CHAPTER 3: AFFECTED ENVIRONMENT

GENERAL PROJECT SETTING

The Island of Hawai‘i is the youngest island in the Hawaiian Island chain, which is located approximately 2,390 miles west of California and is considered the most geographically remote high island chain in the world. The Hawaiian Islands formed as undersea volcanoes that erupted and built mountains that rose from the sea floor, with the Island of Hawai‘i first emerging 430,000 years ago (Juvik and Juvik 1998).

Today, Hawai‘i Volcanoes National Park encompasses two active volcanoes: Mauna Loa and Kīlauea. Mauna Loa erupts every 20 years on average and features two active rift zones (areas associated with the rise and eruption of magma) that create fissures, cinder and spatter cones, lava flows, and faults; Kīlauea, which has erupted from the Pu‘u ‘Ō‘ō, Kupaianaha and Thanksgiving Eve Breakout vents on the eastern side of the park since 1983, has added approximately 212 acres to the island’s southern shore (as of January 2007), and is among the world’s most active volcanoes. As with all Hawaiian Island volcanoes, Mauna Loa and Kīlauea release basaltic lavas that are high in silica and low in sodium and potassium (NPCA 2008; Ziegler 2002).

The geographic isolation and geologic history of the island, combined with a wide range of climates (described below), have resulted in a wide variety of vegetation and habitat types, ranging from coastal lowlands to alpine environments and from wet forests to xeric systems. These are described in more detail in the “Vegetation” section of this chapter. Almost all of the native terrestrial flowering plants and animals are unique to the Hawaiian Islands and play important roles in the traditional culture of Native Hawaiians (NPCA 2008; Ziegler 2002).

The geographic isolation and geologic history of the island, combined with a wide range of climates (described below), have resulted in a wide variety of vegetation and habitat types, ranging from coastal lowlands to alpine environments and from wet forests to xeric systems.

In general, the park climate is characterized by a two-season year, by mild and fairly uniform temperature conditions everywhere except at high elevations, and by marked geographic differences in rainfall. Climate data has been recorded at the park headquarters (around 4,000 feet (1,219 meters) above sea level) since 1949 and shows that temperatures range from an average minimum of 59°F to a maximum of 67°F in winter, and from 63°F to 71°F in summer. Average annual temperature from 1949 to 2006 was about 61°F. The highest recorded temperature was 89°F in December of 2000, while the lowest was 34°F in January of 1978 (WRCC n.d., 2006). It is important to note that temperature and precipitation vary by exposure to trade wind showers and elevation, which ranges from sea level to 13,677 feet (4,169 meters) at the summit of Mauna Loa. For example, temperatures at the summit of Kīlauea can be 12 to 15 degrees cooler than coastal lowlands, and mean temperatures in alpine areas on Mauna Loa—which include elevations of about 8,500 feet to the 13,677 foot summit (2,591 to 4,169 meters) and can experience snowfall—range from 43°F to 48°F (NPS 2007c, 2008a). In addition, wet forests in the park average 90 to 140 inches of rain per year, while precipitation in coastal lowlands averages from 20 to 60 inches (NPS 2007c).

VEGETATION

As described previously, vegetation in the park varies with the climate, elevation and topographic exposure (exposed or sheltered from trade wind showers). The fire management plan (NPS 2005a) for Hawai‘i Volcanoes National Park identifies seven environmental zones, adapted from vegetation maps

created by Mueller-Dombois and Fosberg (1974), each with different plant communities: alpine/aeolian, subalpine, mesic/wet forest, montane seasonal, mid-elevation seasonal, coastal lowland, and Kahuku pasture/mesic forest. The plant communities supported in these zones (shown on figure 7) are home to more than 400 native species of vascular plants, as well as 600 non-native vascular plant species. These plant communities are described in the following sections, which include discussions of climatic and geographic factors that affect their composition, as well as the highly invasive non-native species present that threaten park ecosystems and the fire environment. These descriptions are followed by a summary of the influence that non-native ungulates have on plant communities.

ALPINE/AEOLIAN

The upper portions of the Mauna Loa and Kahuku units are in this zone, which varies in elevation from 8,500 feet to the 13,677-foot summit of Mauna Loa (2,591 to 4,169 meters). This zone experiences average temperatures ranging from 43°F to 48°F and rainfall from 20 to 28 inches, with frequent nightly frost in the winter months. Most of the alpine zone is characterized by nearly barren lava flows with sparse, low, vegetation consisting of small patches of stunted native shrubs, mostly pūkiawe (*Leptecophylla tameiameiae*) and ʻōhelo (*Vaccinium reticulatum*). Grasses, sedges, lichens, and mosses comprise the rest of the plant life (NPS 2005a). This zone also contains isolated kīpuka, which are large and small areas untouched by recent lava flows that are "islands" of plant and animal life surrounding by a "sea" of lava (NPCA 2008; NPS 2005a). There is very little or no vegetation in the areas above 11,000 foot elevation. Within this zone, no fires have been documented; and there is essentially no wildfire potential. Most of the alpine zone is still exposed to occasional mouflon sheep and feral goats.

SUBALPINE

This zone extends from 6,500 to 8,500 feet (1,981 to 2,591 meters) (and higher). The average annual temperature ranges from 49°F to 54°F, with occasional winter frost. In the Mauna Loa Unit, rainfall averages are from 30 to 40 inches per year (summers are dry and most precipitation is in the winter). Low-lying clouds cause fog-drip from trees and shrubs, which contributes to precipitation. The climate of the Kahuku subalpine environment is decidedly moister, with nearly daily cloud cover and light precipitation on the southeast slope, upslope of the Kaʻū and Kapāpala forest reserves (Doty and Mueller-Dombois 1966).

In the Mauna Loa Unit, much of the subalpine vegetation is concentrated in two major kīpuka on older pāhoehoe lava flows. Sparsely vegetated lava flows dominate many areas of this zone. The most widespread plant community in the subalpine is ʻōhiʻa (*Metrosideros polymorpha*) scrub, with an understory of open native shrubs and grasses. Scrub is characterized by scattered, short, ʻōhiʻa with native shrub and grasses. ʻŌhelo, pūkiawe, and ʻaʻaliʻi (*Dodonaea viscosa*) are the most abundant native shrubs, while the most abundant grass is the native bunchgrass *Deschampsia nubigena*. Vegetation on the extensive, younger ʻaʻā flows consists of scattered and very scattered native ʻōhiʻa trees and native shrubs. In the Mauna Loa Unit, where ungulates have been removed, native plants dominate the vegetation, māmane (*Sophora chrysophylla*) is regenerating, and recovery of rare plants (including the endangered Mauna Loa silversword [*Argyroxiphium kauense*]) through active restoration has begun. (NPS 2005a). Vegetation is similar in Kahuku, but four decades of browsing by mouflon sheep has reduced native species abundance and diversity (Benitez et al. 2008; NPS 2005a).

The potential for large or intense wildfires in the subalpine is low. Patches of vegetation with closely spaced shrubs and grasses are small and discontinuous. Vegetation is sparse and low growing, with low fuel loadings. Young lava flows dissect subalpine fuel beds creating a natural barrier to firespread.

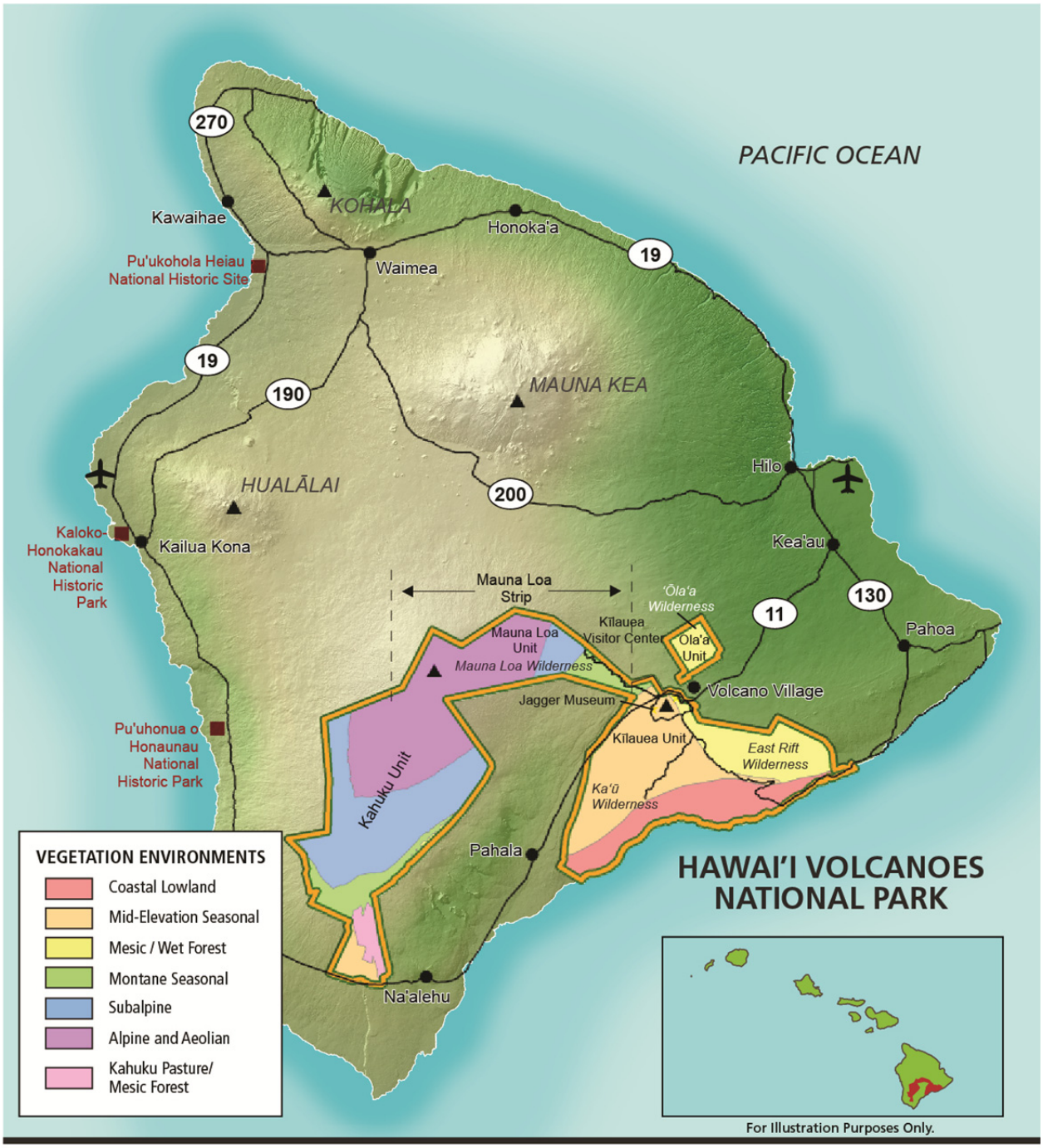


FIGURE 7:
Hawai'i Volcanoes National Park Vegetation Environments

MONTANE SEASONAL

In the Mauna Loa unit, the montane seasonal zone occurs between 4,000 and 6,700 feet (1,219 to 2,042 meters) and is dry during the summer, with variations in annual rainfall depending on elevation (60 inches per year at 4,000 feet (1,219 meters) in elevation and 40 inches per year at 6,000 feet (1,829 meters) in elevation). In Kahuku, the area at 5,000 to 6,000 feet (1,524 to 1,829 meters) on the southwest-facing slope can also be characterized as montane seasonal. This zone in Kahuku is wet in the summer, and is characterized by frequent afternoon cloud buildup and low-lying fog (NPS 2005a).

In the Mauna Loa Unit, most of the montane seasonal environment is densely vegetated and found on 750- to 4,000-year-old lava flows, although several massive, more recent (late prehistoric or historic) ʻaʻā flows also penetrate this zone. The vegetation of this zone varies considerably with soil depth and substrate age. For example, the most diverse and well-developed forests occur at Kīpuka Kī and Kīpuka Puaulu—the most biologically rich site in the park—which are islands of ash soil more 1,500 to 3,000 years old on the lower east end of the Mauna Loa Unit (4,000 to 4,400 feet (1,219 to 1,341 meters) in elevation). Although included in the montane seasonal fire management unit, these kīpukas support a rare mesic forest community characterized by mānele (*Sapindus saponaria*) / koa (*Acacia koa*) / ʻōhiʻa forest community, as well as several threatened, endangered, or candidate species, or species of concern (discussed later in this chapter) (NPS 2005a).

Above 5,000 feet (1,524 meters) elevation, most soils are shallow, discontinuous ash deposits over weathered pāhoehoe. Where deeper soils occur, koa dominates the forest and contains an understory comprised of native shrubs pūkiawe and ʻaʻaliʻi, sedges, and a mixture of alien meadowrice grass and native grasses. At lower elevations koa forest understory is dominated by alien pasture grasses, a legacy of 150 years of cattle grazing. Across elevations within this zone, small stands of shrubland and grassland persist on shallow soils. The shrublands are dominated by native shrubs pūkiawe and ʻaʻaliʻi with a continuous understory of mixed alien and native grasses at lower elevations and native bunchgrasses above 5,000 foot elevation. Grasslands are generally small and are dominated by alien grasses at lower elevation and native bunch grasses at upper elevation.

Vegetation in the montane seasonal zone in Kahuku is dominated by closed stands of ʻōhiʻa forest with a native shrub, fern, and mixed native-alien grass understory. Koa may or may not be a component in these forests. Koa is more prevalent on the west side of Kahuku (above TNC Kona Hema Preserve). This area was impacted by cattle and logging and much of the native understory has been replaced by nonnative kikuyu and meadowrice grass. Since non-native ungulate removal efforts were initiated, vigorous recruitment of young koa has occurred.

Across the Kahuku and Mauna Loa units, ʻaʻā flows are characterized by open to sparse ʻōhiʻa woodlands with a sparse native shrub understory in many areas. Other areas consist of very scattered native shrubs (grass is never abundant) (NPS 2005a).

Historically, wildfires have been rare in this zone. Only one large wildfire has been observed on the Mauna Loa Unit. In 1975, a fire swept through 2,000 acres of koa forest, shrublands and grasslands from an adjacent ranch. In spite of abundant fuel, there has been no wildfires since then. Part of this may be due to vigorous fire prevention, closing the Mauna Loa Strip Road in very high and extreme fire danger. Fire history of Kahuku is not known in detail. A wildfire starting in adjacent ranchlands penetrated a stand of ʻōhiʻa and koa in 1993. Recovery of koa and other species following wildfire has been inhibited by browsing of mouflon sheep, while ʻōhiʻa and naio (*Myoporum sandwicense*), plants ignored by sheep, are recovering rapidly after fire by resprouting. Fire may have played an important role in the evolution of portions of the montane seasonal zone on the Mauna Loa Unit (Mueller-Dombois 1981). This is suggested by the fact that there are continuous fine fuels in the form of native grasses and shrubs and that

many of the dominant plant species, including koa, ʻaʻaliʻi, and native grasses recover rapidly from fire by resprouting (in the absence of ungulates). On the other hand, the montane seasonal communities are at a highly dynamic stage of development. The suite of species on Mauna Loa Unit that responded positively to release from herbivores may share characteristics common to fire-adapted species. Historical fire is not known from the unique, species-rich Kīpuka Kī and Kīpuka Puaulu. The fire tolerance of the many woody species in these mesic forest kīpuka, including the numerous rare species, is not known.

MESIC/WET FOREST

Mesic and wet forests grade into each other along the sharp rainfall gradients that characterize the park. Almost all wet forests, which include areas with approximately 90 to 140 or more inches per year, are found on the eastern edge of the park, which receives nearly daily trade-wind rains. These forests are found in four locations: on the eastern rim of the summit caldera of Kīlauea Volcano, along the East Rift of Kīlauea above approximately 2,300 feet (701 meters) in elevation, in ʻŌlaʻa Forest (a 10,000-acre part of the park east of the community of Volcano), and in Kahuku on the eastern edge of the pastures and upslope of Kaʻū and Kapāpala forest reserves between 3,000 and 5,000 feet (914 and 1,524 meters) in elevation (NPS 2005a).

Mesic/Wet Forest Habitat – Hawaii Volcanoes National Park

Source: National Park Service

Wet forests at Hawaiʻi Volcanoes National Park are characterized by two major plant associations: tree fern (*Cibotium glaucum*) and uluhe fern (*Dicranopteris linearis*) forests. Tree fern forests are multi-layered, dominated by ʻōhiʻa and tree ferns, and are best developed on the older, deep ash soils of ʻŌlaʻa Forest and some areas of the East Rift. Most of the wet forest in ʻŌlaʻa is dominated by a dense canopy of tree fern, often co-mingled or slightly overtopped by open stands of other native trees. The relatively young substrates of volcanically active areas at Kīlauea summit and the East Rift support closed canopy stands of ʻōhiʻa, with a subcanopy of other native trees and tree ferns. Ground cover is dense and consists of a high diversity of native ferns, as well as native shrubs and herbaceous plants (NPS 2005a).

Uluhe fern forests are found at the summit of Kīlauea and along the East Rift, and are characteristic of early successional communities that occur on younger lava flows and in secondary successional communities following ʻōhiʻa dieback. Uluhe is a dense matted fern that grows 3 to 20 feet (1 to 6 meters) tall and suppresses all vegetation, native and non-native. As a result, species diversity is lower in uluhe forests when compared to tree fern forests (NPS 2005a).

Mesic forests, which receive approximately 60 to 90 inches of rain per year, are found primarily east of Chain of Craters Road and west of wet forests, mākai (oceanside) of wet forest in the southeastern section of the park, and upslope of Kaʻū and Kapāpala forest reserves in Kahuku. These forests are dominated by closed to open stands of ʻōhiʻa and koa forest with highly variable understory vegetation. In Kahuku, the understory consists of tree ferns and native trees or shrubs. East of Chain of Craters Road, the understory is similar, but many areas have dense stands of introduced faya tree (*Morella faya*) or native uluhe fern. The understory of mesic forest in the lower East Rift of Kīlauea is dominated by continuous swards of introduced swordfern (*Nephrolepis* sp.) (NPS 2005a).

Wildfire is uncommon in most mesic and wet forest in the park. In wet forest, fires have typically occurred in uluhe after rainless periods of several weeks and when the dead fronds and leaf litter dries out. Only the mesic forest stands in the lower East Rift have had a recent history of fire. In these stands, the dense native understory has been replaced by invasive swordfern which carries wildfire readily under dry, windy conditions.

MID-ELEVATION SEASONAL

This zone is found between approximately 1,000 and 4,000 feet (305 and 1,219 meters) in elevation in the leeward part of the park. As a result, it is sheltered from daily trade-wind rains and precipitation varies from 20 to 60 inches per year. Vegetation of the mid-elevation seasonal environment varies with substrate and rainfall. For example, younger flows, or deep cinder with little ash-soil development, typically support sparse native shrubs, primarily pūkiawe and ʻaʻaliʻi, and scattered, short ʻōhiʻa. Flows with deeper ash support dry ʻōhiʻa woodland. However, this plant community has been altered by the introduction of non-native plants and fire. In many areas, the understory is dominated by non-native bush beardgrass (*Schizachyrium condensatum*), broomsedge (*Andropogon virginicus*), and molasses grass (*Melinis minutiflora*), which form a nearly continuous matrix between the open layers of native shrubs. In Kahuku, where mouflon sheep and other ungulates remain on the landscape, a similar open to sparse woodland structure with an understory dominated by tall non-native grasses bush beardgrass, broomsedge and barbed wire grass (*Cymbopogon refractus*) prevails. The non-native shrub Christmasberry (*Schinus terebinthifolius*) is also present and dominates portions of this zone. Other areas of the park (not including Kahuku) have been invaded by the non-native faya tree, which has become a codominant with ʻōhiʻa in some areas and displaced it in others. In addition, the majority of dry ʻōhiʻa woodlands on Kīlauea have burned in the last 40 years, creating savannas of scattered ʻōhiʻa and native shrubs with abundant non-native grass (NPS 2005a).

Wildfire has been most prevalent in the mid-elevation seasonal environment of the park. Invasion of fire-adapted non-native broomsedge and bush beardgrass was noted in the mid 1960s (Doty and Mueller-Dombois 1966), despite the presence of large numbers of feral goats in the area. Apparently, the grasses were not a preferred forage for goats (Baker and Reeser 1972), and instead grew abundantly thereby facilitating the spread of large wildfires. Nearly two-thirds of the mid-elevation seasonal environment (excluding young lava flows) have been affected by wildfire over the last 40 years. After fire, grasses out-compete native woody plants and increase in cover and fuel loading (Hughes et al. 1991; D'Antonio et al. 2000). Burned sites are then predisposed to more severe fires in the future compared to adjacent unburned woodlands because of increased fuel loadings and because wind speeds are substantially greater in the more open post-fire savannas (Freifelder 1998). Over the last ten years, the park has conducted several large scale planting projects in burn areas with the goal of restoring native plant diversity and vegetation structure in affected areas (Loh et al. 2007; McDaniel et al. 2008). The park has adapted its native plant restoration efforts to this new fire regime by focusing recovery efforts on native species that are more fire-tolerant (Loh et al. 2007; Loh, et al. 2009). Among the fire-tolerant native species are many that are considered highly palatable to goats (e.g., naio, māmane, ʻiliahi [*Santalum paniculatum*], koʻokoʻolau [*Bidens hawaiiensis*]) and could not be restored without first excluding these animals from

the area. In Kahuku, where mouflon sheep and other feral ungulates remain on the landscape, species favored by ungulates as forage such as māmane and ʻiliahi are uncommon.

COASTAL LOWLAND

The coastal lowland environment lies below the mid-elevation seasonal environment and includes the immediate shoreline, the coastal plain upland of the large fault scarps or pali (cliffs/ridges), and the faces of the pali. Typically warm and dry, rainfall varies from less than 20 inches per year in the western part of the park to about 60 inches per year along the eastern boundary. These dry conditions, combined with the relatively young age of the substrate, limit the development of vegetation in this zone (NPS 2005a).

A narrow band of coastal strand vegetation is found along parts of the immediate shoreline. Vegetation varies from naupaka (*Scaevola taccada*) dominated scrub to sparse salt-tolerant herbs. The endangered grass *Ischaemum byrone*, the endangered loulu palm (*Pritchardia affinis*), and the species of concern, *Portulaca villosa* grows in a number of locations where planted. The endangered shrub ʻōhai (*Sesbania tomentosa*) grows in some coastal strand sites. Interior, the coastal lowlands are now largely dominated by grasses. The wetter, eastern portions have the remains of a coastal shrubland, modified by fire. Prior to fire this community was dominated by tall ʻākia (*Wikstroemia sandwicensis*) shrubs, along with other native shrubs including ʻa'ali'i and ʻūlei. Alien broomsedge and bush beardgrass, along with native pili grass (*Heteropogon contortus*), formed a matrix between the shrubs and permitted wildfires to spread. Most of the ʻākia shrublands burned in the Pu'u ʻŌ'ō eruptions that started in 1983 and only persist in small pockets. The remainder has since been buried by lava or converted to low open shrubland with scattered ʻa'ali'i and ʻūlei, with broomsedge, bush beardgrass, and pili grass growing between the shrubs. The drier, western portion of the coastal lowlands are dominated by alien grasslands with patches of alien shrubs. The dominant grasses are alien Natal redtop (*Melinis repens*), thatching grass (*Hyparrhenia rufa*), molasses grass (*Melinis minutiflora*), bush beardgrass, and broomsedge. Native pili grass, a fire-adapted species, is an important component of the grasslands in some areas. The coastal lowlands also contain small scattered stands of dry and mesic forests on the faces of the pali. Younger flows are dominated by open stands of ʻōhi'a, while older flows support stands of native tree lama (*Diospyros sandwicensis*) with an understory of the shrub alahe'e (*Psydrax odorata*). A number of threatened, endangered, candidate species, including kauila (*Alphitonia ponderosa*), hala pepe (*Pleomele hawaiiensis*), ʻahakea (*Bobea timonioides*), and ʻohe makai (*Reynoldsia sandwicensis*) occur in lama forest. Lama forest in the park have been greatly reduced in the last 30 years by lava flows so that just a few patches remain (NPS 2005a).

Fire is generally not a major concern in the coastal strand, except for the upper fringe of the strand in some areas. Where grass fuels are present, they tend to be low growing and scattered. Further inland, wildfire has become relatively frequent over the last 30 years. Feral goats were removed in the early 1970s. Although this allowed for some recovery and prevented further loss of pili and other native plant species from damage by herbivores, tall, perennial, fire-promoting grasses quickly replaced low growing grasses adapted to grazing pressure. Within remaining dry and mesic forest, grass fuels are common only in the smaller lama forest patches. However, fire may carry in alien sword fern and lantana during extreme fire conditions.

