x		
POACEAE	*Hyparrhenia rufa* (Nees) Stapf	Thatching grass	A		U	Grass				x			
POACEAE	*Isachne distichophylla* Munro ex. Hillebr.	`Ohe	E		U	Grass				x			
POACEAE	*Melinis minutiflora* P. Beauv.	Mollasses grass	A		C	Grass				x			
POACEAE	*Melinis repens* (Willd.) Zizka	Natal redtop grass	A		C	Grass			x	x			
POACEAE	*Oplismenus hirtellus* (L.) P. Beauv.	Basketgrass	A		U	Grass				x		x	
POACEAE	*Panicum konaense* Whitney & Hosaka	Kona panic grass	E	RARE	R	Grass					x		
POACEAE	*Panicum maximum* Jacq.	Guinea grass	A		R	Grass				x		x	
POACEAE	*Panicum tenuifolium* Hook. & Arnott	Mountain pili	E		U	Grass			x				

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
POACEAE	*Paspalum conjugatum* Bergius	Hilo grass	A		C	Grass				x			
POACEAE	*Paspalum dilatatum* Poir.	Dallis grass	A		C	Grass			x	x			
POACEAE	*Paspalum urvillei* Steud.	Vasey grass	A		C	Grass				x			
POACEAE	*Pennisetum clandestinum* Chiov.	Kikuyu grass	A		A	Grass			x	x	x		
POACEAE	*Pennisetum polystachyion* (L.) Schult.	Feathery pennisetum	A		R	Grass			x				
POACEAE	*Pennisetum purpureum* Schumach.	Elephant grass	A		En	Grass							x
POACEAE	*Pennisetum setaceum* (Forssk.) Chiov.	Fountain grass	A		R	Grass				x			x
POACEAE	*Poa annua* L.	Annual bluebrass	A		U	Grass		x		x	x		
POACEAE	*Poa pratensis* L.	Kentucky bluegrass	A		U	Grass				x	x		
POACEAE	*Sacciolepis indica* (L.) Chase	Glenwoodgrass	A		U	Grass				x			
POACEAE	*Schizachyrium condensatum* (Kunth) Nees	Bush beardgrass	A		C	Grass		x	x	x	x		
POACEAE	*Setaria parviflora* (Poir.) Kerguelen	Foxtail grass	A		C	Grass			x	x	x		
POACEAE	*Sporobolus africanus* (Poir.) Robyns & Tournay	African dropseed	A		A	Grass		x	x	x	x		
POACEAE	*Trisetum glomeratum* (Kunth) Trin.	Pili uka, mountain pili	E		U	Grass		x	x				

Group/Family	Scientific Name	Common Name	Status[1]	RTE[2]	Abu.[3]	Life Form	Pit Cra[4]	E[4]	W[4]	C[4]	SW[4]	H/P[4]	AL[4]
POACEAE	*Vulpia bromoides* (L.) S. F. Gray	Brome fescue	A		U	Grass		x	x	x			
RUSCACEAE	*Pleomele hawaiiensis* Degener & I. Degener	Halapepe	E	END	UNK, R	Tree					(x)		x
SMILACACEAE	*Smilax melastomifolia* Sm.	Hoi kuahiwi	E		U	Vine	x			x			
ZINGIBERACEAE	*Hedychium coronarium* J. Konig	White ginger	A		U	Herb						x	
ZINGIBERACEAE	*Hedychium gardnerianum* Sheppard ex Ker-Gawl.	Kahili ginger	A		U	Herb				x		x	

[1] Status: A = Alien, introduced; E = Endemic; I = Indigenous; P = Polynesian Introduction.
[2] RTE: RARE = Rare Species; END = Endangered; THR = Threatened; CAN = Candidate Endangered; SOC = Species of Concern.
[3] Abu. is Abundance: Abundant; Common; Uncommon; Rare; Localized (lc); or Unknown.
[4] Locality Columns: Pit crater is deep crater in central pastures; E is East region; W is West region; C is Central pasture region; SW is Southwest region; H/L is House and planting sites; AL is Adjacent land.