KAHUKU PASTURE/MESIC FOREST

This zone encompasses 7,200 acres of former cattle pasture containing remnants of mesic forest located on the lower east end of the Kahuku Unit on the south slope of Mauna Loa, extending from 2,500 feet in elevation to 5,000 feet in elevation (762 to 1,524 meters in elevation). The area extends east to mesic forest (60 to 80 inches of rain per year) and to the west lies adjacent to seasonally dry ʻōhiʻa woodlands (40 to 60 inches of rain per year) (NPS 2005a).

Vegetation is generally characterized by abundant alien grasses and an open canopy of ʻōhiʻa or ʻōhiʻa-koa. Fragments of native forest are scattered across this area and become increasingly abundant on the east end of the park boundary that lies adjacent to the state Kaʻū Forest Reserve. Vegetation surveys conducted in 2007, identified a number of rare plants remaining in forest fragments and as individuals in the pasture, including the only ʻohe (*Tetraplasandra hawaiensis*) and olonā (*Touchardia latifolia*) individuals found in the Kahuku Unit and several endangered species discovered in a pit crater and ravine (Benitez et al. 2008). Until recently, domestic cattle along with mouflon sheep and pigs damaged remaining forest fragments and suppressed establishment of many native seedlings. Domestic cattle were removed in 2010. Experiments in four 10-acre fenced exclosure units are evaluating methods for restoring native forest following exclusion of all ungulates.

There is very little documented fire history for this area. The last reported wildfire was in 2005, when a human-caused fire swept across several acres of Kikuyu grass (*Pennisetum clandestinum*).

INFLUENCE OF NON-NATIVE UNGULATES

Non-native ungulates have caused extensive damage to individual plants and altered plant communities in the park. These impacts have occurred across the different vegetation environments everywhere ungulates have been found. Because much of the endemic vegetation of Hawaiʻi evolved over millions of years in the absence of large mammalian herbivores they are particularly vulnerable to the effects of non-native ungulates.

Feral pigs are a major modifier of Hawaiian wet forest. Pigs selectively seek out certain native plant species for food including hāpuʻu tree ferns, other understory ferns, ʻieʻie (Freycineatia arborea), and lobeliads (Diong 1982; Stone and Loop 1987).

On the Island of Hawaiʻi, feral goats, sheep, pigs, cattle and domestic cattle destroy native vegetation through trampling and feeding, leading to species loss (Baker and Reeser 1972; Scowcroft and Conrad 1992; Stone and Loope 1987). In forests, large-canopy trees often persist for some time despite this disturbance, but natural regeneration of canopy species is suppressed, and forest integrity declines dramatically. Also, as vegetation is removed conditions are created for the establishment of non-native plants that contribute further to the decline of native plant communities (Jacobi 1981; Merlin and Juvik 1992). Rare plant species, due to their low numbers, are particularly at risk for local extirpation or extinction (USFWS 1996a, 1996b, 1999). Feral pigs are a major modifier of Hawaiian wet forest. Pigs selectively seek out certain native plant species for food including hāpuʻu tree ferns, other understory ferns, ʻieʻie (*Freycineatia arborea*), and lobeliads (Diong 1982; Stone and Loop 1987). The destruction of hāpuʻu, a major component of wet forest on the Island of Hawaiʻi, is a particular concern as the fibrous trunk serves as nurse logs for native seedlings. Pigs create conditions for the spread of highly disruptive invasive weeds by opening up habitat as well as transporting propagules in their hair and feces (Aplet et al. 1991; Diong 1982; LaRosa 1992). Also, by removing vegetation, pigs increase erosion and nutrient losses which in turn may limit the potential for vegetation recovery.

Many of these impacts along with the subsequent response of vegetation following release from ungulate pressure have been documented within the park. These include damage by feral goats in the parks dry and seasonally dry environments on Kīlauea (Baker and Reeser 1972); feral pigs in wet forest in ʻŌlaʻa and Kīlauea's East Rift (Katahira 1980; Cooray and Mueller-Dombois 1981; Taylor and Stone 1986; Aplet et al. 1991; Loh and Tunison 1999); effects of multiple ungulates in montane seasonal habitat on Mauna Loa (Spatz and Mueller Dombois 1973; Tunison et al. 1994); and koa regeneration following mouflon sheep control in montane seasonal habitat at Kahuku (Loh et al. 2005; HDLNR 2005c).

In the subalpine where ungulates have been removed, native plants dominate the vegetation, māmane is regenerating, and recovery of rare plants (including the endangered Mauna Loa silversword) through active restoration has begun. Species diversity is lower in the Kahuku subalpine zone, where animals remain (NPS 2005a; Benitez et al. 2008).

Where ungulates have been removed from portions of mesic and wet communities on Kīlauea and 'Ōla'a, native understory species and tree seedlings are recovering and managers are implementing recovery efforts for rare, threatened, and endangered species (Loh and Tunison 1999; Pratt et al. 1999; Pratt et al. 2009). Outside of fenced units, native understory vegetation continues to deteriorate (Cole et al. in press). The impact on native understory vegetation is noticeable in portions of Kahuku where impacts by feral mouflon sheep, pigs and cattle have removed much of the vegetation understory.

In the montane seasonal zone of the Mauna Loa Unit, koa forest rapidly expanded into shrublands and grasslands following removal of ungulates in the 1970s (Tunison et al. 1994; Tunison et al. 1995). However, at lower elevations, the understory below the koa canopy is dominated by non-native pasture grasses, a legacy of decades of cattle grazing. In Kahuku, past cattle grazing and continued presence of mouflon sheep and pigs continue to impact this zone by damaging mature plants and seedlings. However, in former koa forest where animal numbers have been reduced to remnant levels, rapid regeneration of koa by root sprout and seedlings has occurred (Loh et al. 2005; HDLNR 2005c). Seedling regeneration by other native trees and shrubs (e.g., ʻaʻaliʻi, māmane, akala [*Rubus hawaiiensis*] and naio) is limited by the scarcity of mature individuals remaining in the area.

In the mid-elevation seasonally dry zone of Kīlauea, removal of feral goats prevented further loss of native species through browsing, and allowed for the reintroduction of rare plants by park managers. However, the invasion of fire-adapted non-native broomsedge and bush beardgrass, which began in the 1960s while ungulates were present and continued following animal removal, has increased fire frequency and size, resulting in the loss of fire-sensitive native plants (Tunison et al. 2001). Park staff have modified native plant restoration efforts to this new fire regime by focusing recovery efforts on native species that are fire-tolerant (Loh et al. 2007; Loh et al. 2009). Among these fire-tolerant native plants are many species that are considered highly palatable to goats (e.g., naio, māmane, ʻiliahi [*Santalum paniculatum*], koʻokoʻolau [*Bidens hawaiiensis*]) and could not be restored without first excluding these animals from the area. In Kahuku, where mouflon sheep and other ungulates remain on the landscape, many of these species are uncommon.

In the coastal lowlands of Kīlauea, high concentrations of feral goats left many areas denuded of vegetation and heavily eroded (Baker and Reeser 1972). Following the removal of goats in the 1970s, vegetation in the coastal lowlands has been characterized by recovering coastal strand vegetation, remnant dry shrubland and forest and native pili grasslands to the east, and invasion of tall non-native fire-adapted grasses to the west (Tunison et al. 2001). Since the removal of goats, park managers have begun restoration efforts for rare plants (Pratt et al. 2009); and conducted several small research burns to evaluate the use of prescribe fire to perpetuate fire-tolerant native species (many of which were vulnerable to herbivores) in pili grasslands (Tunison et al. 2001).

NON-NATIVE PLANTS

Over half of the 950 vascular plant species found at Hawaiʻi Volcanoes National Park are non-native, and more than 100 species are considered highly disruptive to native ecosystems (Smith 1985). The more disruptive species reduce native plant diversity and abundance and cause the local extinction of

Over half of the 950 vascular plant species found at Hawaiʻi Volcanoes National Park are non-native, and more than 100 species are considered highly disruptive to native ecosystems (Smith 1985).

species. Some non-native species such as faya tree (*Morella faya*), fountain grass (*Pennisetum setaceum*), and strawberry guava (*Psidium cattleianum*) are able to completely replace native plant communities and form monospecific stands.

About 50 of the non-native plants in the park are locally distributed, making it feasible to contain or eliminate their populations. For more widespread species, management is focused on excluding them from high priority management areas called Special Ecological Areas (SEAs). Fountain grass is among the few widespread species that is removed parkwide. Fountain grass is a highly aggressive fire-promoting non-native species occurring at very low densities over 100,000 acres of the drier sections of the park. One of the few non-native species that can colonize young lava flows, if left unchecked it would convert barren lava flows to non-native grass savannas, increase fire potential, prevent the natural succession of native shrubland and forest, and greatly alter the visual landscapes of the park. Biannually, managers search for and remove all fountain grass plants from the park.

Non-native Fountain Grass
Source: NPS - http://www.nps.gov/plants/alien/fact/pese1.htm.

See the "Cumulative Impact Scenario" section in chapter 4 for more information on non-native plant control in the park.

VEGETATION AND THE ROLE OF CLIMATE CHANGE

Results of documented temperature changes in Hawai‘i show a fairly rapid rise in surface temperature over the past 30 years, with more rapid warming occurring at higher elevations (Giambelluca et al. 2008). Stronger warming trends, especially at higher elevations, can have severe ecological impacts in Hawai‘i, including consequences on water resources and native biodiversity (Giambelluca et al. 2008).

The two key climatic features of Hawaiian montane forests are the northeast trade winds and the associated trade-wind inversion, which influence humidity and precipitation, and as a result influence the distribution of plant communities. Studies show that both local temperature and the elevation of the trade-wind inversion, which averages 1,900 meters, have responded substantially to past climate changes (Benning et al. 2002). If the frequency of occurrence or the height of the trade-wind inversion are affected by climate warming, it will have substantial effects on precipitation throughout Hawai‘i, but especially on the upper mountain slopes. Trends in rainfall (lower rainfall) and recent changes in the trade-wind inversion suggest warming may result in drier conditions, which would result in severe impacts on the highly vulnerable ecosystems found in areas above the mean inversion height (Giambelluca and Luke n.d.). Increased variability of rainfall coupled with potential for drought could have profound impacts on cloud forest. For example, results from a study of successional vegetation on lava flows at Mauna Loa suggest that severe drought is a likely mechanism causing or reinforcing a shift from dominance by woody species to dominance by herbaceous species (Loope and Giambelluca 1998).

As a result of global climate change, changes in the occurrence or height of the trade-wind inversion, carbon dioxide, temperature, water availability, nutrient availability, and cloud cover can all affect the resistance of plants and trees to introduced herbivores.

As a result of global climate change, changes in the occurrence or height of the trade-wind inversion, carbon dioxide, temperature, water availability, nutrient availability, and cloud cover can all affect the resistance of plants and trees to introduced herbivores. For example, increased carbon dioxide can reduce leaf nitrogen, and herbivores will respond with either decreased growth or increased consumption. Herbivores and pathogens can alter the species composition and size structure of forests, which can in turn affect ecosystem processes such as evapotranspiration (loss of water from the soil by evaporation and transpiration from plants), carbon dioxide flux (change in the output and intake of carbon dioxide), and heat transfer, thereby creating feedbacks to climate (Ayres and Lombardero 2000). Anthropogenic climate change and shifts in the trade-wind inversion (changing patterns of cloud cover, rainfall, and humidity) can both interact with past land-use changes and biological invasions to drive several of the remaining native species of Hawai‘i to extinction (Benning et al. 2002). In general, invasion by a single species combined with warming trends can alter the composition and dynamics of an entire ecosystem (Simberloff 2000; Vitousek et al. 1997).

NATIVE WILDLIFE AND WILDLIFE HABITAT

Hawai‘i Volcanoes National Park protects a unique diversity of wildlife and habitat. The majority of the native wildlife in Hawai‘i is endemic (found nowhere else on earth) (NPCA 2008). This section focuses on the native terrestrial wildlife species, including mammals, birds, invertebrates, and reptiles in the park that could be affected by ungulate management and by the expected results of the proposed alternatives.

MAMMALS

The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is the only native land mammal in the park and in the Hawaiian Islands. Known in Hawai‘i as ‘ōpe‘ape‘a, the nonmigrant Hawaiian hoary bat occurs over a wide range of elevations (primarily from sea level to 7,500 feet [2,288 meters]). Data regarding the habitat and population status of this species are very limited, but available documentation suggests that the ‘ōpe‘ape‘a appears to be most numerous in native dry to mesic forests, and is often associated with native forest edges (Pratt et al. 2009; USFWS 2009a). The Hawaiian hoary bat was first listed as federally endangered in 1970 and continues to hold that status (USFWS 2009a). More information regarding this species is provided in the “Rare, Unique, Threatened, or Endangered Species” section of this chapter.

Hawaiian Hoary Bat
Source: National Park Service

The only native marine mammal associated with Hawai‘i Volcanoes National Park is the Hawaiian monk seal (*Monachus schauinslandi*), or ‘īlio-holo-i-ka-uaua. This mammal is also federally listed as endangered, and can be observed occasionally

swimming offshore or resting at remote beaches in the park. Because neither this species nor its habitat would be affected by non-native ungulate management actions, it is not analyzed further in this document.

The other 12 mammals in Hawai‘i Volcanoes National Park are all non-native (NPCA 2008).

BIRDS

Many bird species survive in and depend on the habitat provided within the park boundaries, from the seacoast to the alpine/aeolian (NPS 2006h). Of the 87 species of birds present in the park, 41 are non-native (NPCA 2008).

‘i‘iwi
Photo credit © Jack Jeffrey

Hawaiian forest birds are an important component in native Hawaiian rainforests, carrying out vital ecosystem processes such as seed dispersal, pollination, and nutrient cycling (USGS 2005a). Of the 23 surviving endemic Hawaiian songbird species, those living in the park include 6 Hawaiian honeycreepers: ‘apapane (*Himatione sanguinea*), ‘amakihi (*Hemignathus virens virens*), ‘i‘iwi (*Vestiaria coccinea*), ‘ākepa (*Loxops coccineus*), ‘akiapōlā‘au (*Hemignathus munroi*), and the Hawai‘i creeper (*Oreomystis mana*) (NPCA 2008; NPS 2006g). In general, Hawaiian honeycreepers are now restricted to koa and ‘ōhi‘a forests at high elevations, generally above 4,000 feet (1,219 meters), while some rare species of Hawaiian honeycreepers are restricted to forests above 5,000 feet (1,525 meters). ‘Apapane, ‘amakihi, ‘i‘iwi, ‘akiapōlā‘au, and the Hawai‘i creeper all rely on tall ‘ōhi‘a trees for nesting habitat. The ‘ākepa generally nest in tree hollows, rather than on tall branches like other Hawaiian honeycreepers (Pratt et al. 2009). The latter three species are all listed as federally endangered, and are further addressed in the “Rare, Unique, Threatened, or Endangered Species” section of this chapter. Hawaiian honeycreepers, once abundant in the park and the Hawaiian Islands, have experienced drastic reductions in population size since the arrival of Europeans. Factors contributing to their demise include loss of forest habitat, introduction of small mammals and predators, and various avian diseases such as mosquito-transmitted diseases (USGS 2006c).

The pueo, or Hawaiian short-eared owl (*Asio flammeus sandwichensis*), is another bird species endemic to Hawai‘i. This species can be found on the island from sea level to 8,000 feet (2,450 meters). While the pueo occupies a variety of habitats, including dry and wet forests, shrublands, grasslands, and montane parklands, many bird species in the park are dependent on food resources from the forest understory and midcanopy (NPS 2009j; HDLNR 2005a). The native thrush, ‘ōma‘o (*Mayadestes obscurus*), spends much time midcanopy eating fruits of subcanopy trees, including kāwa‘u (*Ilex anomala*), kōlea (*Myrsine* spp.), and ‘olapa (*Cheirodendron trigynum*) (NPS 2009j; USGS 2006b). Ōma‘o is the most common of the Hawaiian thrushes and occurs mainly in native ‘ōhi‘a and koa forests above 3,280 feet (1,000 meters). This species prefers forests with a closed canopy 80 to 130 feet (25 to 40 meters) in height, with many fruiting trees in the understory (Audubon 2007). ‘Oma‘o also occur and breed in alpine habitat on Mauna Loa. These birds may be a distinct population from forest ‘Oma‘o (Hawaii Audubon Society 2005). The Hawai‘i ‘elepaio (*Chasiempis sandwichensis*), or flycatcher, is an insect feeder that occurs in a variety of forest habitat, including dry to mesic koa forest on Mauna Loa and ‘ōhi‘a wet forest in ‘Ōla‘a and Kīlauea (Stone and Pratt 2007).

Three additional endangered species of endemic Hawaiian birds found in the park include the nēnē (Hawaiian goose, Branta sandvicensis), ʻuaʻu (Hawaiian petrel, Pterodroma sandwichensis), and ʻio (Hawaiian hawk, Buteo solitarius) (NPS 2008b).

Three additional endangered species of endemic Hawaiian birds found in the park include the nēnē (Hawaiian goose, *Branta sandvicensis*), ʻuaʻu (Hawaiian petrel, *Pterodroma sandwichensis*), and ʻio (Hawaiian hawk, *Buteo solitarius*) (NPS 2008b). Habitat for the nēnē is highly variable, and ranges from sparsely vegetated lava flows to scrubland to open grasslands (NPS 2009j). Uaʻu nesting habitat is quite variable statewide, ranging from heavily vegetated, forested slopes on Lanai and Kauai to subalpine and alpine environments on Maui and Hawaiʻi (Simons and Hodges 1998). In the park, the species nests in pits, cracks and lava tubes within sparsely-vegetated, weathered pahoehoe lava flows on Mauna Loa (Hu et al. 2001). The ʻio prefers native and non-native forests, grasslands, and cane fields, and generally nests in native ʻōhiʻa trees (USFWS 1984). These species are described further in the "Rare, Unique, Threatened, or Endangered Species" section of this chapter.

INVERTEBRATES

Approximately 98 percent of the native invertebrates documented in the park are endemic to Hawaiʻi (NPS 2003a). The majority of these invertebrates are dependent on the health of the native plant populations, which they use for food and shelter (NPCA 2008).

Among the more than 1,100 documented native invertebrate species in the park, there are only two native butterflies: the Kamehameha butterfly (*Vanessa tameamea*), which is Hawaiʻi's state insect, and the Blackburn's blue (*Udara blackburni*). Māmaki is the preferred host plant for the Kamehameha butterfly, while koa and ʻāʻaliʻi are favored by Blackburn's butterfly (HDLNR 2009). Other native invertebrates include 200 species of moths; over 150 beetles (order Coleoptera) that include the colorful koa bug (*Plagithmysius varians*); approximately 150 species of bees and wasps (order Hymenoptera); and a number of hoppers, scales and insects (order Hemiptera), true bugs (order Heteroptera), nerve-winged insects (order Neuoptera), crickets and katydids (order Orthoptera), damseflies and dragonflies (order Odonata), spiders (order Araneae), thrips (order Thysanoptera), and book and bark lice (order Psocoptera). The endemic picture wing fly (family Drosophilidae), of which there are approximately 90 species documented in the park, is among the most studied endemic invertebrate groups and an example of island-hopping speciation (Stone and Pratt 2007).

Other native invertebrates present in the park include the giant Hawaiian darner (*Anax strenuus*), the largest native Hawaiian insect and largest dragonfly in the United States; Hawaiian cave tree crickets (*Thaumatogryllus cavicola*), which live on the ceilings of lava tubes; several carnivorous caterpillars, including *Hyposmocoma molluscivora*, which was discovered in 2003 and is remarkable for its ability to spin webs similar to spiders; and the happy-face spider (*Theridion grallator*), which occurs under plant leaves awaiting its prey (NPCA 2008; Rubinoff and Haines 2006; HDLNR 2009; UNEP-WCMC 2007). Among the terrestrial mollusks or pūpū, the small Hawaiian tree snails (subfamily Achatinellinae) are the most commonly encountered in the park.

REPTILES AND AMPHIBIANS

There are no land-dwelling reptiles and amphibians native to the Island of Hawaiʻi, but two species of sea turtle use the park's shore: the hawksbill sea turtle (*Eretmochelys imbricata*) and the green sea turtle (*Chelonia mydas*). Because these species would not be affected by non-native ungulate management actions, they are not discussed further in this document.

WILDLIFE AND ROLE OF CLIMATE CHANGE

In addition to the factors associated with vegetation (described in the "Vegetation" section of this chapter), which would also affect wildlife habitat, climate change has implications unique to wildlife in Hawai‘i. For example, the biogeographic ranges of species like mosquitoes are set by climate, and changes in climate, including seasonal changes in temperature and rainfall, could lead to a change in ranges and newly established populations (Atkinson and LaPointe 2009; Giambelluca et al. 2008). Accelerated warming at higher elevations may have substantial impacts on Hawai‘i's native endangered and threatened bird species by allowing disease-carrying mosquitoes to reach the high-elevation forests in which the birds find refuge (Giambelluca et al. 2008). Hawaiian honeycreepers, for example, have been eliminated from low- and mid-elevation forests largely due to introduced predators and diseases (Benning et al. 2002). The trade-wind inversion, as described in the "Vegetation" section of this chapter, is likely to have a substantial role in determining the upper extent of forest bird habitat in the Hawaiian Islands. If the trade-wind inversion and its effects on rainfall prevent expansion of forest bird habitat into higher elevations, remaining high-elevation forest bird populations may be squeezed between expanding disease transmission from lower elevations and the upper limits of suitable habitat. These changes would likely drive remaining populations of honeycreepers to extinction (Atkinson and LaPointe 2009). This process could be accelerated by the presence of feral pigs and other non-native ungulates, which can create larval mosquito habitat in otherwise well-drained forests like those in the park, where there are few natural standing water sources (Atkinson and LaPointe 2009; NPS 2009e).

These conclusions are further supported by landscape analyses of three high-elevation forest refuges (Hawai‘i, Maui, and Kaua‘i), which show that climate change is likely to combine with past land-use changes and biological invasions to drive several of the remaining populations of Hawaiian honeycreepers to extinction, especially on the islands of Hawai‘i and Kaua‘i (Benning et al. 2002).

Native Wildlife and Noise

In addition to its effect on humans, noise can adversely affect wildlife communities in parks by interrupting important communication networks for survival and reproduction between insects, birds, and mammals. For example, certain wildlife communications may signify mating calls, danger from predators, and territorial claims (NPS 2009c).

RARE, UNIQUE, THREATENED, OR ENDANGERED SPECIES

FEDERALLY LISTED SPECIES

Under the ESA of 1973, the NPS has the responsibility to address impacts to federally listed threatened and endangered species. The terms "threatened" and "endangered" describe the official federal status of certain species in the park as defined by the ESA. The term "candidate" is used officially by the USFWS when describing those species for which the USFWS has on file sufficient information on biological vulnerability and threats to support issuance of a "proposed rule to list," but issuance of the proposed listing rule is precluded by higher listing priorities. While listing actions of higher priorities go forward, the USFWS works with several private and government agencies to carry out conservation actions for these species to possibly eliminate the need for listing.

The ESA also requires the designation of "critical habitat" for listed species when "prudent and determinable." Critical habitat includes geographic areas that contain the physical or biological features that are essential to the conservation of the species and may need special management or protection, even if the area is not occupied by the species at the time of listing. Critical habitat designations affect only

federal agency actions or federally funded or permitted activities. The ESA requires that such actions avoid "destruction" or "adverse modification" of designated critical habitat (USFWS 2009b).

As of 2010, 437 plant and animal taxa in Hawai'i were listed as endangered or threatened by the USFWS, or approximately 30 percent of all such plants and animals listed for the entire United States (USFWS 2010).

As of 2010, 437 plant and animal taxa in Hawai'i were listed as endangered or threatened by the USFWS, or approximately 30 percent of all such plants and animals listed for the entire United States (USFWS 2010). Based on a review of lists provided by the USFWS (Leonard 2009) and additional information on species in the park provided by NPS staff (NPS 2009j), 35 plants are listed as threatened, endangered, or candidate species under the ESA in the park and its vicinity (NPS 2009e). The park is also home to 13 endangered, 2 threatened, and 3 candidate animal species, including birds, insects, mammals, and reptiles. However, only the endangered, threatened, and candidate species and their habitat that would likely be affected due to non-native ungulate management actions are analyzed and are shown in table 7. These include species historically found in the park (e.g., 'ō'ū [*Psittirostra psittacea*] and a'e [*Zanthoxylum hawaiiense*]) as well as reintroduced and outplanted individuals, the latter a federally listed species translocated to a park unit outside its historic range (NPS 2007d) (e.g., koki'o [*Kokia drynarioides*]) (NPS 2009j).

TABLE 7: ENDANGERED, THREATENED, AND CANDIDATE SPECIES OF HAWAI'I VOLCANOES NATIONAL PARK AND ITS SURROUNDING AREAS THAT COULD BE IMPACTED AS A RESULT OF NON-NATIVE UNGULATE MANAGEMENT ACTIONS

Common Names	Scientific Name	Federal Status
Mammals		
Hawaiian hoary bat	*Lasiurus cinereus* ssp. *semotus*	Endangered
Birds		
Nēnē, Hawaiian goose	*Branta sandvicensis*	Endangered
'Io, Hawaiian hawk	*Buteo solitarius*	Endangered
'Akiapōlā'au	*Hemignathus munroi*	Endangered
'Ākepa, honeycreeper	*Loxops coccineus coccineus*	Endangered
Hawai'i creeper	*Oreomystis mana*	Endangered
'Ō'ū	*Psittirostra psittacea*	Endangered
'Ua'u, Hawaiian petrel	*Pterodroma sandwichensis*	Endangered
'A'o, Newell's shearwater	*Puffinus auricularis newelli*	Threatened
'Akē 'akē, band-rumped storm petrel	*Oceanodroma castro*	Candidate
Insects		
Pomace fly, hammerhead picture-wing[1]	*Drosophila heteroneura*	Endangered
Flying earwig Hawaiian damselfly	*Megalagrion nesiotes*	Endangered
Pomace fly, Mull's picture-wing	*Drosophila mulli*	Threatened
Pomace fly, pāpala picture-wing	*Drosophila digressa*	Candidate
Plants		
Palai lā'au, Pendant Kihi fern	*Adenophorus periens*	Endangered
Ka'ū, Mauna Loa silversword[1]	*Argyroxiphium kauense*	Endangered
no common name	*Asplenium peruvianum* var. *insulare (A.*	Endangered

Common Names	Scientific Name	Federal Status
	fragile var. *insulare)*	
ʻŌhā wai, Lindsey's ʻōhā	*Clermontia lindseyana*	Endangered
ʻŌhā wai, Pele's ʻōhā	*Clermontia peleana peleana*	Endangered
Hāhā[2]	*Cyanea hamatiflora* ssp. *carlsonii*	Endangered
Hāhā, haʻiwale, kanawao keʻokeʻo[3,4]	*Cyanea shipmanii*	Endangered
Hāhā, haʻiwale, kanawao keʻokeʻo[1]	*Cyanea stictophylla*	Endangered
Haʻiwale[1]	*Cyrtandra giffardii*	Endangered
Haʻiwale	*Cyrtandra tintinnabula*	Endangered
Hau kuahiwi[1]	*Hibiscadelphus giffardianus*	Endangered
Hilo ischaemum[1]	*Ischaemum byrone*	Endangered
Kokiʻo[3]	*Kokia drynarioides*	Endangered
Alani, Zahlbruckner's pelea[1]	*Melicope zahlbruckneri*	Endangered
Maʻaloa	*Neraudia ovata*	Endangered
ʻAiea	*Nothocestrum breviflorum*	Endangered
Hōlei	*Ochrosia kilaueaensis*	Endangered
Kīponapona[4]	*Phyllostegia racemosa*	Endangered
Laukahi kuahiwi[1]	*Plantago hawaiensis*	Endangered
Hawaiʻi hala pepe[1]	*Pleomele hawaiiensis*	Endangered
Poʻe, ʻihi mākole[1]	*Portulaca sclerocarpa*	Endangered
Loulu	*Pritchardia affinis*	Endangered
ʻŌhai[1]	*Sesbania tomentosa*	Endangered
ʻĀnunu; white-bur cucumber[1]	*Sicyos alba*	Endangered
no common name	*Spermolepis hawaiiensis*	Endangered
no common name	*Stenogyne angustifolia*	Endangered
Aʻe, Hawaiʻi pricklyash	*Zanthoxylum hawaiiense*	Endangered
ʻAhinahina, Haleakalā silversword, Hawaiian catchfly[3]	*Argyroxiphium sandwicense* ssp. *macrocephalum*	Threatened
Sheriff's catchfly[1]	*Silene hawaiiensis*	Threatened
ʻAkū	*Cyanea tritomantha*	Candidate
ʻOhe	*Joinvillea ascendens* ssp. *ascendens*	Candidate
Holei[3]	*Ochrosia haleakalae*	Candidate
Many-flowered phyllostegia	*Phyllostegia floribunda*	Candidate
Makou, large-flower native buttercup	*Ranunculus hawaiensis*	Candidate
ʻĀnunu, large-leaved ʻānunu, largeleaf bur-cucumber	*Sicyos macrophyllus*	Candidate

Source: Leonard 2009; NPS 2009j.

[1]Species has designated critical habitat in and adjacent to Hawaiʻi Volcanoes National Park.

[2]Species has critical habitat in and adjacent to the park, but species is not known to occur there.

[3]Outplanted species.

[4]Species located adjacent to the park, but natural populations not known to occur in Hawaiʻi Volcanoes National Park.

Mammals

Endangered

Hawaiian hoary bat (*Lasiurus cinereus* ssp. *semotus*). The Hawaiian hoary bat is an endemic subspecies of the hoary bat, a medium-sized, nocturnal, insectivorous bat with brown and gray, white-tinged fur. Hoary bats are solitary and roost among foliage in trees. The Hawaiian hoary bat has been observed foraging in a variety of both open and more vegetated habits, including over open water and near the edges of native forests. The Hawaiian hoary bat is widely distributed on the Island of Hawai‘i and in the park; it is most frequently observed between sea level and 7,500 feet (2,286 meters) (USFWS 1998b). The breeding season for this species typically occurs from April to August when bats seem to shift into the lowlands of the island (Fraser et al. 2007). The largest populations of the Hawaiian hoary bat are thought to occur on Kaua‘i and Hawai‘i. Population numbers are not fully known; however, the bat is believed to have declined in number over the last 100 years (USFWS 1998b). Threats to the Hawaiian hoary bat include habitat destruction (elimination of roosting sites and vegetation supporting invertebrate food sources) and possibly direct and indirect effects of pesticides, introduced insects, and disease (USFWS 1998b; Fraser et al. 2007).

Birds

Endangered

Hawaiian goose; nēnē (*Branta sandvicensis*). The Hawaiian goose has a black head and nape, buff cheeks and neck with black furrows and is heavily barred above and lighter underneath (NPS 2009e). Habitat for this species is highly variable, and ranges from sparsely vegetated lava flows to scrubland to open grasslands from sea level to approximately 7,000 feet in elevation. At the park, nēnē typically nest on lava flows concealed in patchy vegetation; however, nest site selection varies widely across the state. The nesting season is primarily from October through March. Hatchlings are particularly vulnerable to nutritional inadequacies and severe weather; goslings of all ages are vulnerable to predation prior to fledging. During the non-breeding season, the Hawai‘i Volcanoes National Park nēnē flock typically moves to higher elevations in search of seasonally available forage (including berries) and a wetter climate, as lower-elevation breeding areas often dry out during summer months (NPS 2009e).

Hawaiian goose; nēnē
Source: National Park Service

The total population of Hawaiian geese in the park is small (approximately 200 birds), but it is increasing due to successful breeding seasons as a result of habitat management and predator control. In 2006 and 2007, 40 and 30 fledglings were produced, respectively. In previous years the average count was approximately 15 (NPCA 2008). Threats include predation of adults, goslings and eggs by non-native predators (mongooses, cats, dogs, rats, and pigs), habitat loss, poor quality of some remaining habitat, and vehicle collisions (Pratt et al. 2009).

Hawaiian hawk; ʻio (*Buteo solitarius*). The Hawaiian hawk is small and broad-winged with dark or light plumage. Habitat includes most native and non-native forests (including papaya, guava, and macadamia orchards), grasslands, and cane fields. The Hawaiian hawk is more abundant in windward than in leeward forests, avoids dry scrub areas, and prefers either open savanna or denser rain forest (Audubon 2007; USFWS 1984). Nesting occurs March through September, and eggs are typically laid in late April and early May. Clutch size generally varies from one to three eggs (USFWS 1984). Nesting occurs in the high branches of trees of various kinds and heights, ranging from 32 to 78 feet (10 to 24 meters). In a recent survey, native ʻōhiʻa trees were selected 80 percent of the time (Audubon 2007). The Hawaiian hawk can be found anywhere from near sea level to 8,500 feet (2,590 meters) (USFWS 1984). In the park, individuals are regularly sighted in mesic and wet forest on Kīlauea summit and lower Mauna Loa. In a recent survey of Kahuku unit, birds occurred in mesic and wet koa ʻōhiʻa forest, ʻōhiʻa–māmane–naio subalpine woodland, and open pasture with remnant stands of native forest (Tweed et al. 2007). Threats include destruction or disturbance of nesting habitat, predation, avian diseases, and extensive modification and reduction of native forest habitat (USFWS 1984).

ʻAkiapōlāʻau (*Hemignathus munroi*). The ʻakiapōlāʻau is a medium-sized (5.5 inches [14 centimeters]), stocky, short-tailed, yellow-green (males) or green (females) Hawaiian honeycreeper with a long, sickle-shaped upper mandible and a short, straight lower mandible. All recent observations of this species have been in montane mesic and wet forest dominated by koa and ʻōhiʻa or in subalpine dry forest dominated by māmane and naio. ʻAkiapolaʻau often join mixed-species foraging flocks, possibly to enhance predator detection. Historically, this species was much more common and widespread than it is today, being found in native forest island-wide. Now critical to the ʻakiapolaʻau are forests at higher elevations where mosquitoes are absent or occur only seasonally. ʻAkiapōlāʻau can be found breeding during any month of the year; however, breeding and molting occur primarily from February to July. Nests are most often found in the branches of tall ʻōhiʻa trees (USFWS 2006a).

In the park, ʻakiapōlāʻau, has been detected within the boundaries of Kahuku above Kaʻū Forest Reserve between 5,000 and 6,400 feet (1,525 and 1,950 meters) (Tweed et al. 2007). Detections were made within the boundaries of Kahuku above Kaʻū Forest Reserve (Tweed et al. 2007). Threats to this species include habitat loss and degradation, predation, introduced diseases, and introduction of non-native species. This species is particularly vulnerable to these threats and slow to recover due to its low reproductive rate (USFWS 2006a).

ʻĀkepa (*Loxops coccineus coccineus*). The Hawaiʻi ʻākepa is a red-orange (males) or grayish green (females), 4-inch songbird with an asymmetrical bill. Highest densities of ʻākepa are found in old growth forests with large, canopy-emergent ʻōhiʻa or koa trees. Foraging occurs primarily among ʻōhiʻa leaves, and occasionally among koa leaves and seedpods. Large ʻōhiʻa trees are particularly important to ʻākepa, because they provide both nest sites and the preferred foraging substrate, whereas large koa trees provide primarily cavities (USFWS 2006a). ʻĀkepa are believed to nest exclusively in tree cavities (Tweed et al. 2007). The ʻākepa has a clearly defined breeding season, with nest-building from early March to late May, egg-laying from mid-March to late May, hatching in late March to early June, and fledging from the beginning of April to the end of June (USFWS 2006a).

In the park, ʻākepa have been detected within the boundaries of Kahuku in subalpine woodland with scattered `ōhi`a trees above the Kaʻū Forest Reserve. Although suitable nesting trees do not occur in the subalpine woodland in the park, potential nesting trees do occur downslope in mature montane forest (Tweed et al. 2007). The historical range of this species once included much of the island, but ʻākepa have been extirpated from lower elevations (below 4,300 feet [1,300 meters]), presumably because of the distribution of introduced mosquitoes that transmit avian malaria and avian pox (USFWS 2006a). Additional threats include habitat loss and degradation, introduced predators, and competitors.

Hawaiʻi creeper (*Oreomystis mana*). The Hawaiʻi creeper is an olive-green to gray honeycreeper with a white chin and throat. Hawaiʻi creepers travel in family groups and are most common in mesic and wet forests above 5,000 feet (1,500 meters). The species prefers undisturbed, old-growth forests with large, canopy-emergent ʻōhiʻa or koa trees, and foraging primarily takes place on the branches, trunks, and foliage of these live trees. Nests have been found from January to August, but peak breeding for this species occurs from February to May. Most Hawaiʻi creepers build open cup nests (with a small percentage being cavity nests) at midcanopy at approximately 43 feet (13 meters) in height. The reproductive potential for the Hawaiʻi creeper appears to be low due to its small clutch size (usually two eggs), relatively long developmental period, and limited breeding areas (USFWS 2006a). In the park, honeycreepers occur in Kahuku above the Kaʻū Forest Reserve. All observations of this species in Kahuku have occurred in forest habitat between 5,000 and 6,400 feet (1,525 and 1,950 meters) (Tweed et al. 2007). Threats include modification and loss of habitat, avian diseases, competition with introduced birds, and predation by introduced mammals (USFWS 2006a).

ʻŌʻū (*Psittirostra psittacea*). ʻŌʻū is a heavy-bodied, 7-inch Hawaiian honeycreeper with a thick hooked bill. The upper and lower parts of this bird are varying shades of olive-green, with a bright yellow head distinguishing the male and an olive-green head distinguishing the female. ʻŌʻū are historically known from a wide range of forest habitats, extending from sea level to alpine areas; however, ʻōʻū are now confined to mid-elevation (3,000 to 5,000 feet [914 to 1,524 meters]) mesic and wet ʻōhiʻa forests with 47 to 98 inches (1,200 to 2,500 millimeters) annual rainfall. A peak in nesting has been suggested during April and May, but nesting of the ʻōʻū has never been described and little is known of its breeding habits (USFWS 2006a).

Historically, this species was found on the islands of Kauaʻi, Oʻahu, Molokaʻi, Lanaʻi, Maui, and Hawaiʻi, but the last verified sighting was in 1989 on Kauaʻi. In the park, ʻōʻū are thought to be extirpated, and may be extinct on the Island of Hawaiʻi. A few ʻōʻū were noted in ʻŌlaʻa Forest and near Nāhuku (Thurston Lava Tube) in 1959-1961, but none were detected at Makaopuhi and Nāpau. Later detections in the Park were in ʻŌlaʻa Forest in 1975 and 1978, southeast of park headquarters in 1977, and in the eastern lowland forests (Kalapana area) in 1979. The last confirmed sighting of ʻōʻū in the park was in ʻŌlaʻa Forest in 1987 (Pratt et al. 2009).

Threats include modification and loss of habitat, avian diseases, and predation. Introduced ungulates have caused forest degradation by reducing or eliminating forest habitat and food resources, and have created mosquito breeding sites, all of which threaten ʻōʻū and other forest birds (USFWS 2006a). Although a widespread and adaptable species, the ʻōʻū may have been particularly susceptible because it favored lower elevations, where these threats were (and continue to be) more severe (Pratt et al. 2009).

Hawaiian petrel; ‘ua‘u
Source: National Park Service

Hawaiian petrel; ‘ua‘u (*Pterodroma sandwichensis*). The Hawaiian petrel is a seabird that ranges thousands of miles over the central tropical Pacific and nests only on the Hawaiian Islands (Audubon 2007). The ‘ua‘u averages 16 inches (40 centimeters) in length, and has dark gray upperparts with a white forehead and underparts. When ‘ua‘u are not at open sea, their nesting habitat includes bare rock, talus slopes, or the edges of lava flow (USFWS 1983). In the park, Hawaiian petrels nest in colonies primarily above 8,000 feet (2,440 meters) elevation on Mauna Loa at several sites. At the Kahuku Unit on the western slope of Mauna Loa, nesting may extend down to 5,500 feet (1,680 meters) elevation (Pratt et al. 2009). ‘Ua‘u are long-lived and lay only a single egg per year, making this species very susceptible to population declines. During their nesting season ‘ua‘u return to the same nesting burrows every year, entering and exiting their burrows only at night (Audubon 2007). In the park, nesting season begins typically in April and extends through November. Monitoring for nesting activity is not comprehensive, but approximately 30 to 60 active nests are estimated annually for the Mauna Loa Unit. Nesting activity occurs at Kahuku, but the number of nests is unknown (NPS 2009e). Young birds, identified by traces of natal down, occasionally are found in November on roads or near lighted buildings. These individuals were on their nocturnal fledging journey to the sea and collided with some obstruction or became disoriented by artificial lighting. Once at sea, Hawaiian petrels are rarely sighted from shore. The primary threat is predation by introduced feral cats and mongooses (Pratt et al. 2009). Habitat destruction by feral ungulates, and disorientation by artificial lights are additional limiting factors for this species.

Threatened

Newell’s shearwater; ‘a‘o (*Puffinus auricularis newelli*). Ranging from 12 to 14 inches (30 to 36 centimeters) in length, this small to medium-sized seabird has black upperparts, which sharply contrast with its white undersides (USFWS 1983). Newell’s shearwater is a highly pelagic species that forages over deep water east and south of Hawai‘i (Audubon 2007; NESH Working Group 2005). Colonies are typically located in areas of open native forest dominated by ‘ōhi‘a with a dense understory of uluhe fern (NESH Working Group 2005). Newell’s shearwater typically requires an open, downhill flight path to get airborne and thus favors ridge crests or embankments for its nesting habitat (USFWS 1983). Nesting, in which a single egg is laid, occurs from April through November (NESH Working Group 2005). Nests can be found in burrows or deep crevices of high-elevation forests (Audubon 2007). Pushed to extremes to avoid predation by pigs, mongooses, and cats, the birds now nest almost entirely on slopes that exceed 65 degrees (Audubon 2007; NESH Working Group 2005). This species was documented nesting at Makaopuhi Crater in the park, but the site was overrun by lava in 1972 (USFWS 1994b). In summer 2005, researchers were unable to document nesting by ‘a‘o in the park, though numerous incidental auditory detections by park staff in 2003 and 2005, and five predated carcasses discovered over the years suggest that this species still occurs in the park (Swift and Burt-Toland 2009). Threats include nest depredation by introduced predators, collision with powerlines, disorientation by artificial lights, and degradation of habitat by feral ungulates (Audubon 2007; NESH Working Group 2005).

Candidate

Band-rumped storm petrel; ʻakeʻake (*Oceanodroma castro*). This small seabird is a dark sooty-brown with a distinctive white band across the rump. Listed as endangered by Hawaiʻi, the species is uncommon in Hawaiʻi, seen only during the breeding season of April through November (Hawaiʻi Audubon Society 2005). Breeding habitats are not known, but breeding is suspected on Hawaiʻi, Kauaʻi, and possibly Maui. In the park, high-elevation (greater than 8,000 feet [2,438 meters]) nesting is suspected on Mauna Loa. However, while birds have been identified in the area and at least two predated carcasses recovered, nest sites have not been documented. The band-rumped storm petrel is threatened by introduced predators as well as disorienting artificial lights and powerlines (NPS 2009e; Pratt et al. 2009).

Insects

Endangered

Pomace fly; hammerhead picture-wing (*Drosophila heteroneura*). Hammerhead picture-wing is the proposed common name for this species. The picture-wing *Drosophila* have been referred to as the "birds of paradise" of the insect world, due to their relatively large size (0.17 to 0.25 inches [4.32 to 6.35 millimeters]), colorful wing patterns, and the territorial behaviors and elaborate courtship displays of males (USFWS 2006b). This species breeds predominantly in *Clermontia* spp. (ʻōhā) and other lobelioids. Breeding normally occurs year-round, but egg laying and larval development increase following the rainy season as the availability of decaying matter, which the flies feed on, increases in response to the heavy rains (USFWS 2008b). Hammerhead picture-wing is considered to be endemic to the Island of Hawaiʻi where, historically, it was known to be relatively widely distributed between 3,400 and 6,000 feet (1,036 and 1,829 meters) above sea level. Its historical range in the park includes Kahuku, in addition to ʻŌlaʻa and Thurston (USFWS 2006b). In the 1930s, visitors to the park were directed to montane mesic forest kīpuka to see one of the species' major host plants, *Clermontia hawaiiensis*. These mesic kīpuka were used as cattle paddocks as recently as the 1940s and *Clermontia hawaiiensis* was no longer present in the kīpuka in the early 1970s. The absence of host plants in many areas of the park can likewise be directly attributed to ungulate activity (Foote, pers. comm., 2009b). There are three documented extant populations: private land at Hualālai Volcano where it was last observed in 1993; a site at approximately 4,436 feet (1,352 meters) above sea level near a host plant species, *Clermontia clermontioides*, last observed in 1998; and at the Kona Unit of the Hakalau Forest National Wildlife Refuge, last observed in 2001 (USFWS 2006b).

The historical distribution of the hammerhead picture-wing in the park was probably limited by decreased forest cover or loss of suitable food material as a result of past and current feral ungulate activity. In addition, fire and the resulting invasion of fire-adapted non-native plants threaten habitat of this species in dry to mesic grassland, shrubland, and forests on the island (USFWS 2008b). Critical habitat for this species has been designated on 4,582 acres on Hawaiʻi, 687 acres of which are located in the park. The primary constituent elements for Hammerhead picture-wing are as follows:

1. Mesic to wet, montane, ʻōhiʻa and koa forest between the elevations of 2,980 to 5,755 feet (908 to 1,754 meters).
2. The larval stage host plants *Cheirodendron trigynum* ssp. *trigynum*, *Clermontia clermontioides*, *C. clermontioides* ssp. *rockiana*, *C. hawaiiensis*, *C. kohalae*, *C. lindseyana* (endangered), *C. montis-loa*, *C. parviflora*, *C. peleana* (endangered), *C. pyrularia* (endangered), and *Delissea parviflora*, which exhibit one or more life stages (from seedlings to senescent individuals) (USFWS 2008b).

Flying earwig Hawaiian damselfly (*Megalagrion nesiotes*). This endangered insect is a large and elongated damselfly, endemic to Hawai‘i. Males are up to 5 centimeters long and have a silvery blue-grey color. Females are predominantly brownish in color and are more rarely seen. In the late 19th century, the flying earwig Hawaiian damselfly was observed from Hā‘ao Springs in Ka‘ū Forest Reserve below the southeast boundary of Kahuku Unit to Kīlauea and the region of the park in Puna District. The species is currently known to occur in streambanks in moist to wet montane forest from about 1,000 to 3,000 feet (300 to 900 meters) elevation on East Maui. Most recent observations come from dense banks of uluhe fern mats (*Dicranopteris linearis*). Its habits suggest that its immatures may inhabit damp fern litter, similar to a related species (*Megalagrion oahuense*) on the Island of O‘ahu (Pratt et al. 2009). Extensive tracts of uluhe fern habitat in the park have not yet been surveyed for this damselfly. Without such surveys, it is premature to state that the species is extirpated from the Island of Hawai‘i and the park (Foote, pers. comm., 2009b). This species was last observed on East Maui in 2005. There is evidence of long-term decline in streamflow in this region of east Maui, and the combination of drought and stream diversions over the last decade may have led to this damselfly’s extinction. More recently, the uluhe fern banks formerly occupied by this species have become overtopped by a non-native weed (Koster’s curse, *Clidemia hirta*) (Pratt et al. 2009). Other threats to this species include agriculture/urban development and habitat modification by non-native ungulates (74 FR 32490–32510).

The flying earwig Hawaiian damselfly was listed as federally endangered by the USFWS in June 2010. Although the USFWS finds that designation of critical habitat is prudent for the species, it is unable to identify the physical and biological features that are considered essential to the conservation of the species (i.e., primary constituent elements). Therefore, the USFWS finds that critical habitat for the flying earwig Hawaiian damselfly is not determinable at this time, and the agency intends to continue gathering information regarding the essential life history requirements of the species to facilitate identification of essential features and areas (75 FR 35990-36012).