APPENDIX B. HISTORICAL RECORDS OF VASCULAR PLANTS PREVIOUSLY COLLECTED IN KAHUKU NOT FOUND DURING RECENT SURVEYS

Species	Common Name	Origin[1]	Label Information	Herbarium[2]
Adenophorus tripinnatifidus (Hook. & Arn.) C. Chr.	No common name	E	Specimen from parkland 8 mi NE of Nene cabin, elev. 1,829 m. Collected by H. St. John, #26814, 1971.	USNM
Alphitonia ponderosa Hillebr.	Kauila	E	Specimens from Kahuku 1887 lava flow; Kahuku 1,800 ft elev.; and Ocean View 2,080 ft and 610 m elev. Collected by G. W. Russ, sn, 1927; H. St. John, #22145, 1946; D. Herbst and Ishikawa, #5066, 1974; and Kimura and Keawe # 6, 1980.	BISH
Doryopteris decipiens (Hook.) J. Sm. X D. decora Brack.	`Iwa`iwa	E	Specimen from 1887 lava flow, dry barren `a`a, 1,950 ft elev. Collected by H. St. John et al., #22421, 1946.	BISH
Dryopteris sandwicensis (Hook. & Arn.) C. Chr.	No common name	E	Specimen from parkland 8 mi. NE. of Nene cabin, elev. 1,829 m. Collected by H. St. John, #26814, 1971.	USNM
Huperzia erosa Beitel & W. H. Wagner	Wawae`iloe	E	Specimen from N side of E lobe of 1950 flow near jeep rd., 5,900 ft elev. Collected by H. St. John, #26802, 1971.	BISH
Neraudia ovata Gaud.	No common name	E	Specimen from Kahuku `a`a flow at 457 m elev. Collected by L. W. Bryan, sn, 1956.	BISH
Parentucellia viscosa (L.) Caruel	No common name	A	Specimen from Kahuku, 5,000 ft elev., in meadow near rd to Nene cabin. Collected by H. St. John, #26828, 1971.	BISH
Plantago pachyphylla A. Gray	Laukahi kuahiwi	E	Specimen from SW Mauna Loa, Kahuku Ranch, 5,000 ft. elev., red soil on pahoehoe with native shrubs. Collected by S. Carlquist, #2106, 1966.	BISH
Pleomele hawaiiensis Degener & I. Degener	Halapepe	E	Specimens from Pu`u Kamaoa 4 mi. W of Kahuku Ranch HQ, and 0.5 mi. E of King Kam Ave. Collected by Meebold, #20866, 1935 and Meineke, sn, 1975.	BISH, USNM
Portulaca villosa Cham.	`Ihi	E	Specimen from 1887 lava flow, no elev. Collected by D. P. Rogers, sn, 1946.	BISH
Pouteria sandwicensis (A. Gray) Baehni & Degener	`Ala`a	E	Specimen collected at Kipuka Pu`ukamaoa at 2,500 ft elev.; second specimen at Kahuku, no other data. Collected by A. Meebold #20947, 1935; and Meineke, sn, 1964.	BISH, USNM

Species	Common Name	Origin[1]	Label Information	Herbarium[2]
Ranunculus plebeius R. Br. ex DC	Common Australian buttercup	A	Specimen from Kahuku-Ainapo Trail. Collected by E. Hosaka, #1461, 1936.	USNM
Scaevola gaudichaudii Hook. & Arnott	Naupaka kuahiwi	E	Specimen from Kahuku 1,500 ft elev., on `a`a. Collected by L. W. Bryan, sn, 1956.	BISH
Stenogyne angustifolia A. Gray	No common name	E	Specimen from Kahuku, no other data. Collected by A. Meebold, #20866, 1935.	BISH
Streblus pendulinus (Endl.) F. V. Muell.	A`ia`i	I	Specimen from Kahuku, no other data. Collected by A. Meebold, #20113, 1935.	BISH
Vaccinium dentatum Sm.	`Ohelo	E	Specimen from Kahuku at 6,450 ft elev. Collected by G. W. Russ, sn, 1928.	BISH
Xylosma hawaiiense Seem.	Maua	E	Specimen from Kahuku, no other data. Collected by J. F. Rock, #12963, 1917.	BISH

[1] Origin: E is endemic to the Hawaiian Islands; I is indigenous; A is alien, introduced.
[2] Herbaria: BISH is Bernice P. Bishop Museum Herbarium, Honolulu, HI; USNM is National Museum of Natural History of the Smithsonian Institution, Washington, DC.

APPENDIX C. INVASIVE ALIEN PLANTS ENCROACHING ON KAHUKU

SPECIES	COMMON NAME
Catharanthus roseus (L.) G. Don	Madagascar periwinkle
Nerium oleander L.	Oleander
Thevetia peruviana (Persoon) K. Schumann	Be still tree
Montanoa hibiscifolia Benth.	Tree daisy
Sambucus mexicana K. Presl ex DC	Mexican elder
Casuarina equisetifolia L.	Common ironwood
Clusia rosea Jacq.	Autograph tree
Euphorbia cotinifolia L.	Herba mala
Macaranga mappa (L.) Mull.-Arg.	Bingabing
Acacia mearnsii De Wild.	Black wattle
Ficus microcarpa L. fil.	Chinese banyan
Bocconia frutescens L.	Plume poppy
Eschscholzia californica Cham.	California poppy
Hunnemannia fumariifolia Sweet	Mexican tulip poppy
Pittosporum undulatum Venten.	Victorian box
Grevillea banksii R. Br.	Kahili flower
Eriobotrya japonica (thunb.) Lindl.	Loquat
Pennisetum purpureum Schumach.	Elephant grass