Threatened

Pomace fly; Mull’s picture-wing (*Drosophila mulli*). The proposed common name for *Drosophila mulli* is Mull’s picture-wing. This species has very few markings on its thorax and wings, compared to most other picture-wings. Similar to Hammerhead picture-wing, this species is restricted to the Island of Hawai‘i. *D. mulli* has only been observed on or under the native loulu palm (*Pritcharida beccariana*). The loulu palm is identified as the host plant for this species (USFWS 2006b). Plants are found in ‘Ōla‘a Unit in the park and in the adjacent State-owned forest at Ōla‘a Forest Reserve and in upper Waiakea Reserve. USFWS has identified at least two separate populations of the fly based on collections from *Pritchardia* located in the State-owned upper Waiakea Reserve and ‘Ōla‘a Forest Reserve. Rats and non-native beetles are both unchecked seed predators of the palm, and no fencing or rat control has been implemented in the state reserve (Foote, pers. comm., 2009b). The last recorded observation at the ‘Ōla‘a Forest Reserve site occurred in 2001 (USFWS 2006b). Similar to other picture-wing fly species, primary threats include non-native wasp predation and loss of host plants. Many hosts of drosophilids are among the most susceptible to damage from non-native ungulates, especially when combined with competition from non-native plants. In addition, microclimate alteration, such as opening of the canopy or understory, may also adversely affect the flies, either directly through increased desiccation or by causing host plants to dry more rapidly and rot differently (Magnacca et al. 2008).

Candidate

Pomace fly; pāpala picture-wing (*Drosophila digressa*). The proposed common name for this species is the pāpala picture-wing, because of its close association with pāpala (*Charpentiera obovata*). Pāpala picture-wing generally occurs in mesic to wet forests ranging in elevation from 4,200 to 4,600 feet (1,280 to 1,402 meters), and is endemic to the Island of Hawai‘i (USFWS 2009j). In the park, host plants of suitable size to provide breeding habitat are limited to ‘Ōla‘a Forest but, like *Clermontia hawaiiensis*, pāpala once grew to large stature in montane mesic kīpuka of the park. Park staff have been replanting it in mesic sites over the last several decades, but the trees are not yet the same stature as those in ‘Ōla‘a Forest where pāpala picture-wing has been found. Feral pigs degrade and destroy host plants and habitat in ‘Ōla‘a Forest by directly trampling plants and spreading non-native plant seeds (73 FR 75175–75244; USFWS 2009j). In addition, feral pigs probably eat young plants and uproot them while digging in the soil for invertebrates (USFWS 2009j). Non-native plants degrade host plant habitat and compete for light, space, and nutrients (73 FR 75175–75244). The greatest threat to this species is loss of host plants (USFWS 2009j). In areas where pigs have been removed, the black twig-borer can also cause serious damage to *Charpentiera* (Davis 1970; Foote, pers. comm., 2009b). Direct predation by non-native social insects, particularly yellowjacket wasps, is also a serious threat (73 FR 75175–75244). Pāpala picture-wing has been known to occur in the park, but has neither been confirmed nor collected on the island since 2006 despite general *Drosophila* surveys in its historical habitat (USFWS 2009j).

Plants

Endangered

Pendant Kihi fern; palai lā‘au (*Adenophorus periens*). Palai lā‘au is a small to medium-sized epiphytic (not rooted on the ground) fern. Its yellowish green fronds that taper at each end are usually between 4 to 16 inches (10 to 40 centimeters) long and covered with hairs (Pratt et al. 2009; USFWS 1999). Currently, palai lā‘au is restricted to Hawai‘i, Moloka‘i, and Kaua‘i at 2,300 to 4,260 feet (700 to 1,300 meters) in elevation. The largest Island of Hawai‘i population is in Kahauale‘a Natural Area Reserve, adjacent to the park (Pratt et al. 2009). It is possible that this species is extirpated from the park (Pratt et al. 2009). Historically, this species was found growing on trees in wet forests in the East Rift near or on Kane Nui o Hamo as late at the 1980s (Pratt et al. 1999). Unconfirmed reports also indicate this species may have been found in the ‘Ōla‘a area of the park (Higashino et al. 1988). On the Island of Hawai‘i, the primary threat to this species is habitat degradation by pigs, which damage the understory plants, altering the moist, shady conditions apparently required by the fern. Other threats include infestation and replacement of native wet forest with non-native plant species (namely strawberry guava), habitat destruction by fires, and fumes from volcanic eruptions. As of 1999, it is estimated that the total number of individuals in the state may be less than 2,000 (USFWS 1999). Park recovery efforts have included fencing to exclude feral ungulates and controlling non-native plants from portions of wet forest in the East Rift and ‘Ola‘a.

Mauna Loa silversword; Ka‘ū (*Argyroxiphium kauense*). Ka‘ū is a single stemmed or sparingly branched rosette shrub that reaches approximately 8 feet (2.5 meters) tall when flowering, and is topped by a rosette of silvery hairy leaves. Flowering generally occurs in August to September (Pratt et al. 2009). Endemic to the Island of Hawai‘i, Ka‘ū is known from three sites on Mauna Loa from 5,330 to 6,230 feet (1,625 to 1,900 meters) in elevation: Kahuku Unit, Kapāpala Forest Reserve, and Upper Waiākea Forest Reserve (NPS 2009j; Pratt et al. 2009). The only natural occurring population in the park contains approximately 700 individuals in a fenced exclosure at Kahuku at approximately 6,000 feet (1,829 meters) in an woodland transitional between closed forest and subalpine. Ka‘ū was introduced to the park’s Mauna Loa Unit in 1975, and in 1999–2005 thousands of seedlings were planted in two exclosures on the Mauna Loa Strip near 7,000 feet (2,135 meters) in elevation. Plantings have also been made in three new ungulate-proof exclosures at Kahuku (Pratt et al. 2009). In total, over 15,000 individuals have been planted inside protected fenced units in the park.

Mauna Loa Silversword; Ka‘ū
Source: National Park Service

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 and listed as endangered in 1993. Surveys conducted by Jacobi and Warshauer in the 1970s indicated more plants were present 30 years ago than today. Jacobi estimated the extent of Ka‘ū occurrence to be at least 10 times the current range at Kahuku (Jacobi and Warshauer 2006, as cited in Benitez et al. 2008). The small population sizes and possible inbreeding depression may pose threats to the species (USFWS 1996b). The most immediate threats, however, are non-native ungulates, primarily sheep, mouflon sheep, goats, and pigs (Pratt et al. 2009; USFWS 1996b). Critical habitat was designated for this species in four units totaling 14,431 hectares (35,657 acres) on the Island of Hawai‘i (USFWS 2009e). Part of its critical habitat is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Ka‘ū are as follows:

1. Landform/forest type: moist, open forest; subalpine mesic shrubland; bogs; and weathered, old pāhoehoe or ‘a‘ā lava with well developed pockets of soil.
2. Plant community: *Asplenium peruvianum* var. *insulare*, *Carex alligata*, *Carex* sp., *Coprosoma ernodeoides*, *Coprosoma montana*, *Deschampsia nubigena*, *Dodonaea vascosa*, *Dubautia ciliolata*, *Gahnia gahniiformis*, *Geranium cuneatum*, *Leptecophylla tameiameiae*, *Metrosideros polymorpha*, *Plantago hawaiensis*, *Rhynchospora chinensis*, *Silene hawaiiensis*, or *Vaccinium reticulatum*.
3. Elevation: from 5,193 to 8,024 feet (1,583 to 2,246 meters) (USFWS 2003).

***Asplenium peruvianum* var. *insulare* (*Asplenium fragile* var. *insulare*)**. *Asplenium fragile* var. *insulare*, a member of the spleenwort family (Aspleniaceae), is an endangered fern with a short suberect stem and leaf stalks from 2 to 6 inches (5 to 15 centimeters) long (USFWS 1998a). This species is currently known to occur in eight populations on Hawai‘i between elevations of 5,250 and 7,800 feet (1,600 and 2,377

meters); those nearest to the park are Kūlani Correctional Facility, Kapāpala, and Kaʻū forest reserves (Pratt et al. 2009; USFWS 1998a). *A. fragile* var. *insulare* was historically collected at additional sites on Mauna Kea, Mauna Loa, Hualālai, and near Hilo (Pratt et al. 2009). The Mauna Loa Unit above 5,500 feet (1,680 meters) in elevation and Kahuku Unit above 6,030 feet (1,840 meters) contain the only known populations of this fern in the park. One lava tube in the Mauna Loa Unit has supported a population of *A. fragile* var. *insulare* since 1943 (Pratt et al. 2009). At Kahuku, this species was found at four subalpine sites above Kaʻū Forest Reserve (Benitez et al. 2008; Pratt et al. 2009). In the park, this species is known to occur in subalpine, montane seasonal, and alpine/aeolian environments, which are described in the "Vegetation" section of this chapter (NPS 2005a; USFWS 1998a). It is generally restricted to large-diameter, moist lava tubes at high elevation (Benitez et al. 2008; Pratt et al. 2009). The fern is typically found on tube walls and ceilings in the lighted zone near the opening, but some individuals have been found in deep, dark recesses of lava tubes. The fern has also been observed growing in lava cracks and on cliffs (Pratt et al. 2009). Feral goats and mouflon sheep are potential threats to *Asplenium fragile* var. *insulare,* although it seems to persist in lava tubes (Pratt et al. 2009; USFWS 1998a). Additional threats may include non-native plant species that infest lava tubes, such as common mullein (*Verbascum thaspus*) (Pratt et al. 2009). Park recovery efforts have included fencing to exclude feral ungulates and control of mullein in the Mauna Loa Unit.

Lindsey's ʻōhā wai; (*Clermontia lindseyana*). Lindsey's ʻōhā wai is a perennial tree that grows from approximately 8 to 20 feet (2.5 to 6 meters) tall. It can be either terrestrial or epiphytic, living on the surface of other plants (Pratt et al. 2009; USFWS 1996a). The extant populations of Lindsey's ʻōhā wai grow on the Island of Hawaiʻi and the leeward slopes of Haleakalā, East Maui (Pratt et al. 2009). On the Island of Hawaiʻi, plants have been reported from eastern Mauna Kea and eastern, southeastern, and southwestern Mauna Loa at elevations above 4,300 feet (1,311 meters) (Benitez et al. 2008; USFWS 1996a). In 1996, there were 12 known populations and 86 individuals thought to persist on the island. In the park, this species is known to occur naturally in several sites in the Kahuku Unit. These sites were found in mesic to wet ʻōhiʻa forest located adjacent to the Kaʻū Forest Reserve at 5,905 to 6,234 feet (1,800 to 1,900 meters) in elevation (Benitez et al. 2008; NPS 2009j; Pratt et al. 2009). Among the major threats to Lindsey's ʻōhā wai are trampling and grazing by cattle, trampling and browsing by goats, and rooting and trampling by pigs (USFWS 1996a). A 2008 survey indicated extensive damage from pig activity and either feral cattle or mouflon sheep browsing in the areas of Kahuku where ʻōhā wai were observed (Benitez et al. 2008). Currently the species is protected in ungulate-free exclosures only in Hakalau Forest, Kūlani, and Kīlauea forest and as planted individuals inside fenced exclosures in the Mauna Loa and Kahuku Units of the park. A 2008 survey indicated extensive damage to naturally occurring individuals from pig activity and either feral cattle or mouflon sheep browsing in the areas of Kahuku where ʻōhā wai were observed (Benitez et al. 2008).

Pele's ʻōhā wai; (*Clermontia peleana* subsp. *peleana*). Pele's ʻōhā wai is an epiphytic shrub or small tree that grows between 5 and 20 feet (1.5 and 6 meters) tall on large ʻōhiʻa, koa, and ʻolapa trees (Pratt et al. 2009; USWFS 1996a). Endemic to the islands of Maui and Hawaiʻi, plants have been found in rainforests of East Maui, and windward Mauna Kea and Mauna Loa between 1,740 to 3,770 feet (530 to 1,150 meters) elevation (Pratt et al. 2009; USFWS 1996a). In 1996, there were four known populations on the Island of Hawaiʻi, consisting of a total of eight individuals (Pratt et al. 2009). This species was thought to be extinct in the wild when the last individual died by 2000. Recently, six individuals were discovered along the Wailuku River. Major habitat destruction resulting from non-native ungulates, particularly pigs, is a primary cause of the decline of this taxon. Slugs are also thought to be a limiting factor. Since 2001, the park has planted nearly 400 individuals in protected sites in the park's ʻŌlaʻa Forest from which feral pigs have been removed (NPS 2009e).

Hāhā (*Cyanea hamatiflora* ssp. *carlsonii*). This species is a palm-like tree that grows to a height of approximately 10 to 26 feet tall (3 to 8 meters). It is typically found in ʻōhiʻa-dominated montane wet

forests at elevations between 4,000 and 5,700 feet (1,219 and 1,737 meters) (USFWS 1996a). There are only two known extant populations, both on the Island of Hawai‘i, located on privately and state-owned land at Honuaula Forest Reserve and Keokea. At the time of federal listing, the two populations contained approximately 19 individuals. The declining Honuaula population currently has only 2 individuals, and the Keokea population contains 15 individuals (USFWS 2009f). Two subpopulations were planted in 1995 and 1996 in the native range: 45 individuals at Honuaula Forest Reserve and 6 individuals at Pu‘uwa‘awa‘a (USFWS 1996a). In addition, two individuals were outplanted in a fenced area in South Kona in 2006 and one in Kīpāhoehoe Natural Area Reserve in 2008. The current status of the outplanted individuals, however, is not known (USFWS 2009f). Non-native plants are a serious threat to the long-term survival of this species. In addition, grazing and trampling by cattle and uprooting by feral pigs degrade habitat and open major sites for non-native plant invasion (USFWS 1996a). Although no plants have been documented in the park, designated critical habitat for Hāhā lies adjacent to the park (Leonard 2009; NPS 2009e). As mentioned previously, the ESA requires that such actions avoid “destruction” or “adverse modification” of designated critical habitat (USFWS 2009b). The primary constituent elements for this species on the Island of Hawai‘i are as follows:

1. Landform/forest type: Mesic montane forest dominated by *Acacia koa* or *Metrosideros polymorpha*.
2. Plant community: *Athyrium* sp., *Cibotium* spp., *Clermontia clermontioides*, *Coprosma* sp., *Dryopteris* sp., *Hedyotis* sp., *Ilex anomala*, *Myoporum sandwicense*, or *Sophora chrysophylla*.
3. Elevation: 4,482 to 5,759 feet (1,366 to 1,755 meters) (USFWS 2003).

Hāhā (*Cyanea shipmanii*). *C. shipmanii* is a small unbranched or sparsely branched shrub that grows to a height of 8 to 13 feet (2.5 to 4 meters). This species is distinguished by its small flowers, slender stems, and stalked and divided leaves. Preferred habitat includes montane mesic forest dominated by ‘ōhi‘a on the windward slopes of Hawai‘i, at elevations between 5,400 and 6,200 feet (1,650 and 1,900 meters). At the time of federal listing in 1994, only four populations were known, containing fewer than 10 individuals (USFWS 1996a). By 2007, the species had declined to only 2 extant wild individuals in Upper Waiākea Forest Reserve and Pu‘u Kipu Unit of the Kīlauea Reserve (USFWS 2009g). Just outside the park, a lone individual of *C. shipmanii* was recently discovered along the Kahuku boundary (PEPP 2009). Major threats to this species include non-native ungulates and non-native plant species (USFWS 1996a; USFWS 2009g). In particular, the remaining wild individual in the Upper Waiākea Forest Reserve is threatened from habitat destruction due to pigs and herbivory or disturbance by sheep. The Kīlauea populations are at risk from fruit and seed predation by rats (USFWS 2009g).

Hāhā; ha‘iwale; kanawao ke‘oke‘o (*Cyanea stictophylla*). *C. stictophylla* is a small tree or shrub approximately 2 to 20 feet (0.6 to 6 meters) in height. The stems are sparsely branched and occasionally equipped with sharp outgrowths. Hāhā is distinguished from other taxa in the genus by its large, deeply lobed flowers and small calyx lobes (USFWS 1996a). This species is endemic to the Island of Hawai‘i, and is known from Kona and Ka‘ū districts at elevations of 4,590–6,400 feet (1,400–1,950 meters) (Pratt et al. 2009). Preferred habitat of hāhā is generally lowland to montane, mesic to wet forest dominated by ‘ōhia‘a and koa (USFWS 1996a). In Hawai‘i Volcanoes National Park, two plants were discovered inside a pit crater, which is not accessible to ungulates, located in the Kahuku pasture/mesic forest zone at 3,281 feet (1,000 meters) elevation (Benitez et al. 2008; NPS 2009j, 2009e). In 1996, there were three known populations and fewer than 20 known individuals on the Island of Hawai‘i, with 46 outplanted individuals persisting in exclosures on Pu‘uwa‘awa‘a and Ka‘ū Forest Reserve. The primary reasons for decline of this species are destruction of habitat by cattle grazing and feral pigs (USFWS 1996a). Feral goats and mouflon sheep are also threats to this soft-wooded species (Pratt et al. 2009). The park is currently propagating and planting individuals inside protected exclosures. Critical habitat for this species is found

in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for *C. stictophylla* on the Island of Hawai‘i are as follows:

1. Landform/forest type: *Acacia koa* or wet *Metrosideros polymorpha* forests.
2. Plant community: *Cibotium* sp., *Melicope* spp., *Urera glabra*.
3. Elevation: 3,466 to 6,288 feet (1,056 to 1,917 meters) (USFWS 2003).

Ha‘iwale (*Cyrtandra giffardii*). *Cyrtandra giffardii* is a small shrubby tree that grows from 10 to 20 feet in height with opposite leaves positioned on the upper nodes of the stem. The habitat for this species is found in mesic/wet forest environments dominated by tree fern at elevations between 2,400 and 4,900 feet (720 and 1,500 meters). In 1996, there were 11 known populations and more than 1,000 known individuals on the Island of Hawai‘i. As of 1994, 90 known individuals occurred in the Koa and Pu‘u fenced units of ‘Ōla‘a Forest in Hawai‘i Volcanoes National Park. Subsequent surveys identified several plants in adjacent fenced units (Pratt et al. 2009). The major threat to Ha`iwale is rooting and trampling by pigs and competition from invasive plants Known plants in the park are located in areas that have been fenced and managed to exclude pigs and control of non-native plants are carried out in portions of these units (USFWS 1996a). Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for *C. giffardii* on the Island of Hawai‘i are as follows:

1. Landform/forest type: wet montane forest dominated by *Cibotium* sp. or *Metrosideros polymorpha*, and *Metrosideros polymorpha–Acacia koa* lowland wet forests.
2. Plant community: *Astelia menziesiana*, *Diplazium sandwichianum*, *Hedyotis terminalis*, *Perrottetia sandwicensis*, or other species of *Cyrtandra*.
3. Elevation: 2,146 to 4,723 feet (654 to 1,440 meters) (USFWS 2003).

Ha‘iwale (*Cyrtandra tintinnabula*). This endangered small shrub grows from approximately 3 to 7 feet (1 to 2 meters) in height. Its papery, toothed leaf blades are moderately covered with yellow-brown hairs. *C. tintinnabula* grows in lowland wet/mesic forest environments dominated by dense koa, ‘ōhi‘a, and tree fern (USFWS 1996a). This species is endemic to the Island of Hawai‘i and generally occurs between 2,390 and 3,410 feet (730 and 1,040 meters) elevation (Pratt et al. 2009). In 1996, there were three known populations and 18 known individuals on the Island of Hawai‘i (USFWS 1996a).In the park, *C. tintinnabula* was discovered in July 2001 growing on the lower walls of a prominent geological feature (‘Ōla‘a Trench) and two adjacent craters in the northeast quarter of ‘Ōla‘a Forest at 3,609 feet (1,100 meters) elevation (NPS 2009j; Pratt et al. 2009). Rooting and browsing by feral pigs directly damage and disturb the habitat of this species, breaking its weak and delicate stems. Because much of the native habitat is lost, appropriate pollinators may also be absent (USFWS 1996a).

Hau kuahiwi (*Hibiscadelphus giffardianus*). Hau kuahiwi is an endangered tree species that can grow up to 39 feet (12 meters) tall. Endemic to the Island of Hawai‘i, this species occurs naturally only at Kīpuka Puaulu near 4,000 feet (1,220 meters) elevation (NPS 2009j; Pratt et al. 2009). When it was discovered in 1911, there was only one tree remaining, which was found on the edge of a collapsed lava tube on the southwestern edge of the kīpuka (Pratt et al. 2009). At the time of federal listing in 1996, hau kuahiwi was extinct in the wild and known only from 11 reintroduced individuals at Kīpuka Puaulu in the park. Planted individuals are also found at Kīpuka Kī and a handful of sites in the montane seasonal environment of the Mauna Loa Strip, which is described in the “Vegetation” section of this chapter (NPS 2005a, 2009e; Pratt et al. 2009). As of 2008, the number of known planted individuals is estimated at over 400 (USFWS 2008f). In the past, habitat degradation and predation by cattle and feral pigs, as well as goats, were major threats to Hau kuahiwi. These threats have been controlled by the park, and all naturally occurring and planted individuals are in fenced areas. Current threats include competition from

non-native plant species, fire, and rats that strip the bark and eat the seeds (Pratt et al. 2009; USFWS 2008f). In addition, the recently introduced two-spotted leaf hopper attacks the foliage of the plant species and may contribute to drought damage (Pratt et al. 2009). Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Hau kuahiwi on the Island of Hawai‘i are as follows:

1. Landform/forest type: mixed montane mesic forest.
2. Plant community: *Acacia koa*, *Coprosma rhynchocarpa*, *Dodonaea viscosa*, *Melicope* spp., *Metrosideros polymorpha*, *Myoporum sandwicense*, *Nestegis sandwicensis*, *Pipturus albidus*, *Psychotria* sp., *Sapindus saponaria*.
3. Elevation: 3,914 to 4,181 feet (1,193 to 1,274 meters) (USFWS 2003).

Hilo ischaemum (*Ischaemum byrone*). This perennial grass is distinguished from other native Hawaiian grasses by its tough outer flower bracts and dissimilar basic flower units. It contains creeping underground stems and erect stems that grow from 16 to 31 inches (40 to 80 centimeters) in height (USFWS 1996a). This perennial grass is found in scattered locations on the windward coastlines of Maui, Moloka`i, and Hawai`i islands. In 1996, there were 17 known populations and several thousand known individuals on the Island of Hawai‘i (USFWS 1996a). In the park, Hilo ischaemum was found naturally along the immediate shoreline among boulders and rocks or in cracks in the pāhoehoe surface in the eastern coastal lowlands from Kamoamoa to Lae ‘Apuki (Pratt et al. 2009). All of these sites were covered by lava flows from 1993 through 2006. Plants were salvaged from the largest population at Kamoamoa, propagated ex situ, and their progeny were planted at Lae Apuki, Hōlei Sea Arch, Kealakomo, Kahue, Ka‘aha, and Kalue in more western and drier locations than the naturally occurring populations. In 2010, less than 1% of the planting survived, almost but one of these plantings at the eastern most site at Hōlei Sea Arch. The most immediate threat to Hilo ischaemum in the park is lava flows. Feral goats may also be a potential threat (Pratt et al. 2009). Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Hilo ischaemum on the Island of Hawai‘i are as follows:

1. Landform/forest type: coastal wet to dry shrubland; near the ocean; rocks or pāhoehoe lava in cracks and holes.
2. Plant community: *Fimbristylis cymosa*, *Scacevola taccada*.
3. Elevation: 0 to 91 feet (0 to 28 meters) (USFWS 2003).

Koki‘o (*Kokia drynarioides*). This small tree is endemic to the leeward slopes of Hualālai in North Kona on the Island of Hawai‘i between 1,510 and 2,950 feet (460 and 900 meters) elevation (Pratt et al. 2009; USFWS 1994a). It reaches up to approximately 26 feet (8 meters) tall and has shallowly lobed leaves with large, ornamental, scarlet flowers (Pratt et al. 2009). This tree inhabits dry forests on rough, relatively unweathered lava flows and is found in mid-elevation and montane seasonal environments (NPS 2005a; USFWS 1994a). Koki‘o is not historically known in the park; individuals were outplanted at Kīpuka Puaulu, Kīpuka Kī, Kīpuka Nēnē, Hilina Pali, and ‘Āinahou Ranch between 1924 and 1958, but only the Kīpuka Nēnē planting persists (NPS 2009e; Pratt et al. 2009). Currently, two populations exist: the first at Ka‘ūpūlehu, located outside the park, containing one mature individual; and the second population at Kīpuka Nēnē, containing a single surviving individual. Seventy-five outplanted individuals at Ka‘ūpūlehu appear to be reproducing (USFWS 2009h). Fire is a serious threat to the remaining trees due to the invasion of fire-prone non-native grasses. Past threats included domestic cattle and feral goats, which browsed and damaged native trees of the dry forests of North Kona, and interfered with tree reproduction and recruitment. Insects such as Chinese rose beetle are also reported to attack koki‘o leaves (Pratt et al. 2009).

Zahlbruckner's pelea; alani (*Melicope zahlbruckneri*). This endangered tree is endemic to the southeastern portion of the Island of Hawai'i and reaches approximately 33 to 39 feet (10 to 12 meters) tall. This tree is known from few sites, including Kīpuka Puaulu and Moa'ula in Ka'ū District; Glenwood in Puna District; and recently reported from Laupāhoehoe Natural Area Reserve in Hamākua District (Pratt et al. 2009). In Hawai'i Volcanoes National Park, only one naturally occurring population of 20 trees is known (NPS 2009e; Pratt et al. 2009) from montane seasonal forest in Kīpuka Puaulu (NPS 2009j; Pratt et al. 2009). Four plants of alani have also been successfully planted at Kīpuka Kī (Pratt et al. 2009). Inside the park, ungulate threats have been controlled (USFWS 2008f). Current threats include seed predators, such as rats and insects; loss of natural pollinators; the recently introduced two-spotted leaf hopper; and competition from non-native plant species (Pratt et al. 2009; USFWS 2008f). Critical habitat for this species is found in Hawai'i Volcanoes National Park (Leonard 2009). The primary constituent elements for alani on the Island of Hawai'i are as follows:

1. Landform/forest type: *Acacia koa–Metroideros polymorpha* dominated montane mesic forest.
2. Plant community: *Coprosma rhynchocarpa*, *Melicope* spp., *Myoporum sandwicense*, *Nestegis sandwicensis*, *Pipturus albidus*, *Pisonia brunoniana*, *Psychotria hawaiiensis*, *Sapindus saponaria*, *Zanthoxylum dipetalum*.
3. Elevation: 3,476 to 4,383 feet (1,060 to 1,336 meters) (USFWS 2003).

Ma'aloa (*Neraudia ovata*). This endangered sprawling shrub is endemic to the leeward side of the Island of Hawai'i between 980 and 4,820 feet (300 and 1,470 meters). Its stems can reach approximately 3 to 9 feet (0.9 to 2.7 meters) long and male and female flowers are borne on separate plants. This shrub inhabits dry forests, open lava flows, and subalpine forest. Currently remaining natural populations of Ma'aloa include 14 to 18 mature individuals and up to 125 immature individuals. At the time of federal listing, the species was known from 11 individuals in two populations. In addition, plantings at various locations on the island, have resulted in approximately 327 individuals (USFWS 2008c). While the natural population of Ma'aloa was extirpated from the park, individuals were recently planted near the presumed original site, as well as at Kīpuka Kī and several sites along Hilina Pali Road (Pratt et al. 2009). The plantings of Ma'aloa the park are all in fenced units managed to exclude goats and mouflon sheep. Threats to this species include browsing by ungulates, competition with non-native shrubs and grasses, and insects (particularly the spiraling whitefly) (Pratt et al. 2009).

'Aiea (*Nothocestrum breviflorum*). Endemic to the Island of Hawai'i at elevations of 1,800 to 6,000 feet (550 to 1,830 meters), this tree species grows from approximately 33 to 39 feet (10 to 12 meters) in height. The trunk, about 18 inches (45 centimeters) in diameter, has a soft, sappy wood with dark brown bark. Habitats of 'aiea are found in montane seasonal environments, lowland dry forest, montane dry forest, and montane mesic forest (USFWS 1996a). Individuals generally occur on 'a'ā lava substrates at elevations ranging from 260 to 6,000 feet (180 to 1,830 meters). In 1996, there were six known populations on the Island of Hawai'i. In the park, this species was reported from dry forest near 1,804 feet (550 meters) to mesic forest at 4,300 feet (1,310 meters) (Pratt et al. 2009). The species was lost from these historical sites and exists in the park today only as plantings at Kīpuka Puaulu and Nāulu in areas fenced and protected from goats, mouflon sheep and cattle (Pratt et al. 2009). On the island, this species has been negatively impacted by cattle and sheep grazing, and by the introduction of non-native plant taxa such as Brazilian peppertree, which may afford enough fuel to support a destructive fire (USFWS 1996a).

Hōlei (*Ochrosia kilaueaensis*). Hōlei is a medium-sized tree, endemic to the Island of Hawai'i at elevations between 2,200 and 4,000 feet (670 and 1,220 meters). It grows to about 50 to 60 feet (15 to 18 meters) in height and contains a milky sap. It is found in montane seasonal environments and occurs at elevations between 2,200 and 4,000 feet (670 to 1,220 meters) (USFWS 1996a). In 1996, there was one possible extant population at Pu'uwa'awa'a on state-owned land; however, the population was last

collected at an unknown date, and it is unknown how many individuals are present in the population, if any (USFWS 1996a). In the park, hōlei is known only from Kīpuka Puaulu, where the last tree was observed in 1927. It is now considered to be likely extirpated from the park, and possibly extinct (NPS 2009j; Pratt et al. 2009). If the species is still extant, potential threats include goats, domestic cattle, pigs, sheep, fire, and non-native plants. Feral goats browse and trample the native vegetation, disturbing the substrate and understory. Predation of fruits by black rats is also a potential threat to the viability of this species (Pratt et al. 2009; USFWS 1996a).

Kīponapona (*Phyllostegia racemosa*). Kīponapona is in the mint family (Lamiaceae), and is a climbing vine with many-branched, square stems and spicy-smelling leaves. Flower clusters, densely covered with short, soft hairs, are composed of 6 to 12 flowers. It is typically found epiphytically in disturbed koa, ʻōhiʻa, and hāpuʻu-dominated montane mesic or wet forests, at elevations between 4,650 and 6,070 feet (1,400 and 1,850 meters) (HDLNR 2005b). Although individuals were listed by USFWS as part of the park flora (Leonard 2009), no natural plants have been documented in the park. Outplantings of some individuals were made in the park, but none survived (NPS 2009e). Threats include habitat disturbance by feral pigs and cattle, logging, competition from non-native plant taxa, habitat change due to volcanic activity, and risk of extinction from naturally occurring events and/or reduced reproductive vigor due to the small number of existing populations and individuals (HDLNR 2005b).

Laukahi kuahiwi (*Plantago hawaiensis*). Laukahi kuahiwi is a perennial herb characterized by thick, leathery basal leaves and short stem containing red-brown wooly hairs (USFWS 1996a). It occurs at elevations from 5,900 to 8,040 feet (1,800 to 2,450 meters) mainly on the leeward side of the island, and its habitat is somewhat variable (USFWS 1996a). Laukahi kuahiwi grows in either montane wet sedgeland with mixed sedges and grasses, or in montane mesic forest growing with stunted koa and ʻōhiʻa; it is sometimes found growing in cracks in lava (USFWS 1996a). About 5,000 individuals are thought to be present in at least eight populations on the Island of Hawaiʻi (Benitez et al. 2008; USFWS 1996a). In the park, this species has been found naturally occurring on Mauna Loa near 7,000 feet (2,134 meters) elevation in subalpine and montane seasonal environments of Kahuku and the Mauna Loa units (NPS 2005a, 2009j, 2009e). Feral goats and mouflon sheep have been excluded from the two populations that occur on Kīpuka Kulalio and Kīpukamaunaʻiu in the Mauna Loa unit by protective fencing since the 1970s. Populations found in Kahuku are not fenced or protected from non-native ungulates (Pratt et al. 2009). Browsing by the ungulates affects the viability of this species by precluding the establishment of juveniles and damaging the habitat, thereby opening suitable sites for the establishment of non-native weeds (USFWS 1996a). Critical habitat for this species is found in Hawaiʻi Volcanoes National Park (Leonard 2009). The primary constituent elements for Laukahi kuahiwi on the Island of Hawaiʻi are as follows:

1. Landform/forest type: montane wet sedgeland (often in damp cracks of pāhoehoe lava) with mixed sedges and grasses, montane mesic forest, dry subalpine woodland, or *Metrosideros polymorpha* and native shrub.
2. Plant community: *Acacia koa*, *Coprosma ernodeoides*, *Coprosma montana*, *Dodonaea viscosa*, *Leptecophylla tameiameiae*, *Metrosideros polymorpha*, or *Vaccinium reticulatum*.
3. Elevation: 5,198 to 8,243 feet (1,584 to 2,513 meters) (USFWS 2003).

Hawaiʻi hala pepe (*Pleomele hawaiiensis*). This tree exhibits long, narrow leaves that are borne at the branch tips, and pale yellow flowers. It can grow to approximately 21 feet (6 meters) in height. Hawaiʻi hala pepe is endemic to dry (or occasionally moist) forests on old lava flows on the leeward side of the Island of Hawaiʻi at elevations of 985 to 2,820 feet (300 to 860 meters) (Pratt et al. 2009). In the park, this species has been identified in coastal lowland and mid-elevation seasonal forest environments at Nāulu Forest, Kealakomo Kīpuka, Poliokeawe Pali, the Great Crack and Kahuku (NPS 2005a, 2009j; Pratt

et al. 2009). Fewer than two dozen plants have been observed in these areas. In 2001–2003, hala pepe was planted successfully at the Nāulu and Kealakomo sites. The species faces the threats that endanger many native plants of the dry lowlands, including fire spread by non-native grasses; non-native animals, including feral goats and rats; and non-native plant species (Pratt et al. 2009). Feral goats have been eliminated from hala pepe habitat in the older section of the park. Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Hawai‘i hala pepe on the Island of Hawai‘i are as follows:

1. Landform/forest type: dry and mesic lowland forests of lama (*Diospyros sandwicensis*) and ‘ōhi‘a (*Metrosideros polymorpha*).
2. Plant community: *Bidens micrantha* ssp. *ctenophylla, Bobea timonioides, Caesalpinia kavaiensis, Cocculus trilobus, Colubrina oppositifolia, Diospyros sandwicensis, Dodonaea viscosa, Erythrina sandwicensis, Kokia drynarioides, Metrosideros polymorpha, Myoporum sandwicense, Neraudia ovata, Nestegis sandwicensis, Nothocestrum breviflorum, Nototrichium sandwicense,Osteomeles anthyllidifolia, Psydrax odorata, Reynoldsia sandwicensis, Santalum paniculatum, Sida fallax,* or *Sophora chrysophylla*.
3. Elevation: 281 to 2,925 feet (86 to 892 meters) (USFWS 2003).

Po‘e; ‘ihi mākole (*Portulaca sclerocarpa*). Po‘e is an endangered perennial with a fleshy, tuberous taproot that becomes woody with maturity. It inhabits montane dry shrubland and is often found on bare cinder, near steam vents, and in open ‘ōhi’a-dominated woodlands at elevations between 3,380 and 5,340 feet (1,030 and 1,628 meters). In 1996, there were 12 known populations and more than 1,000 known individuals on the Island of Hawai‘i (USFWS 1996a). In the park, this species grows in the Puhimau Geothermal Area, along Hilina Pali Road, and in Keanakāko‘i (NPS 2009j, 2009e). At the time of the 1996 USFWS report, the Puhimau Geothermal Area supported just under 1,000 plants, but since that time the population of this species has declined to fewer than 300 individuals (Pratt et al. 2009). In the park, a major threat to this species is competition from non-native grasses such as beardgrass and broomsedge, as well as potentially feral goats and rats which are seed predators. Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Po‘e on the Island of Hawai‘i are as follows:

1. Landform/forest type: montane dry shrubland, often on bare cinder, near steam vents, and in open *Metrosideros polymorpha*–dominated woodlands.
2. Plant community: *Dodonaea viscosa*, *Melanthera venosa*, *Sophora chrysophylla*.
3. Elevation: 3,380 to 5,340 feet (1,030 to 1,630 meters) (USFWS 1996a).

Loulu (*Pritchardia affinis*). Loulu is a palm tree that grows from 33 to 82 feet (10 to 25 meters) in height. It inhabits coastal lowland forest environments and coastal mesic forest on the leeward side of the Island of Hawai‘i, possibly near or in brackish water, at elevations of 0 to 2,000 feet (0 to 610 meters). In 1996, there were eight known populations and between 50 and 65 known individuals on the Island of Hawai‘i (USFWS 1996a). Until recent fires and lava flows in the park, there was one group of trees (probably planted) on the Kalapana Trail at 985 feet (300 meters) elevation (Pratt et al. 2009). More recently, this tree has been planted in coastal talus slopes behind the shoreline at Kālu‘e and in coastal strand vegetation at Keauhou in the park (NPS 2009j; Pratt et al. 2009).Continued development and human disturbance are serious threats to the viability of this species, as our feral pigs, which root and destroy seedings, preventing regeneration island-wide (USFWS 1996a). In the park’s coastal lowlands, rats predation on seeds is probably the most important threat to loulu restoration efforts (Pratt et al. 2009). In some coastal lowland location, fire carried by alien grasses may be a threat.

‘Ōhai (*Sesbania tomentosa*). ‘Ōhai is typically a sprawling shrub with branches up to 45 feet (14 meters), but may also be a small tree up to 20 feet (6 meters) in height (USFWS 1999). This species is found in coastal sites with plants growing in sand and ash pockets over pāhoehoe in disturbed coastal vegetation dominated by naupaka kahakai; coastal lowlands vegetated primarily with native pili and non-native grasses; and lowland dry woodlands of ‘ōhi‘a, native shrubs, and non-native grasses (Pratt et al. 2009). Less than 5,000 individuals of this plant are believed to exist (USFWS 1999). In Hawai‘i Volcanoes National Park, it has been identified in the ‘Āpua Point, Kīpuka Nēnē, Hilina Pali, Kamo‘oali‘i, Kū‘ē‘ē, and Kīpuka Pepeiau areas (NPS 2009j; Pratt et al. 2009). Feral goats and fire are major threats to this species. Rats, non-native grasses, and loss of natural pollinators are also potential threats to this tree species (Pratt et al. 2009). Critical habitat for this species is found in Hawai‘i Volcanoes National Park in fenced units that protect it from feral goats (Leonard 2009). The primary constituent elements for ‘Ōhai on the Island of Hawai‘i are as follows:

‘Ōhai
Source: National Park Service

1. Landform/forest type: open, dry *Metrosideros polymorpha* forest with mixed native grasses, *Scavevola taccada* coastal dry shrubland on windswept slopes, and weathered basaltic slopes.
2. Plant community: *Dodonaea viscosa*, *Fimbristylis hawaiiensis*, *Ipomoea pes-caprae*, *Jacquemontia ovalifolia* ssp. *sandwicensis*, *Leptecophylla tameiameiae*, *Melanthera integrifolia*, *Myoporum sandwicense*, *Sida fallax*, *Sporobolus virginicus*, *Waltheria indica*.
3. Elevation: 0 to 3,025 feet (0 to 922 meters) (USDA-NRCS 2005).

White-bur cucumber; ‘ānunu (*Sicyos alba*). White-bur cucumber is a short-lived annual vine with black-spotted stems. Its habitat includes wet forest of ‘ōhi‘a, hāpu‘u, or tree ferns near 4,000 feet (1,220 meters) elevation (Pratt et al. 2009). In the park, this species is only known in the ‘Ōla‘a Forest (Pratt et al. 2009), but is also found in similar habitats just outside the park in ‘Ōla‘a Forest Reserve, and Pu‘u Maka‘ala Natural Area Reserve (NPS 2009j, 2009e). Threats to the survival of this plant include feral pigs and non-native plants (Pratt et al. 2009). Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for White-bur cucumber on the Island of Hawai‘i are as follows:

1. Landform/forest type: *Metrosideros polymorpha–Cibotium glaucum*–dominated montane wet forests.
2. Plant community: *Astelia menziesiana*, *Athyrium microphyllum* and other ferns, *Broussaisia arguta*, *Cheirodendron trigynum*, *Coprosma* sp., *Cyanea tritomantha*, *Cyrtandra lysiosepala*, *Perrottetia sandwicensis*, *Platydesma spathulata*, *Pritchardia beccariana*, *Psychotria* sp., *Stenogyne* sp.
3. Elevation: 3,170 to 5,072 feet (966 to 1,546 meters) (USDA-NRCS 2005).

Spermolepis hawaiiensis. *Spermolepis hawaiiensis* is an endangered annual herb bearing small white flowers. This species is known from open areas in the lowland and montane zones, as well as cultivated fields at low elevation. On the Island of Hawai‘i, *S. hawaiiensis* is extant at several sites in Pōhakuloa Training Area and Pu‘u Anahulu (Pratt et al. 2009). In Hawai‘i Volcanoes National Park, historical records (1943) indicate its existence in coastal lowland and mid-elevational woodland environments west of Kīpuka Kahali‘i (Pratt et al. 2009). Since last documented, this area has been covered by lava. There have been unsuccessful attempts to establish plants through seed broadcasting along the Chain of Craters and Hilina Pali roads. Feral goats may have been a factor in the original decline of this species in the park (Pratt et al. 2009). Other threats include other ungulates, non-native plants, fire, and landslides (Pratt et al. 2009).

Stenogyne angustifolia. *Stenogyne angustifolia* is a sprawling perennial vine. Flowers are borne in the leaf axils and are maroon to yellow in color (USFWS 1993). The extant population of this species is found in dry subalpine shrubland, but plants of Moloka‘i, Maui, and leeward Hawai‘i formerly occurred in lower-elevation dry habitats. All known naturally occurring individuals on the Island of Hawai‘i are at the Pōhakuloa Training Area (a military training area) between 5,080 and 7,050 feet (1,550 and 2,150 meters) (Pratt et al. 2009). In the park, historical records indicate its existence between Kīlauea and Kapāpala, where it was collected in 1868 (NPS 2009j; Pratt et al. 2009). This species has also been planted at two sites in the Mauna Loa Strip; however, survival of plantings has been poor. Threats to the species include fire and competition with non-native plants. Trampling and disruption from non-native ungulates, including goats, sheep, and cattle, are also significant threats to *S. angustifolia* (Pratt et al. 2009).

Hawai‘i pricklyash; a‘e (*Zanthoxylum hawaiiense*). Hawai‘i pricklyash is a medium-sized tree with pale, smooth bark that reaches 26 feet (8 meters) in height. This species generally occurs in lowland dry and mesic forests, and montane dry forest, at elevations between 1,800 and 5,710 feet (550 and 1,740 meters) (USFWS 1996a). Individuals occur on lava flows and, in the park, prefer forests dominated by koa, ‘ōhi‘a, and mānele (Pratt et al. 2009). In 1996, five populations of this tree were known to occur at Pu‘uwa‘awa‘a and Pōhakuloa Training Area on the Island of Hawai‘i (USFWS 1996a). In the park, this species was reported from Kīpuka Puaulu in 1921, but the observation was not documented by a specimen, and there are no reported occurrences of this species between Pōhakuloa and the park. Feral goats, sheep, and pigs as well as domestic cattle are all threats to Hawai‘i pricklyash, but are excluded from Kīpuka Puaulu. Additional threats may include fire and non-native plants (Pratt et al. 2009).

Threatened

Haleakalā silversword; Hawaiian catchfly; ‘ahinahina; (*Argyroxiphium sandwicense* ssp. *macrocephalum*). This species is a single-stemmed rosette shrub that grows up to 10 feet (3 meters) tall (Pratt et al. 2009). ‘Ahinahina is endemic to the subalpine and alpine deserts of Haleakalā on East Maui; however, it was outplanted to Mauna Loa, where a few plants persist in the alpine environment of the park (NPS 2009j, 2009e). In its natural habitat, this species was threatened by feral goats until the Haleakalā Crater District was fenced and goats were removed. Feral goats, mouflon sheep, and pigs are potential threats to outplanted individuals in the park. Argentine ants (*Linepithema humile*) are a potential threat because of their impacts on insect pollinators (Pratt et al. 2009).

Hawaiian catchfly; Sheriff's catchfly (*Silene hawaiiensis*). Hawaiian catchfly is a sprawling shrub endemic to the Island of Hawai‘i found primarily in dry open areas in montane seasonal and subalpine environments (USFWS 1996a). In the park, plants occur on ash flows and dry lava flows and have been identified in the Mauna Loa Unit, Kīlauea Crater rim, and Ka‘ū Desert areas of the park (NPS 2009j; Pratt et al. 2009). One population in the park near 5,600 feet (1,710 meters) elevation lost more than 70 percent of its plants in 5 years, and a second population decreased by more than 50 percent from 1998 to 2000

because of browsing by mouflon sheep that penetrated a fenced area of the park (Pratt et al. 2009). In the Kahuku Unit, where mouflon sheep are abundant, only one documented and two reported (unconfirmed) individuals were discovered in 2005 surveys (NPS 2009e). These individuals were not relocated in subsequent surveys. In 1996, there were 11 known populations and around 11,000 known individuals on the Island of Hawai‘i (USFWS 1996a). Fragile branches and stems are easily broken or browsed almost to the base of the plant. As a result, feral animals (goats, pigs, and sheep) are detrimental to the survival of this species (USFWS 1996a). This plant is preferred forage for mouflon sheep, as evidenced by browsing and mortality described above resulting from ingress sheep on the Mauna Loa Unit. Recovery efforts in the park include six foot tall fences to exclude mouflon sheep and outplanting at Kahuku in fenced silversword exclosures.

Critical habitat for this species is found in Hawai‘i Volcanoes National Park (Leonard 2009). The primary constituent elements for Hawaiian catchfly on the Island of Hawai‘i are as follows:

1. Landform/forest type: weathered lava or variously aged lava flows and cinder substrates in montane and subalpine dry shrubland.
2. Plant community: *Dodonaea viscosa*, *Leptecophylla tameiameiae*, *Metrosideros polymorpha*, *Rumex giganteus*, *Sophora chrysophylla*, *Vaccinium reticulatum*.
3. Elevation: 3,352 to 7,915 feet (1,021 to 2,412 meters) (USDA-NRCS 2005).

Candidate

‘Akū (*Cyanea tritomantha*). ‘Akū is a palm-like tree approximately 6 to 10 feet (1.8 to 3 meters) tall (USFWS 2009k). This species is endemic to the Island of Hawai‘i, and has been documented in the Kohala Mountains in the north and farther south along the windward (eastern) sides of Mauna Kea, Mauna Loa, and Kīlauea volcanoes. The naturally occurring populations nearest the park are in Pu‘u Maka‘ala Natural Area Reserve and ‘Ōla‘a Forest Reserve (Pratt et al. 2009). Overall, there are 16 current populations of this tree totaling approximately 300 to 400 individuals (USFWS 2009k). In the park, it has been found in wet forest environments in the ‘Ōla‘a Forest (NPS 2009j). Feral pigs are probably the primary threat to this species. Potential additional threats include non-native slugs, other non-native invertebrates, and rats. Recovery efforts in the park include fencing of natural populations and plantings of individuals in protected fenced units in ‘Ōla‘a (NPS 2009e).

‘Ohe (*Joinvillea ascendens* ssp. *ascendens*). ‘Ohe is an erect herb that can reach approximately 5 to 16 feet (1.5 to 5 meters) tall and contains fruits that are reddish orange (Pratt et al. 2009; USFWS 2009l). It is primarily located in wet forest and streambeds at middle elevations. Habitat in the park is montane wet ‘ōhi‘a forest with hāpu‘u understory (Pratt et al. 2009). Currently, there are 38 known populations (10 on the Island of Hawai‘i) totaling approximately 180 individuals (USFWS 2009l). In the park, there has been only one documented collection in Ōla‘a Forest, near the middle of the Large Tract, south of the trench and crater feature (NPS 2009j; Pratt et al. 2009). Herbivory and disturbance by feral pigs are potential threats in unfenced areas of the ‘Ōla‘a Forest, where this plant was last observed (Pratt et al. 2009). Competition from non-native plant species is a potential threat as well, along with low seed germination (USFWS 2009l; Pratt et al. 2009).

Hōlei (*Ochrosia haleakalae*). Hōlei is a tree that can reach 7 to 26 feet (2 to 8 meters) tall, with white flowers and yellow or plum-colored mature fruits (USFWS 2008d). It is endemic to East Maui and the northeastern portion of the Island of Hawai‘i, where it is found at elevations between 2,300 and 3,940 feet (700 and 1,200 meters) (Pratt et al. 2009). There are 11 total known populations on Maui and Hawai‘i, totaling fewer than 130 wild individuals (USFWS 2008d). Hōlei is not native to the park. However, it was planted in montane mesic forest of koa, ‘ōhi‘a, and mānele in Kīpuka Puaulu (NPS 2009j, 2009e; Pratt

et al. 2009). In wet forests, hōlei is most threatened by feral pigs. In dry and mesic forest habitats, hōlei is primarily threatened by feral goats, domestic cattle, non-native grasses, and wildfire (Pratt et al. 2009). The threats from non-native ungulates apply to plants in unfenced areas located outside the park.

Many-flowered phyllostegia (*Phyllostegia floribunda*). Also known as many-flowered Hawaiian mint, this candidate species is a subshrub with flowers (maroon to red, white on base) on short, leafless lateral branches (USFWS 2009n). Endemic to the Island of Hawai‘i at elevations of 1,410 to 3,710 feet (430 to 1,130 meters), Many-flowered phyllostegia is found in wet lowland or montane forests (Pratt et al. 2009). Currently, the species is known from 10 locations totaling 20 to 30 individuals on state, federal, and private lands (USFWS 2009n). In the park, Many-flowered phyllostegia is found in the ‘Ōla‘a Forest, at one site on the east side of the Ag Unit; the East Rift forest in craters near Nāpau; and has been planted in ‘Ōla‘a Forest Koa Unit and Small Tract (NPS 2009j; Pratt et al. 2009). Many-flowered phyllostegia is typically found in the older sections of the park, where fencing has protected populations from non-native ungulate impacts. Feral pigs are likely the most significant threat to unprotected wet forests supporting this plant (Pratt et al. 2009). In general, endemic mints are highly vulnerable to non-native ungulate impacts (NPS 2009e).

Large-flower native buttercup; makou (*Ranunculus hawaiensis*). Large-flower native buttercup is a perennial herb reaching 79 inches (200 centimeters) in height (USFWS 2009o). Habitat for this species is mesic forest, on grassy or rocky slopes, and in open pastures. It has been recorded at elevations between 5,970 and 6,700 feet (1,820 to 2,040 meters) on East Maui and Hawai‘i (Pratt et al. 2009). On the Island of Hawai‘i, this herb was historically wide-ranging in Kona, Hualālai, Mauna Kea, and Ka‘ū. Currently, this species is known from three locations on the Island of Hawai‘i, with a total of 16 individuals (USFWS 2009o). In Hawai‘i Volcanoes National Park, a single population of fewer than 10 plants has been identified in the western Kahuku Unit (NPS 2009j; Pratt et al. 2009). Non-native ungulates, including goats, mouflon sheep, and cattle, may impact this species. Rats, fire, and non-native grasses are all additional threats to Large-flower native buttercup (Pratt et al. 2009).

Largeleaf bur-cucumber; ‘ānunu; large-leaved ‘ānunu (*Sicyos macrophyllus*). This species is a perennial vine characterized by stems approximately 49 feet (15 meters) long and 2 inches (4 centimeters) in diameter (USFWS 2009m). Habitat for this species is montane mesic forest of koa, māmane, ‘ōhi‘a, and mānele at elevations between 3,940 and 6,560 feet (1,200 to 2,000 meters). On Hawai‘i, it has been recorded in montane wet forest and subalpine forest (Pratt et al. 2009). It is currently known from approximately 11 populations totaling fewer than 50 individuals (USFWS 2009m). In Hawai‘i Volcanoes National Park, ‘ānunu was identified at Kīpuka Kī in 2000 (NPS 2009j). Kīpuka Kī is located in the montane seasonal zone of the Mauna Loa Strip, which is fenced to exclude non-native ungulates (NPS 2009e). Non-native ungulates, domestic cattle, fire, rats, and non-native plants are all potential threats to the species (Pratt et al. 2009).

SPECIES OF SPECIAL CONCERN

NPS policy requires that state-listed species and others identified as species of management concern by the park are to be managed in parks in a manner similar to those that are federally listed. NPS is also cooperating in the protection and enhancement of species of concern listed by Hawai‘i. The species of special concern list is adopted from an informal list, maintained by the USFWS Honolulu Office of Ecological Services, of species of concern, that is, species about which not enough is known to prepare a formal listing package. Many of these species were formerly Category 2 Candidate Endangered Species. This list is subject to change yearly.

In Hawai‘i Volcanoes National Park, 8 animal species and 69 plant species have been identified as rare or sensitive. See table 8 for the list of species.

TABLE 8: SPECIES OF SPECIAL CONCERN IN HAWAIʻI VOLCANOES NATIONAL PARK

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Birds			
Anous minutus melanogenys	Noio, black noddy	Rare or Sensitive	Nests either on vegetation or on sea cliffs; occasionally nests on human-made structures that mimic cliff-nesting habitat. Found near the shoreline and offshore islets.
Bulweria bulwerii	ʻOu, Bulwer's petrel	Rare or Sensitive	Nests in rocky holes, on crevices in cliffs, under rock overhangs, and on the ground under thick vegetation on small oceanic islands and offshore islets. In the park it is found adjacent to the shoreline.
Phaethon lepturus dorotheae	Koaʻekea, white-tailed tropicbird	Rare or Sensitive	Found in craters and pit craters. Breeds by laying a single egg directly onto the ground or a cliff ledge.
Vestiaria coccinea	ʻIʻiwi	Rare or Sensitive	Found above 4,100 feet (1,250 meters) elevation on the islands of Hawaiʻi, Maui, and Kauaʻi; occurs at reduced densities below 3,300 feet (1,000 meters). In the park primarily above 5,000 feet (1,524 meters) and most abundant in upper montane seasonal and lower subalpine zones. ʻIʻiwi occupy mesic and wet forest dominated by ʻōhiʻa (*Metrosideros polymorpha*) and koa (*Acacia koa*) (HDLNR 2005a).
Insects			
Drosophila engyochracea	NCN	Rare or Sensitive	Found in mesic forest kīpuka. Host plant is mānele (*Sapindus saponaria*) (Foote, pers. comm., 2009a). In the park, found only in two locations in the lower montane seasonal zone in the Mauna Loa Unit.
Drosophila hawaiiensis	NCN	Rare or Sensitive	Found in mesic forest kīpuka.
Drosophila silvestris	NCN	Rare or Sensitive	Grows between elevations of approximately 3,280 to 4,270 feet (1,000 to 1,300 meters) on the wetter slops of the volcanoes.
Megalagrion koelense	Koele mountain damselfly	Rare or Sensitive	Often found in the water-filled narrow leaf axils of plants in the East Rift and ʻŌlaʻa sections of the park.
Plants			
Alphitonia ponderosa	Kauila	Species of Concern	Found in dry to mesic lowland forest and lower mid-elevation woodlands. In the park, they are found near Kīpuka Nēnē, along Hilina Pali from the road terminus to Pepeiau, Kealakomo Kīpuka, Poliokeawe Pali, and in the western lowlands near the Great Crack. Plantings have persisted in the Nāulu Forest, Kīpuka Puaulu, and Kīpuka Ki (Pratt et al. 2009).
Anoectochilus sandvicensis	Honohono, Hawaiʻi jewel orchid	Species of Concern	Found in wet forests at low to mid-elevations. In the park, they have recently been found at the ʻŌlaʻa Forest, Koa Unit, the East Rift SEA, and in a kīpuka west of Nāpau. They have also recently been planted in ʻŌlaʻa Koa Unit, Thurston Lava Tube, and Small Tract (Pratt et al. 2009).

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Antidesma pulvinatum	Hame	Rare	In the park, grows in dry to mesic lowland forest in Nāulu (one to two trees) (Pratt et al. 2009).
Asplenium schizophyllum	Fringed spleenwort	Species of Concern	Found in montane rain forests at 2,461–4,921 feet (750–1,500 meters) elevation. In the park, they are probably found only in the ʻŌlaʻa Forest (Pratt et al. 2009).
Bidens hawaiensis (B. skottsbergii)	Koʻokoʻolau, Hawaiʻi beggarticks	Rare	Found in mid-elevation ʻōhiʻa woodland in the park. they have been found at the ʻĀinahou Ranch, along the upper Hilina Pali Road, and near Kīpuka Puaulu and Koʻokoʻolau Craters. They have been planted at ʻĀinahou, the upper Hilina Pali Road, Kīpuka Nēnē, and in ʻōhiʻa woodland near Kīpuka Puaulu (Pratt et al. 2009).
Bobea timonioides	ʻAhakea	Species of Concern	Found in dry to mesic lama (*Diospyros sandwicensis*) forests at low elevations. In the park, they have been found in the Nāulu Forest, Kealakomo Kīpuka, and planted in the East Rift SEA south of the Makaopuhi Crater (Pratt et al. 2009).
Canavalia hawaiiensis	ʻAwikiwiki, Hawaiian jackbean	Rare	Grows in dry to mesic habitats. Found in Kukalauʻula, Puʻu Kapukapu, and above the Kalapana Trail in the park.
Capparis sandwichiana	Pua pilo, maiapilo, native caper	Species of Concern	Found on rocky coastlines and in dry coastal lowlands. They were historically found in the park offshore of Halape, and at low elevations near the eastern park boundary. However, recent plantings at Kalue near Halape did not persist (Pratt et al. 2009).
Chamaesyce celastroides	ʻAkoko	Rare	Grows in coastal dry shrubland on windward talus slopes and in mid-elevation seasonal environments at elevations of 30 to 2,100 feet (9 to 640 meters). Found naturally occurring in ʻĀinahou and along Hilina Pali road and the Kalapana trail; and as planted individuals in Kīpuka Pepeaio.
Charpentiera obovata	Pāpala	Rare	Found in wet to mesic ʻōhiʻa forest on soils over rock rubble. In the park, found in the Kahuku Unit, in Kīpuka Kī and in Kīpuka Puaulu, and the Mānele bend area along the Mauna Loa Strip Road (Benitez et al. 2008).
Clermontia hawaiiensis	ʻŌhā kēpau	Rare	In the park, plants grow in rainforest areas from low to high altitudes. Grows in the Kīlauea Crater Rim, East Rift, and ʻŌlaʻa. Planted in various mesic and wet forests on Kīlauea and lower Mauna Loa Unit.
Clermontia montis-loa	ʻŌhā	Rare	Found most commonly in ōhiʻa/hāpuʻu (*Cibotium* spp.) forest and less commonly in mesic to wet ʻōhiʻa forest. In the park, found primarily in ʻŌlaʻa and the Kahuku Unit eastern region (Benitez et al. 2008).
Cuscuta sandwichiana	Kaunaʻoa	Rare	In the park, plants grow in coastal areas, often in sandy soil. Grows in Kaʻaha.

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Cyanea pilosa ssp. *Longipedunculata*	Hāhā	Rare	Tend to grow in deep forest, often in narrow gulches where there is little wind. Grows in ʻŌlaʻa. Also found inside the park in the forested pit crater in Kahuku (subspecies remains undetermined); formerly found in the vicinity of the Thurston Lava Tube on Kīlauea (Benitez et al. 2008).
Cyrtandra menziesii	Haʻiwale	Species of Concern	Found in mesic to wet ʻōhiʻa forests. In the park, small populations have been found in the Kahuku Unit, in a crater at Puʻu ʻAkihi, in the southeastern section of the central pasture, and in a large forested crater surrounded by pasture (Pratt et al. 2009).
Embelia pacifica	Kilioe, Pacific embelia	Species of Concern	Grows in montane wet forests dominated by ʻōhiʻa and hāpuʻu and mesic kīpuka forests with a mix of koa, mānele and ʻōhiʻa. Found in the park at the ʻŌlaʻa Forest, at Kīpuka Puaulu, and at Kīpuka Kī (Pratt et al. 2009).
Erythrina sandwicensis	Wiliwili	Rare	Grows in lowland dry forests and shrublands. In the park, a few trees still remain in the coastal lowland and possibly at the Great Crack. There are plantings at Puʻu Kaone, ʻĀpua Point, Kāluʻe, the Nāulu Forest, the base of Hōlei Pali near Pali Uli, and northeast of the hairpin turn of the Chain of Craters Road (Pratt et al. 2009).
Eurya sandwicensis	Anini	Species of Concern	Found in wet to mesic forests and on windswept ridges. In the park, they have recently been found in the Kahuku Unit near the northern boundary of Kaʻū Forest Reserve, ʻŌlaʻa Small Tract (planted), and in the ʻŌlaʻa Forest near the Koa Unit boundary (Pratt et al. 2009).
Exocarpos gaudichaudii	Hulumoa, heau, Gaudichaud's exocarpus	Species of Concern	Grows in mesic forests, shrublands, and open ʻōhiʻa woodlands. Found in the park at ʻĀinahou Ranch, south of the ranch house in mid-elevation woodland (Pratt et al. 2009).
Exocarpos menziesii	Heau, Menzies' exocarpus,	Rare	Grows in subalpine ʻōhiʻa woodland and shrublands. Found in the park in the Kahuku Unit and less frequently in the Mauna Loa Unit (Benitez et al. 2008).
Fimbristylis hawaiiensis	Hawaiʻi fimbry	Species of Concern	Grows on old lava flows in coastal lowland and mid-elevation seasonal environments. Grows at Kaʻena Point, Kamoʻoaliʻi and other sites.
Fragaria chiloensis ssp. *sandwicensis*	ʻŌhelo papa, Hawaiian strawberry	Species of Concern	Found on Maui and the Island of Hawaiʻi, at an elevation of 3,800–10,070 feet (1,160–3,070 meters). This plant occurs at scattered localities in subalpine shrubland north of the boundary with Kaʻū Forest Reserve in the park (Pratt et al. 2009).
Gonocormus prolifer	NCN	Rare	Grow in areas that are damp, with shade on rocks or trees. In the park, plants are known from ʻŌlaʻa.
Jacquemontia ovalifolia ssp. *sandwicensis*	Pāʻu o hiʻiaka	Rare	Grows in the coastal strand at ʻĀpua Point, Keauhou, Kālu'e and Ka`aha.

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Pritchardia beccariana	Loulu	Rare	In the park, plants are found in tall, wet forests at ʻŌlaʻa.
Liparis hawaiensis	ʻAwapuhi a Kanaloa, Hawaiian twayblade	Species of Concern	Found in wet to mesic forests at mid-elevations and more rarely in seasonal woodlands. In the park, they have been found in the ʻŌlaʻa Forest, the Kīlauea East Rift near Nāpau Crater, and between the Chain of Craters Road and Keanakākoʻi Crater. However, recent surveys in these areas have yielded no sightings, including in the Kahuku Unit (Benitez et al. 2008; Pratt et al. 2009).
Marattia douglasii	Pala, kapuaʻilio, Hawaiʻi marattia	Rare	Found in ʻōhiʻa/hāpuʻu forest. In the park, found in the Kahuku Unit, and less commonly in the ʻŌlaʻa Rainforest (Benitez et al. 2008).
Melicope hawaiensis	Manena	Species of Concern	Grows in mesic forests dominated by koa, ʻōhiʻa, and mānele as well as dry ʻōhiʻa forests. Found in the park at Kīpuka Puaulu and mid-elevation woodland along Kapāpala Ranch boundary. Also recently planted at Kīpuka Kī (Pratt et al. 2009).
Myrsine lanaiensis	Kōlea, Lanaʻi colicwood	Rare	Found in dry ʻōhiʻa woodland on lava substrate. In the park, found in the southwestern region of the Kahuku Unit and downslope of the ʻĀinahou Ranch house (Benitez et al. 2008).
Nestegis sandwicensis	Olopua	Rare	In the park, plants were formerly found in wet/mesic forest at 100 feet (30 meters) elevation above Kamoamoa. Now found only at 4,250 feet (1,295 meters) in Kīpuka Puaulu, Kīpuka Ki in montane mesic forest.
Nothocestrum longifolium	ʻAiea, longleaf nothecestrum	Rare	Grows in wet/mesic forest. In the park, found primarily in wet forest at ʻŌlaʻa and in mesic forest at Kīpuka Puaulu, Kīpuka Ki, and Kīpuka ʻAiea.
Nototrichium sandwicense	Kuluʻī, Hawaiian nototrichium	Rare	In the park, plants are found at elevations below approximately 750 feet (229 meters) in open dry forests, exposed ridges, and lava fields. Found at Poliokeawe Pali, this species was extirpated and reintroduced.
Phyllostegia ambigua	NCN	Rare	Grows in wet montane forests of ʻōhiʻa and hāpuʻu as well as subalpine forests. Found in the ʻŌlaʻa Forest Small Tract and the Kahuku Unit (Pratt et al. 2009).
Phyllostegia macrophylla	NCN	Rare	Grows on steep slopes and in gulches in diverse mesic to wet forests at an elevation of approximately 1,500 to 6,000 feet (457 to 1,829 meters). Grows in the ʻŌlaʻa region.
Phyllostegia stachyoides	NCN	Species of Concern	Found in mesic to wet montane forests of koa, mānele, and ʻōhiʻa in the park. One collection was found in 1915 at Kīpuka Puaulu in the park (Pratt et al. 2009).
Phyllostegia vestita	Island phyllostegia, clothed Hawaiian mint	Rare	Grows in wet montane forests of ʻōhiʻa and hāpuʻu tree ferns. Found in the park in the ʻŌlaʻa Forest Koa and New units, the East Rift SEA, the crater of Kane Nui o Hamo, and the ʻŌlaʻa Koa Unit (planted) (Pratt et al. 2009).

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Phytolacca sandwicensis	Pōpolo ku mai, Hawai‘i pokeweed	Rare	Historically found in mesic montane forests of koa, ‘ōhi‘a, and mānele as well as wet montane forests of ‘ōhi‘a and hāpu‘u. In the park, they have been found in the ‘Ōla‘a Forest’s Koa and Pu‘u units, and in Kahuku. Recently planted in Kīpuka Puaulu and Kīpuka Ki (Pratt et al. 2009).
Pisonia brunoniana	Pāpala kēpau, Australian catchbird tree	Rare	Found in mesic/wet forest environments and grows in Kīpuka Puaulu and Kīpuka Ki, where it is localized.
Pisonia umbellifera	Pāpala kēpau, umbrella catchbird tree	Rare	Grows in lowland forests.
Pittosporum confertiflorum	Hō‘awa	Rare	Grows in subalpine ‘ōhi‘a woodland and lowland mesic forests, occasionally on old pāhoehoe lava flows. Found in the park in the upper region of the Kahuku Unit and in the East Rift SEA, and less recently in the upper Mauna Loa SEA (Benitez et al. 2008).
Pittosporum hawaiiense	Hō‘awa, Hawaiian pittosporum	Species of Concern	Grows in mesic/wet forests at ‘Āinahou and in Kahuku pasture environments, though the identification in ‘Āinahou could have been a misidentification.
Pittosporum hosmeri	Hō‘awa, Hosmer's pittosporum	Rare	Grows in koa/‘ōhi‘a woodland forest on soil over old lava flows. Less frequently found in ‘ōhi‘a/hāpu‘u forest on substrates of soil over old pāhoehoe flows. In the park, found in numerous sites throughout the Kahuku Unit, and in the park in and around Kīpuka Puaulu and Kīpuka Ki (Benitez et al. 2008).
Plumbago zeylanica	‘Ilie‘e	Rare	Grows in coastal lowlands. Extirpated and replanted at Lae ‘Apuki, Hōlei.
Pneumatopteris hudsoniana	Hudson’s air fern, Laukahi	Rare	Found in lowland forests.
Portulaca villosa	‘Ihi, hairy purslane	Species of Concern	In the park, known only near the coast in shallow ash over pāhoehoe, in a site now covered by lava. Recently planted at four sites in the coastal strand but no plantings survived (Pratt et al. 2009)
Rauvolfia sandwicensis	Hao	Rare	Grows in dry to mesic forests. Found in the park at Nāulu and Hōlei Pali.
Reynoldsia sandwicensis	‘Ohe mākai, ‘ohe	Species of Concern	Grows predominately in dry to mesic lowland forests and less commonly in open vegetation on old lava flows. Found in the park along Poliokeawe Pali near the trail from ‘Āinahou Ranch to coastal Keauhou, east of ‘Āinahou, in the Kealakomo kīpuka, and recently planted at the Nāulu Forest and Kealakomo (Pratt et al. 2009).
Rhus sandwicensis	Neneleau	Rare	Grows in disturbed areas, especially along roadsides and in pastures from relatively wet to dry environments. In the park, plants grow above Nāulu and the Kalapana trail.

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Rubus macraei	ʻĀkala	Species of Concern	Found in montane wet forests, bog margins, and subalpine shrubland. In the park, they have been found in the Kahuku Unit north of Kaʻū Forest Reserve and historically reported in the upper Mauna Loa Strip (Pratt et al. 2009).
Rumex giganteus	Pāwale	Rare	Grows in wet ʻōhiʻa/hāpuʻu forest, and mesic ʻōhiʻa/koa woodland. In the park, found in four different sites in the Kahuku Unit and less frequently at the ʻŌlaʻa Forest, Kīpuka ʻAiea, Mauna Loa SEA, and woodlands near Puʻu Puai (Benitez et al. 2008).
Sanicula sandwicensis	Tall Hawaiian sanicle, snakeroot	Species of Concern	Grows in subalpine shrublands and woodlands, specifically ʻōhiʻa woodland. In the park, a small population exists in the western section of the Kahuku Unit.
Sapindus saponaria	Mānele, ʻae, soapberry	Rare	Grows in mesic forests with deep ash soil in and near Kīpuka Puaulu and Kīpuka Ki.
Scaevola kilaueae	Kīlauea naupaka, huahekili uka	Species of Concern	Found in the park's mid elevation woodland and scrub in the Kaʻū Desert, from the upper Chain of Craters in the east to the Keāʻmoku Flow in the west, and along the upper Hilina Pali Road (Pratt et al. 2009).
Schiedea diffusa ssp. *macraei*	NCN	Species of Concern	Found in mountain rain forests and in ʻōhiʻa/hāpuʻu forests. Found in the park in the ʻŌlaʻa Forest at the eastern edge of the Ag Unit exclosure and planted in the ʻŌlaʻa Koa Unit and Small Tract (Pratt et al. 2009).
Sicyos pachycarpus	Paha, kūpala	Rare	Grows in moist to wet forests at elevations of approximately 500 to 2,600 feet (152 to 792 meters). Probably occurred in Nāulu, but now extirpated.
Sisyrinchium acre	Mauʻu lāʻili, Hawaiian blue-eyed-grass	Species of Concern	Grows in dry subalpine shrubland of scattered ʻōhiʻa trees and native shrubs or bogs. In the park, plants are found in Kīpukamaunaʻiu, in Kīpuka Kulalio, and in the subalpine shrubland at Kahuku (Pratt et al. 2009).
Stenogyne macrantha	Hawaiian stenogyne	Species of Concern	Found in montane ʻōhiʻa/hāpuʻu rain forests. Found in the park in the ʻŌlaʻa Forest, Koa and Ag units, and planted in the Koa Unit and Small Tract.
Stenogyne scrophularioides	Scroph stenogyne, Mōhihi	Rare	Grows in montane ʻōhiʻa/hāpuʻu rain forests. Found in the ʻŌlaʻa Forest's Koa Unit (planted), New Unit, and Small Tract (planted and natural populations) (Pratt et al. 2009).
Stenogyne sessilis	Sessile stenogyne	Rare	In the park, plants were historically documented in Mauna Loa and recently discovered in Kahuku (Benitez et al. 2008).
Tetraplasandra hawaiensis	ʻOhe	Rare	Typically found in mesic to wet lowland forest. In the park, plants are known from Kīlauea' s East Rift, formerly near Nāulu, and Kamoamoa, and as a half dozen scattered individuals in pasture in Kahuku (Benitez et al. 2008; Wagner et al. 1999).

Scientific Name	Common Name	Status	Habitat Description and/or Location in the Park
Tetraplasandra kavaiensis	ʻOheʻohe	Rare	Grows in montane ʻōhiʻa/hāpuʻu rain forests. Found in the park in the ʻŌlaʻa Forest near its boundary with Puʻu Makaʻala Natural Area Reserve (Pratt et al. 2009).
Tetraplasandra oahuensis	ʻOhe mauka	Rare	Grows in mesic valleys and wet forests. In the park, trees are found in ʻŌlaʻa.
Touchardia latifolia	Olonā	Rare	Plants are typically found in mesic valleys and wet forest from 230 to 3,937 feet (70 to 1,200 meters) elevation. In the park, plants are known from ʻŌlaʻa and from a single individual in Kahuku (Benitez et al. 2008; Wagner et al. 1999).
Trematolobelia grandifolia	Koliʻi, large-flower false lobelia	Species of Concern	Found in the exposed areas of montane and mid-elevation rain forests. Often grows on fallen logs and tree ferns in closed wet ʻōhiʻa/hāpuʻu forests and occasionally on cliff tops near bogs. In the park, they are found in all of the fenced units of the ʻŌlaʻa Forest as well as in the unfenced Koa Kīpuka, the Kīlauea Caldera rim rain forest, the East Rift SEA, the forested pit crater at Kahuku, and on Kāne Nui o Hamo (Pratt et al. 2009).
Urera glabra	Ōpuhe	Rare	Typically found on slopes and gulch bottoms in mesic to wet forest. In the park, plants are found in wet forest of ʻŌlaʻa and Kīlauea's East Rift, in mesic forest on Mauna Loa and as a single individual in Kahuku (Benitez et al.2008).
Xylosma hawaiiense	Maua	Rare	In the park, plants occur in mesic forest at Kīpuka Puaulu, ʻŌlaʻa, and Nāulu.
Zanthoxylum dipetalum var. *dipetalum*	Kāwaʻu	Species of Concern	Grows in montane mesic forests of koa, ʻōhiʻa, and mānele. Found naturally growing and planted in the park at Kīpuka Puaulu and Kīpuka Ki (Pratt et al. 2009).
Zanthoxylum kauaense (Z. maviense)	Aʻe	Rare	Grows in mesic dry or wet forests, often composed of koa/ʻōhiʻa and montane wet ʻōhiʻa/hāpuʻu. Found in Kīpuka Puaulu and the ʻŌlaʻa Forest (Pratt et al. 2009).

Source: NatureServe 2009; NPS 2009j.

NCN = no common name.

RARE, UNIQUE, THREATENED, OR ENDANGERED SPECIES AND THE ROLE OF CLIMATE CHANGE

Please see the discussion in the "Vegetation" and "Native Wildlife and Wildlife Habitat" sections of this chapter for information on the role of climate change on the flora and fauna of Hawaiʻi.

CULTURAL/HISTORIC RESOURCES

General Introduction to Hawaiʻi and Western Contact

Initial settlement of Hawaiʻi was likely based from Central East Polynesia (Marquesas, Society and Cook Islands) (Kirch 1985). Colonization may have occurred in the centuries around AD 500, although this is

still a topic of debate among scholars (Graves and Addison 1995; Hunt and Holsen 1991; Kirch 1985). Having carried with them a cultural template from their Polynesian homeland, the original colonists established a religious and sociopolitical system that was soon to evolve into a uniquely Hawaiian culture (Moniz-Nakamura n.d.). Superb sailors, Polynesians migrated to Hawai‘i by navigating with the sun and stars, reading the winds, currents, and the flight of seabirds. Sailing across 2,400 miles of open ocean in large double-hulled canoes, they brought with them items to ensure their survival: pua‘a (pigs), ‘ilio (dogs), and moa (chickens); the roots of kalo (taro) and ‘uala (sweet potato); and the seeds and saplings of niu (coconut), mai‘a (banana), kō (sugar cane), and other edible and medicinal plants (NPS 2009k).

Stylistic similarities of fish hooks and linguistic evidence suggest that two-way voyaging existed between Hawai‘i and other islands in Polynesia, but that this type of contact diminished over time (Fornander 1996 and Kamakau 1991 cited in Cachola-Abad 2000). It is not known when two-way voyaging ceased, however it had long stopped by the time of European contact in 1778 (Cachola-Abad 2000). By 1778 Hawaiian canoes had evolved to vessels that were suited only to coastal and inshore fishing or travel, and were not able to complete open-ocean navigation. The isolation from the rest of Polynesia resulted in the evolution of Hawaiian society into what is distinctively known as the Hawaiian culture (Moniz-Nakamura n.d.).

Polynesian colonizers employed their own traditional fishing and agricultural techniques where possible, and they adapted new techniques to fit the unique conditions of Hawai‘i. Colonization of Hawai‘i was assisted by the availability of certain critical resources such as water, natural vegetation, lithic sources, and marine resources, in addition to suitable habitats. To adapt to their environment colonizers were able to harmonize traditional and adaptive fishing, agricultural techniques, and the means for supplementing the resource base found in Hawai‘i with the plants and animals they introduced. The environment provided Hawaiians with an abundance of resources and they took the opportunity to alter the natural native environment and shape it to a cultural landscape (Moniz-Nakamura n.d.).

Pigs, the only ungulate introduced by Polynesians to Hawai‘i, were of the Asian variety. Therefore, they were smaller than the European pig. Pigs played an important role in the religious, political, social, and subsistence economy of ancient Hawai‘i and into the mid-19th century; some of these traditions continue today in a modern society. Historically, under the *kapu* system, strict rules regarding the eating of pigs were observed, and some families cared for them like pets. By the late 18th century, Captain Cook noted that the pigs “were in abundance and ran without restraint among the houses” (Tomich 1986) while Ellis (2004) noted that pigs “were found sometimes in the mountains.” Late in the 19th century and early 20th century a variety of botanists who traveled in the native forests on Hawai‘i never mentioned seeing wild pigs in the forested areas (Cuddihy and Stone 1990). Handy and Handy (1972) as cited in Cuddihy and Stone (1990) stated, “only young pigs were allowed to run loose; older pigs were kept in pens.”

This isolation of the Hawaiian Islands ended in 1778 with the arrival of British explorer Captain James Cook and his crew, who named the archipelago the Sandwich Islands. Cook’s expedition opened Hawai‘i to the world, and in the next century great change came to the people and the landscape with the arrival of sailors, merchants, missionaries, and businessmen, who altered the social and political structure and had permanent and long-lasting impacts on the culture and the natural landscape. The 19th century was a period of considerable change for the islands and its people. The coming of westerners brought many changes to the islands, including the introduction of new diseases, which decimated the native population; a weakening of the traditional political system with the death of Kamehameha I; the introduction of a market economy, which led to a shift toward land ownership; and the denunciation of the kapu (the socio-religious and socioeconomic system that had served Hawaiian culture for hundreds of years). These changes created a wide-reaching disquiet in Hawaiian society (Durst n.d.).

The first western introduction of hoofed animals to Hawai‘i was the goat and European pig on Captain Cook’s first voyage in 1778. Continued introductions of hoofed animals such as cattle, goats, sheep, European pigs, and horses in the late 18th and early 19th centuries led to widespread changes in the natural landscape. While horses, cattle, and larger pigs were welcome gifts to the monarchy, who realized their value, the price of acceptance was high for those who maintained a subsistence lifestyle.

By the time Captain George Vancouver visited in 1792, he reported that Kaiana, a chief from Kealakekua, had possession of several goats (Tomich 1986). Captain Vancouver left more goats that same year with chief Keeaumoku at Kawaihae. The following year, 1793, Vancouver introduced sheep to the Island of Hawai‘i (the taxon was first introduced to the islands by Captain James Colnett on Kaua‘i in April 1791). In addition to his introductions of goats and sheep, Vancouver was the first to introduce cattle in 1793—as a gift to Kamehameha I. The following year, 1794, Vancouver returned and left another five head of cattle, including three bulls. Although the first few cattle did not survive, the subsequent animals did and flourished. The population of free roaming cattle grew and presented a very real threat to the native forest and the people who feared them. With the introduction of horses to Hawai‘i in 1803 by Captain Richard Cleveland aboard the Lelia Byrd, bullock hunters were afforded a more mobile, safer, and faster way of traveling over the rugged landscape in the attempt to control feral cattle (Durst n.d.).

Vancouver strongly supported Cook’s original intention to stock the islands with several species of domestic animals so that sailors would have ample supply of meat. To this end, he asked Kamehameha I to restrict killing of cattle, sheep, “and other European animals” for 10 years. Kamehameha reluctantly agreed to Vancouver’s request for a kapu (restriction) (Tomich 1986), though he (Kamehameha) had the sole discretionary power to “appropriate a certain number of the male species, in case that sex became predominant, to the use of his own table” (Vancouver 1798).

The descendants of these first European imports made a major impact on Hawai‘i’s economy and ecosystem. Left unfettered, these animals ranged far and wide, where they multiplied and were not managed by the Native Hawaiians. By 1850 goats were reported to be abundant and widespread (Tomich 1986). The Reverend William Ellis, during his 1823 travels around the Island of Hawai‘i, wrote that Joseph Goodrich (who was part of this missionary group) reported seeing wild cattle on Mauna Kea and dead sheep near the summit, suggesting these species had spread throughout the island (Ellis 2004). Goodrich described the cattle as “wild and ferocious,” having been allowed to roam without challenge by humans for so long.

This resulted in animals damaging residences, destroying agricultural crops, heavily impacting the natural vegetation, and harming people, even killing a few who happened in their path (Tomich 1986). The native farmers were at the mercy of these wild beasts. In response to the destruction of upland native forests, village gardens, and taro farms, Hawaiians built stone walls of volcanic rock to keep the animals out of agricultural areas (Durst n.d.).

The original kapu placed on these taxa was not lifted until 1830, well past the 10-year prohibition date (Henke 1929). The decades that had passed allowed the non-native ungulates to multiply and spread, destroying native landscapes as they consumed their way across the islands. When the kapu was finally lifted, Native Hawaiians did not become involved in cattle hunting in the early years. They had come to fear the wild cattle because of the ferocity they had developed as they became feral (Ellis 2004). Thus, management of the wild cattle was left primarily to foreigners, who took advantage of an ever-growing market overseas for cattle meat and hide. Lacking the means to control the feral herds of cattle, the government hired a handful of foreign bullock hunters in an attempt to manage their ever-increasing numbers. As yet, Hawaiians did not consider beef as a foodstuff, but the demand by sailors and those outside of Hawai‘i was great (Durst n.d.). Trading of beef, hides, and tallow soon supplanted the trade for the dwindling sandalwood. The growing shipments of beef and the demand for hides and tallow in

Honolulu resulted in the thinning out of the wild herds of cattle. Under the reign of Kamehameha III, a kapu on cattle was renewed from 1840 to 1844 in which the killing of the wild, unbranded cattle belonging to the monarchy was prohibited (The Polynesian 1841, 51; Hawaiian Historical Society Annual for 1931–1932, 23, as cited in Durst n.d.).

The cattle kapu was once again lifted in 1844. Though the first kahu pipi (cattle hunters) had success with animal control, it wasn't until vaqueros (Spanish for cowboys) came to Hawai'i that the real turning point in feral animal management occurred. Hunting was originally done on foot with the aid of dogs, experience, and cunning. Deep pits were dug near cattle watering holes and covered with vegetation, with the intent of capturing cattle in the pit. Once captured, the animals were dispatched with muskets. The animal was then skinned and butchered and the meat was salted, packed in barrels, and carried for miles by native people to markets at the coast.

Ranching in Hawai'i began prior to the lifting of the kapu on cattle. The industry flourished throughout the 20th century and is still visible today. Many Hawaiians became involved in the ranching business as renowned paniolo (Hawaiian cowboys). While cattle are perhaps the best-known ranching industry in the islands, goat and sheep ranching were also important industries. Many Hawaiians from the Puna and Ka'ū districts became deeply involved in the goat and cattle ranching business, as goats and cattle had become profitable trade items and an important food source. From 1836, yearly exports of cattle hides and goat skins had reached 6,000 and 20,000, respectively. By the 1860s and 1870s that figure had risen to 20,000 hides and 50,000 skins annually (Kemper and Kamins 1993). The meat from goats was also salted and dried and exported each month. The importance of goats to Puna and Ka'ū Hawaiians as a means of subsistence and market product is evident in the Boundary Commission testimonies, where ownership of the animals is described and identified by ahupua'a (Moniz-Nakamura n.d.). By 1862, within the current park boundary, goat ranching was widespread in Puna from Lae'apuki to Panau and Kealakomo. By the early 20th century, goat hunting had become an important means of subsistence for those who lived in Puna and Ka'ū. Meat from goats was eaten by hunters and their families. Emma K. Kauhi (1996), a resident of nearby Kapaahu, relates that in 1925, the men from Kapaahu would go into the mountains in Paliuli in Pānau to hunt goats, donkeys, and wild cattle. Ms. Kauhi states, "A whole lot of men would go and build a corral and drive the goats inside and they would be shared out to all the people" (Moniz-Nakamura n.d.).

Non-native Ungulates and Cultural Resources in Hawai'i Volcanoes National Park

Prior to the NPS involvement with the ungulates, the Hawaiian Kingdom recognized the need to protect the water resources that supported the lucrative agricultural industry, and commercially valuable forest species (Buck 2003). On Sept 19, 1876, King David Kalākaua signed into law the *Act for the Protection and Preservation of Woods and Forest*, which directed the Minister of the Interior to set apart and protect forest lands (Hawai'i Laws Chapter XXX, 39) and authorized the superintendent (of the Kingdom of Hawai'i lands) to "have charge of the construction of fences and barriers required to protect the said woods and forest lands." On January 4, 1893, Queen Lili'okulani approved the establishment of the Bureau of Agriculture and Forestry, which further defined the role of the Hawaiian government in preserving forest (Hawaiian State Archives-Com 2, Box 11). Under the Territory of Hawai'i, these efforts became the responsibility of the Board of Agriculture and Forestry. In Hawai'i Volcanoes National Park, animal control actions conducted by the territorial government began in 1927 and were assumed by the park in 1932 (NPS 1972).

Several areas within the current park boundary, including the districts of Puna and Ka'ū and specific locations of 'Āinahou in Keauhou and Kahuku in Ka'ū, were focal cattle and goat ranching sites. However, feral goats, sheep, and cattle were widespread and beyond the boundaries of the ranches by the

time the U.S. government established the national park on the Island of Hawai‘i in 1916. The control of these non-native ungulates became the responsibility of the NPS.

The NPS *Management Policies 2006* (NPS 2006b) recognizes the following categories of cultural resources: archeological resources, cultural landscapes, structures, museum objects, and ethnographic resources, as specific to *National Historic Preservation Act* property types. This document analyzes potential impacts to three of the five categories: archeological resources, cultural landscapes, and ethnographic resources. Museum objects and historic structures are not likely to be impacted by non-native ungulate management (see discussion in “Chapter 1: Purpose of and Need for Action,” “Issues Dismissed From Further Consideration”). The 13 National Register-listed properties in the park include buildings, trails, the Kīlauea caldera, the Puna-Ka‘ū Historic District and ‘Āinahou Ranch House and Gardens. Structures, such as cabins, trails and roads are unlikely to be affected by ungulate management. Other listed properties that may be affected by ungulate management are discussed under the appropriate cultural resource category (archeology, cultural landscapes, or ethnography). There is a high probability that many cultural resources exist in undocumented or unsurveyed areas of the park. The National Register and the sites listed is incomplete and does not reflect our current understanding and distribution of cultural resources. Consequently, the information that follows is provided based on current surveys that have been completed in addition to the properties listed on the National Register.

ARCHEOLOGICAL RESOURCES

The NPS has been the steward of the lands in Hawai‘i Volcanoes National Park for nearly 100 years. For centuries prior to European contact, this land was cared for and occupied by the Native Hawaiian people. The physical remnants of those who lived and thrived in this setting can still be seen today in the archeological resources that are spread across this vast landscape.

Archeological resources are the physical evidence of past human activity, including evidence of the effects of that activity on the environment (NPS 1998). An archeological overview and assessment of the park was prepared in 2008 (Tuggle and Tomonari-Tuggle 2008). It provides guidance to program managers in the form of recommendations for future study to meet legislative requirements. Recent analysis of all known survey projects indicate that 13% of the park has been surveyed to date. The coverage has been such that samples of most of the regions of the park have been obtained, and a general understanding of occupational patterns has been developed.

The archeological resources at Hawai‘i Volcanoes cross a range of prehistoric Native Hawaiian and Euro/American historic sites. Spatially, ruins extend from the coast to the upland alpine regions. Radiocarbon data suggest that Hawaiians settled in this region of Puna and Ka‘ū by the early 15th century. Evidence of their life on this lava landscape can be found in the remnants of house platforms and caves scattered throughout the lowland and upland areas. Enclosures, which may have been used to pen livestock, and excavated pits and rock mulch mounds suggest animal husbandry and widespread farming took place on what today appears to be barren lava. Five centuries ago, however, this area was host to thriving family communities, or *ohana*, who etched carvings (petroglyphs) that represented their families, traditions, and beliefs into the cooled lava surface.

The Native Hawaiians who lived in this region were linked together by trail systems, which connected families who lived and fished along the coast with farmers who lived and worked further inland. The intricate trail systems also provided people with access to prized resources, such as volcanic glass and basalt, used to make their tools; petrel nests, where seabirds were caught for food; shrines and other sacred sites used for worship and other activities (such as observing the movement of the sun and the changing of the seasons); plants collected for medicine and dyes; and trees harvested for wood for canoes

and houses. These resources are a testament to those who chose to live in the shadow of Kīlauea and Mauna Loa and were shaped by the power of Pele (the Hawaiian goddess of volcanic activity).

Hawaiian Petroglyphs

Source: http://www.nps.gov/havo/photosmultimedia/Landscapes-in-the-park.htm.

Across the entire park, more than 300 archeological sites with associated subsites (approximately 2,000 plus) or features have been identified, evaluated, and recorded in the Archeological Sites Management Information System, the NPS database of archeological information (NPS 2009f). The recent addition of the Kahuku region has contributed to the park's database of sites. More archeological sites are expected to be found, as only a portion of the Kahuku Unit has been systematically surveyed (Quiseng 2008), and there are many other areas of the park for which survey and documentation are still needed.

Of the numerous known Native Hawaiian sites across the landscape, one of the most important sites in the park is the Puʻuloa Petroglyph Field, part of the National Register–listed Puna-Kaʻū Historic District, containing more than 23,000 petroglyphs that depict people, canoes, geometric shapes, and cupules, or *puka* (holes), in which umbilical cords were placed. Included in the historic district are the large agricultural fields in Pānau, Paliuli, and Kealakomo where sweet potato was planted. Another is the "1790 Footprints Area," which is listed on the National Register. Also present are native shrines (*heiau*) such as the Waha'ula Heiau, built in the 13th century and significant for its connection to Paʻao, a priest who appeared on the island, ushering in the second massive migration wave (NPCA 2008). Another resource is a portion of the Ala Kahakai National Historic Trail (NHT), a 175-mile trail corridor with

cultural and historical significance connecting and traversing hundreds of ancient Hawaiian settlement sites and over 200 ahupua‘a, or traditional sea-to-mountain land divisions (NPS 2009h).

Many historic archeological sites can also be found throughout the park, associated with such events as World War II and ranching. Ranching features include houses, ranch walls, animal enclosures, and trails, including the Kahuku to Ainapo Trail that was used to drive cattle across the island. Families that used lands in Ka‘ū and Puna that are now included within the park boundary tended goats—particularly in the Kalapana Extension. Structural remains of these activities provide a testament to the goat and cattle ranching activities that were widespread in the lands within the current park boundary. The park also contains the first airfield ever built on the island, the only physical remnant of the Wilkes Expedition at the summit of Mauna Loa, and an impressive example of early Hawaiian industry, the export of pulu, at the Pulu Factory.

The archeological sites located in Hawai‘i Volcanoes National park are impacted by a number of natural and human-induced elements. These include, among other things, lava flows, fire, visitors, non-native ungulates, and time.

The archeological sites located in Hawai‘i Volcanoes National park are impacted by a number of natural and human-induced elements. These include, among other things, lava flows, fire, visitors, non-native ungulates, and time. Sites located in areas where ungulates tend to gather are of particular concern, because of the impact ungulates have on these features. In the past, affected areas have included the large agricultural fields in Panau, Paliuli, and Kealakomo where sweet potato was planted. Currently, the area of greatest concern for damage to archeological sites by ungulates is the Kahuku Unit, as it contains the largest population of non-native ungulate species. The newly discovered Kau Field System in Kahuku contains lowlying features that were likely impacted by feral goats and sheep (Moniz-Nakamura, pers. comm. 2010). When under cultivation the fields may have been impacted by ungulates eating the plants. After the fields were abandoned the field systems were impacted by large numbers of ungulates that easily trample the features. Caves are especially vulnerable to damage, as ungulates tend to bed down in them, trampling fragile artifacts and knocking over walls. Surface sites are also vulnerable to ungulate activities such as trampling, grazing, digging, rooting, bedding, and depositing fecal material.

CULTURAL LANDSCAPES

Cultural landscapes are geographic areas associated with specific cultures or historical events, and they help illustrate how humans have adapted to and altered their surroundings (NPS 1998). The NPS recognizes four cultural landscape categories: historic designed landscapes, historic vernacular landscapes, historic sites, and ethnographic landscapes. The historic vernacular landscapes—landscapes that evolved through use by the people whose activities or occupancy shaped that landscape—at Hawai‘i Volcanoes National Park that might be impacted by non-native ungulates or ungulate management activities are addressed below. (Ethnographic landscapes are discussed more fully in the “Ethnographic Resources” section below.)

Hawai‘i Volcanoes National Park has identified 19 individual cultural landscapes in the park, which include trails, ranches, roads, historic districts, landing strips, and a military camp. However, only three historic properties with certified cultural landscapes have been thoroughly documented: Crater Rim Historic District, Kīlauea Historic District (formally the Kīlauea Administration and Employee Housing Historic District), and ‘Āinahou Ranch and Gardens. These have been documented through cultural landscape inventories (NPS 2004c, 2006d, 2006e) and have been determined eligible for listing on the National Register. ‘Āinahou Ranch House and Gardens was listed on the National Register in 1994 as significant under National Register criteria B (associated with the lives of persons significant in our past)

and C (embodies distinctive characteristics of a type, period, or method of construction). The associated landscape features of the property were subsequently documented through the NPS Cultural Landscape Inventory process in 2004. It is currently the only certified cultural landscape affected by pigs. Crater Rim and Kīlauea Historic Districts are both managed as ungulate free areas.

Herbert C. Shipman leased land from Bishop Estate to establish ʻĀinahou Ranch before the park acquired it. The period of significance is from 1941 to 1971, which begins when Shipman first constructed his house as a safe haven from a possible Japanese invasion during World War II and ends when Shipman submitted his asking price for the property and terminated his lease with the B.P. Bishop Estate, thereby allowing the NPS to acquire it from the owner. During that period, he established a captive flock of nēnē at the ranch. The ca. 10-acre residential complex includes the main ranch house constructed in 1941 and outlying buildings and structures, including water tanks and sheds. An informally planted garden area of introduced ornamental trees and shrubs that provide a setting for the historic character surrounds the house. Other landscape features include informal and formal paths and trails, rock walls, fences, horse trails and the rubbish dumps. Additional historic landscape characteristics include, land use, views and vistas, and the site's water collection and distribution system. The associated landscape features of the historic property were documented as a historic vernacular landscape through the Cultural Landscape Inventory process in 2004. The Cultural Landscape Inventory for the ʻĀinahou Ranch states that it is in "fair" condition, with structural repairs needed (NPS 2004c).

Additional historic properties (both eligible for and listed on the National Register) have yet to be inventoried for cultural landscape potential.

ETHNOGRAPHIC RESOURCES

The ethnography program at Hawaiʻi Volcanoes National Park is one of the park's most visible cultural resource programs. The park has a strong commitment to integrating native voices in interpretive materials, and the park acknowledges the "living culture" and embraces the sacredness of the summit area. The park maintains solid relationships with a number of Hawaiian elders, or *kupuna*, and Native Hawaiian Organizations as part of ongoing consultation for the protection of cultural resources in the lands of the park. Ethnographic work at Hawaiʻi Volcanoes includes the studies titled *Native Hawaiian Use of Hawaiʻi Volcanoes National Park: A Historical and Ethnographic Overview* and *Ethnographic Studies at Hawaiʻi Volcanoes National Park*; both works were completed for the NPS by Charles Langlas (2003a, 2003b). Other work continues research on the understanding of the greater cultural landscapes found in the park lands.

Ethnographic resources are variations of natural resources and standard cultural resource types. They are subsistence and ceremonial locales and sites, structures, objects, and rural and urban landscapes that traditional users designate as culturally significant to their present way of life. The decision to call resources "ethnographic" depends on whether associated peoples perceive them as traditionally meaningful to their identity as a group and the survival of their lifeways (NPS 1998). Ethnographic resources abound in Hawaiʻi Volcanoes National Park. The volcanic landscape, the volcano summits, and the vegetation connect the Hawaiian people to the park. These same resources have value for non-Hawaiians for a variety of reasons.

The volcanic landscape found throughout the park is considered an ethnographic landscape that is very important to the Native Hawaiians. The volcanic landscapes are recorded in countless chants and stories of Pele. These stories describe in detail the movement of lava, whether destructive or creative in nature. It also describes other phenomena associated with eruptions, such as earthquakes, tsunamis, and explosive eruptions. Pele is more than the goddess, she is volcanism, she is the molten lava creeping along the terrain, and she is also the magma that has cooled. This landscape sustains life for both plants and

animals, including humans. To some Hawaiians, especially those who live in Puna, Kaʻū and South Kona, it is a sacred landscape: they understand that the land belongs to Pele and she can take it whenever she wants.

The longest traditional users of these resources are the Native Hawaiians. The lifestyle of the Hawaiian people was and still is greatly influenced by the landscape on which they live. The Hawaiians had a highly stratified social structure by the time Europeans arrived in Hawaiʻi (NPS 2009k). This system consisted of *nā akua* (gods), the *aliʻi* (chiefs), and the *makaʻainana* (commoners). The gods were pervasive in every aspect of society because the Native Hawaiians were directly tied to the natural world and their gods represented elements of nature—for example the sun (Kanehoalani), freshwater (Kanekawaiola), the ocean (Kanaloa), volcanism (Pele), forest (Laka), and others. All natural phenomena (including the Kanaka [mankind]) are intimately connected (Kealiʻikanakaʻoleohaililani 2009). The aliʻi (chiefs) governed their people on behalf of the gods. They saw to it that the appropriate rituals of reciprocity were observed.

The traditional Hawaiian land management system was very sophisticated. The island was divided much like a pie. The ahupuaʻa were wedge-shaped land divisions that extended vertically from the mountain to the sea and also included offshore fisheries (NPS 2009h). This ensured that people living in the ahupuaʻa had access to a wide range of resources necessary for living. Ahupuaʻa were considered political boundaries that separated chiefdoms. There are still smaller land sections in the ahupuaʻa (HDLNR 2003b). Horizontal land divisions in the ahupuaʻa were environmental zones demarcated by vegetation growth at various elevations. The top of the mountain is known as the kuahiwi; it is very sacred because of its height. Just below the kuahiwi is the kualono, a region where māmane and naio grow sparsely. Below the kualono the wao maʻukele or waokele is named for its wet soggy ground, because it lies within the rain belt. ʻŌhiʻa and koa dominate the canopy. The wao akua is the forested region just below the waokele, said to be occupied by forest spirits. It was important to keep this section of the forest intact and undisturbed because it supplied the seeds that generated new growth and kept the forest alive. The forested region located below the wao akua was known as the wao kanaka, a region where the people came to collect material for domestic purposes. The kula region is the upland grassy plains where pili was collected and used for thatching their homes. Finally, the kahakai, or shoreline, is where niu (coconut trees), hala (pandanus), and other useful plants grew (HDLNR 2003b).

These horizontal land divisions are still recognized and used by Native Hawaiian practitioners today. Practitioners of hula and Hawaiian medicine continue to collect plant material in various ecological zones, although some of the plants needed are no longer found or are harder to find in the wao kanaka due to development and other factors, such as invasive species, and practitioners have been pushed to different zones in order to find the material they need. The Hawaiians' relationship to the land was and still is very important. They know that the waokele and the wao akua are vital for the collection of the water that fills the island's aquifers. They are also aware of the regenerative energy of the forest; hence, the designation of the wao akua and waokele areas as undisturbed areas where the forest was kept intact. Certain ceremonies and rituals are still practiced in these areas.

The imposing presence of natural phenomena formed the basis of early Hawaiian lifestyle. Gods and goddesses were seen as personifications of natural objects and forces of nature. Native Hawaiian beliefs and practices taught that the entity or energy whose primary form or function is necessary for sustaining all life is the deity (Kealiʻikanakaʻoleohaililani 2009). Certain people, places, things, and times were sacred—they were kapu, or forbidden. Women ate apart from men and were restricted from eating pork, coconuts, bananas, and a variety of other foods. The aliʻi imposed kapu (restrictions) that regulated fishing and the harvesting of other resources, thus ensuring their conservation. Any breaking of kapu disturbed the stability of society; the punishment often was death (NPS 2009k).

Sacred or religious features in the park include natural features such as Kīlauea Caldera and Summit area and constructed features such as shrines, heiau, or burial sites. Kīlauea is used for rituals to Pele, goddess of volcanic activity, or to her relatives (Kamohoali‘i, Hi‘iakaikapoliopele, and others). The sites for Pele are by far the most important (Langlas 2003a).

Native Hawaiians from the entire island, and even from the outer islands, go to Kīlauea Caldera to give ho‘okupu (offerings) to Pele and to ask for her help with their lives. Those religious activities have their roots in the Hawaiian past, from well before the time of European contact. Many of the Hawaiians who go to Kīlauea to make offerings to Pele are associated with various hālau hula (dance schools) (Langlas 2003b). Asian cultures have also adopted Pele as their deity, making special trips to the Island of Hawai‘i for the day and leaving incense, fake money, and other food offerings at the edge of the crater.

The Polynesian pig figures prominently in Native Hawaiian culture. There are frequent references to pigs as god figures, gifts, and sacrificial offerings in ethnographic studies (Langlas 2003a, 2003b). However, in some cases, pigs were also depicted as wreaking havoc on resources. For example, Kamapua’a, the Hawaiian pig-god, was from the Island of Oahu, a place called Kaluanui (Asia-Pacific Digital Library 2010), but he traveled freely from Kaua‘i to Hawai‘i. It is probable that Kamapua‘a belonged to the cult of Lono, god of fertility. In some stories he is noted for finding freshwater springs. He was very strong and had the ability to change his body form from a pig, to a handsome man, or a humuhumunukunukuapua‘a (trigger fish). Pigs were known to roam free, as it is recorded in the Kamapua‘a traditions. In some stories Kamapua‘a was a trickster and in other stories he was mean, devastating taro, sweet potato, and sugarcane patches—changing himself into a black hog, he devoured and trampled the sugarcane, rooted up taro, and upset calabashes filled with poi, eating everything in sight (Westervelt 1963). (The cultural significance of the black pig is that it is the most sacred sacrifice to be offered to the high gods [Beckwith 1981].) Kamapua‘a and his followers were also known to have raided Chief Olopana’s (chief of Oahu) chickens and knocked down fishpond walls, making them quite a nuisance. It is said that they passed along the Ewa side of the Island of Oahu, ravaging the land like a herd of swine. Olopana tried again and again to kill him in order to end his destruction but he was far too powerful. These stories are interesting because they illustrate that a pig problem existed prior to Western contact as Native Hawaiians struggled to control the pigs.

Following the introduction of European pigs, goats, cattle, and western economic concepts, Native Hawaiians and subsequent settlers began raising and hunting animals for commercial as well as personal uses (Langlas 2003a). By the 1920s in the Kalapana area, Native Hawaiians allowed their pigs, goats, and cows to forage for food, feeding them occasionally to keep them tame, and fencing the animals out of their houses, yards, and gardens. Several small cattle operations and a commercial goat ranch operated until the 1930s. Once families moved away from these locations and were no longer tending animals, large herds of wild goats were free to roam in areas that are now part of the park from Kapāpala to Panau (Langlas 2003a). Kalapana Hawaiians, along with other individuals from nearby communities, participated in park-authorized goat drives from the 1920s to the 1950s and in subsequent NPS-authorized pig control efforts. Goat drives ceased once large herds were removed from the park (NPS 1972).

According to Langlas (2003a), Native Hawaiians hunted for feral pigs in upper Kahauale‘a (including outside the park), Kamoamoa, and Pānau (part of the Kalapana Extension) through the 1960s, and groups of people made periodic trips west along the coast from Kapa‘ahu to fish and to hunt goat. (It should be noted that during this time any legal hunting of animals in the park was by private contractors or by individuals working under the deputy ranger program as part of the feral animal reduction program.) Traditional Native Hawaiian use of resources through fishing (including areas legislated under the 1938 Kalapana Extension Act), plus ritual practices, still continues in the park (Langlas 2003a).

Prior to becoming part of the park, private cattle ranches were established in several areas of the park. These included Mauna Loa, ʻĀinahou and the Kahuku unit. Starting in the 1860s, ranching activities were dispersed in Kahuku. Most of the cattle from that time were remnant populations of the first cattle brought to Kealakekua Bay, the Island of Hawaiʻi, for Kamehamaha in 1793 (Bergin 2004). The open pasture lands that currently define cattle ranching in Hawaiʻi, and particularly at Kahuku, developed after 1947 (Avery 2009). Prior to that, cattle were allowed to roam in the designated paddocks—no large landscape modification was carried out, with the exception of fencing. Although fencing in the form of dry laid walls was the norm, wire fences were introduced to this landscape. Ranching has become a traditional Hawaiian activity that began in the 1830s, first on Maui and then here on the Island of Hawaiʻi with the Parker Ranch.

Hawaiʻi Volcanoes has many other important human stories, such as contact, conflict, and integration of Hawaiians with foreigners; the scientific exploration and investigation of volcanoes, earthquakes, and adaptation to a changing landscape; and military history that includes the establishment of the Kīlauea Military Camp, the occupation of the park during World War II at both the Kīlauea and the Kahuku sections, buffalo soldiers, and Japanese internment (NPCA 2008). Each of these histories can be tied to a group of people who could attribute a cultural significance to their present way of life.

WILDERNESS

In 1978, under Public Law 95-625, *National Parks and Recreation Act* of 1978, the U.S. Congress designated 123,100 acres of wilderness at the park. There are 7,850 acres of land outside the park that were identified as potential wilderness that could become designated as wilderness should the park acquire those lands in the future (for a total of 130,950 acres). Wilderness areas at Hawaiʻi Volcanoes National Park consist of four disjunct units: the Mauna Loa Unit, which includes the Mauna Loa Strip (above 5,000 feet (1,524 meters) in elevation) and the summit; the ʻŌlaʻa Unit, which includes the ʻŌlaʻa Forest; the East Rift Unit in the upper east rift zone; and the Kaʻū Unit, encompassing the Kaʻū Desert (below 3,000 feet (914 meters) in elevation) (see figure 8). Kahuku Unit is currently being evaluated for wilderness eligibility. Wilderness areas eligible for designation must possess at least the following characteristics (as identified in the *Wilderness Act*):

- The earth and its community of life are untrammeled by humans, where humans are visitors and do not remain.
- The area is undeveloped and retains its primeval character and influence without permanent improvements or human habitation.
- The area generally appears to have been affected primarily by the forces of nature, with the imprint of human work substantially unnoticeable.
- The area is protected and managed to preserve its natural conditions.
- The area offers outstanding opportunities for solitude or a primitive and unconfined type of recreation.

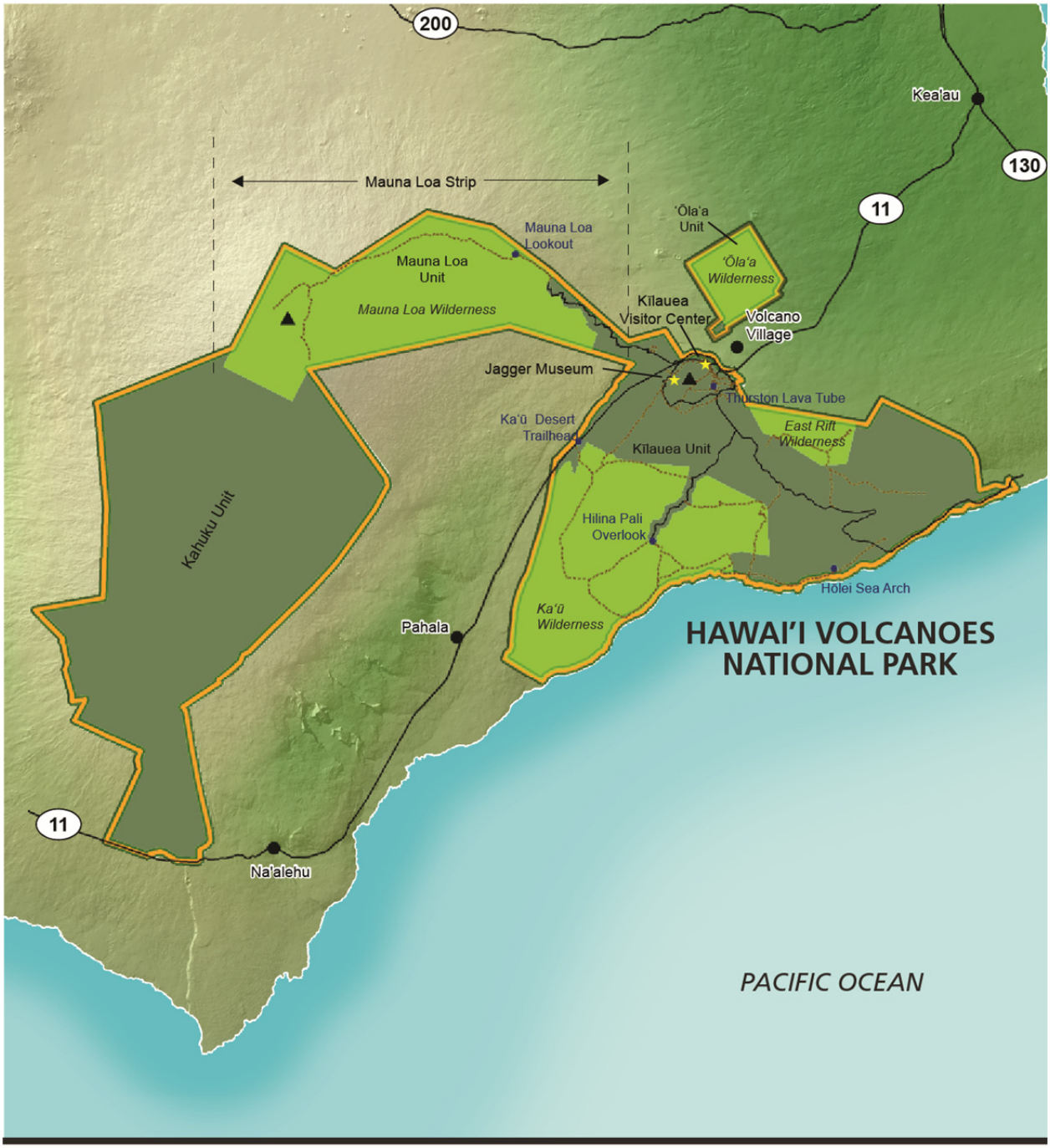


FIGURE 8:
Wilderness Areas

According to the final environmental statement for proposed wilderness at the park, the designated area would "preserve diverse segments of the Island of Hawai‘i in an undeveloped state—from the 13,680-foot summit of Mauna Loa to the Puna and Ka‘ū Coasts, and landscape ranging from barren lava to dense tropical forests and dry coastal reaches with numerous archeological sites" (NPS 1975b). In addition, the final EIS identified the need for management intervention to ensure the survival of endemic communities of plants and animals at risk by non-native species. Specific actions identified were construction of fences and the use of helicopter to exclude nonnative goats and pigs for the protection of park resources.

The management actions in this plan may affect the untrammeled and undeveloped nature of the wilderness areas, but will not have any effect on the opportunity for visitors to enjoy primitive and unconfined forms of recreation.

SOILS

Soils found in the geological region of the park consist mostly of lava, cinder, and rubble, which form organic matter through decomposition. The range in soil conditions reflects the geologic parent material; accumulations of organic matter in the soil and ground litter are the most important factors in soil development on these relatively young substrates. Pāhoehoe, ‘a‘ā, cinders, and weathered ash provide differing contributions of minerals and drainage characteristics, and soil age and composition have considerable influence over plant community composition and hydrology (TMA 2007). Throughout Hawai‘i Volcanoes National Park, sparsely vegetated, homogeneous soil substrates of volcanic origin are typical and include volcanic ash–based soils and well-draining, fertile soils. These newly formed soils originate from historic lava flows. Young ash deposits, for instance, are evident in the Devastation Trail area, where early successional vegetation has recently become established, as well as in other areas of the park that have undergone relatively recent geologic changes due to volcanic eruptions (Matson 1990).

SOIL ASSOCIATIONS

Table 9 lists the major soil associations present in the park and their respective acreages, as mapped by the USDA–NRCS (2009a). Figure 9 illustrates the areas in the park where each of these soil associations are found. Soil associations represent the largest and most general classification in a complex taxonomy for identifying soils. Associations are groups of soil types that consist of two or more dissimilar soil components occurring in a regularly repeating pattern. They represent a landscape that has a distinctive proportional pattern of soils and is named for the major soil types that it represents. It normally consists of one or more major soil series and at least one minor soil series, which are the lowest categories in the soil classification system.

Because the primary issue of concern related to soils is erosion, the soil erodibility factor, or K factor, of the soil series that compose the associations listed in table 9 were used to identify their erosion potential as low, moderate, or high. Although soil erodibility factors were not available for all these soil series, available data indicate that the erosion potential of park soils is predominantly low (USDA-NRCS 2009c). However, some soils, such as the Kīlauea series, have low to high erosion potential depending on the depth of the soil (USDA-NRCS 2009c).

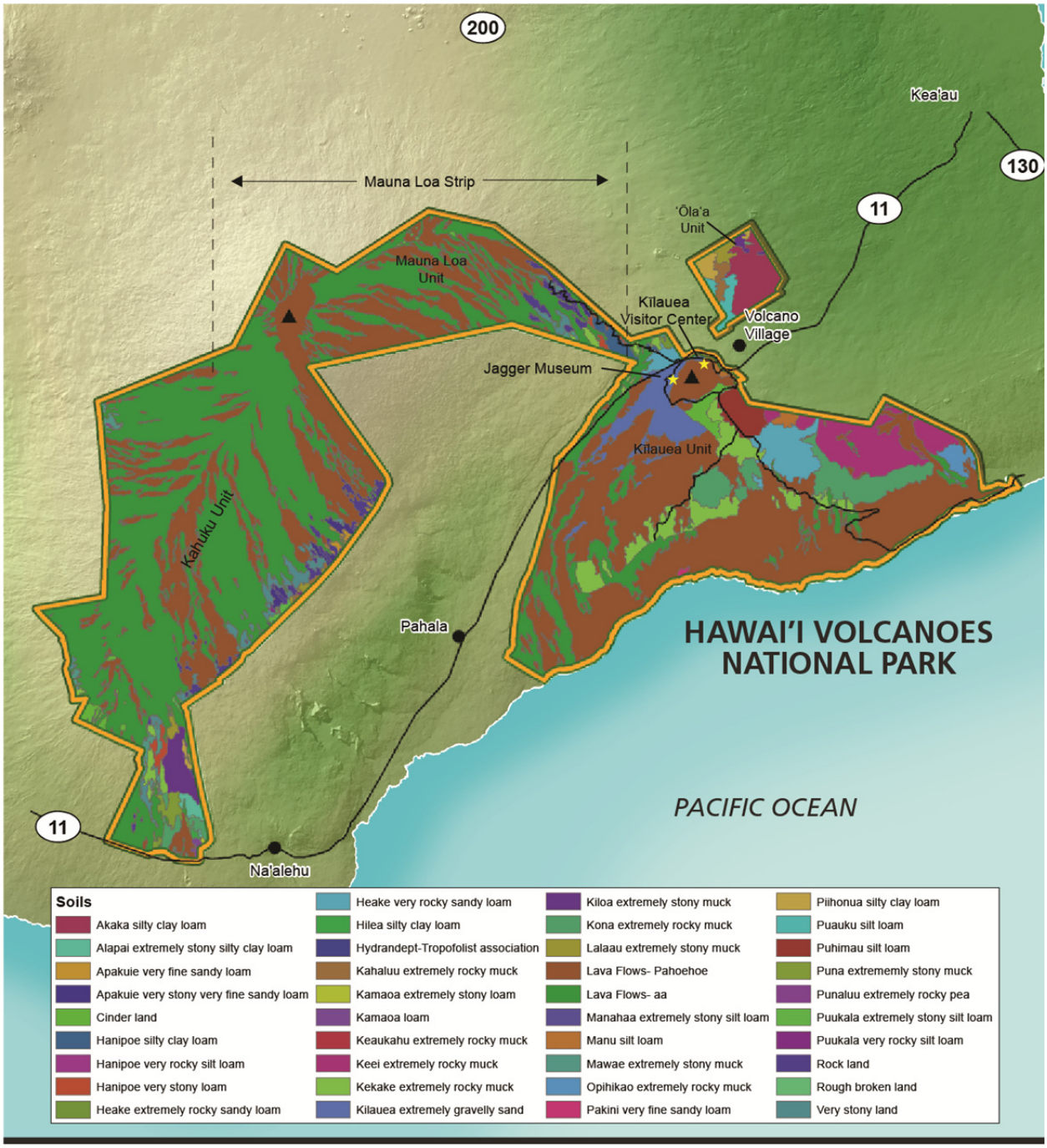


FIGURE 9:
Soils Map

TABLE 9: MAJOR SOIL ASSOCIATIONS PRESENT IN HAWAI'I VOLCANOES NATIONAL PARK

Soil Association	Approximate Acreage
Kaiwiki-Honokaa	829
Kekake-Keei-Kahaluu	28,532
Kilohana-Kilauea-Huikau-Apakuie	19,445
Lava flows	296,819
Maile-Hanipoe	2,510
Malama-Lalaau-Hydrudands	2,949
Piihonua-Akaka	8,078
Puna-Papai-Kiloa-Kaimu	7,519
Waimea-Kikon	11
Total Acreage	**366,690**

Source: USDA-NRCS 2009a.

Note: acreages were calculated using geographic information systems data and overstate the total acreage of the park; they should be used for relative comparisons only.

SOUNDSCAPES

INTRODUCTION

According to the NPS, a soundscape is defined as the "total acoustic environment of an area," which includes both natural and human sounds (NPS 2009c).

According to the NPS, a soundscape is defined as the "total acoustic environment of an area," which includes both natural and human sounds (NPS 2009c). According to Section 4.9 of NPS *Management Policies 2006*, the natural soundscape of a park refers to the combination of all of the natural sounds occurring in the park, absent the human-induced sounds, as well as the physical capacity for transmitting those natural sounds (NPS 2006b). Natural sounds may range from bird calls and insect chirps to sounds produced by physical processes, like wind rushing through leaves on trees, thunder, pouring rain, and lava fountains and flows. In a 1998 survey in which people were asked to define the most important reasons for having national parks, 72 percent indicated that parks provide opportunities to experience natural peace and the sounds of nature. Further, visitor preference studies identified birds, animals, wind, and water as very pleasing sounds (NPS 2009c).

The soundscape at Hawai'i Volcanoes includes both natural and human components. The "natural quiet" that occurs in the absence of human sound sources is also defined as the "natural ambient" sound level of a park. These natural ambient sound conditions exist in the absence of any human-produced noises. Common natural ambient sounds at Hawai'i Volcanoes include wind, thunder, rain, the rustle of vegetation, ocean surf, birds, and insects, as well as the crackling, clinking, and rockfall sounds associated with new lava flows and eroding volcanic features. These sounds may be heard as a composite of sound, not individually.

Noise is generally defined as unwanted or intrusive sound. Noise can adversely affect park resources or values, including but not limited to natural soundscapes, wildlife, wilderness, and visitor experience. Human sound sources at Hawai'i Volcanoes that are commonly perceived as noise include cars, buses, aircraft, and motorcycles; visitors yelling or talking loudly; sounds associated with cell phones, personal

music players, and cameras; and mechanized maintenance equipment such as weed-whackers (Lawson et al. 2007).

The magnitude of noise is usually described by its sound pressure. The A-weighted decibel (dBA) scale is commonly used to describe noise levels because it reflects the frequency range to which the human ear is most sensitive. Sound levels measured using a dBA scale are generally expressed as dBA. Throughout this section, all noise levels are expressed in dBA. Several examples of sound pressure levels in the A-weighted scale are listed in table 10. Normal speech has a sound level of approximately 60 dBA.

TABLE 10: COMMON NOISE LEVELS AND THEIR EFFECTS ON THE HUMAN EAR

Source	Decibel Level (dBA)	Noise Level
Normal breathing	10	Very low
Leaves rustling at Canyonlands National Park	20	Very low
Soft whisper, quiet library (15 feet), Snake River (at 300 feet)	30	Low
Crickets at Zion National Park (at 16 feet), Snake River (at 100 feet)	40	Low
Light auto traffic (100 feet)	50	Medium
Conversational speech (3 feet), 4-stroke snowmobile (30 mph at 50 feet), automobile (45 mph at 100 feet)	60*	Medium
Personal watercraft (82 feet)	68–76	High
Vacuum cleaner, 2-stroke snowmobile (30 mph at 50 feet)	70	High
Off-road recreational vehicles	70–90	High
V8 “muscle” boat (82 feet)	85–86	High
Heavy truck or motorcycle (25 feet)	90	High
Thunder	100	High
Military jet at Yukon-Charley Rivers National Preserve (328 feet above ground level)	120	High
Shotgun	125	High

Sources: Kormanoff and Shaw 2000; Michael Minor and Associates n.d.; American Speech-Language-Hearing Association n.d.; NPS 2007c; and McCusker, pers. comm., 2007.

*Sound levels above 60 dBA begin to interfere with close-range conversational speech.

In 2003–2004, baseline acoustic data was collected throughout the park as part of the development of the ongoing ATMP/EIS related to the impacts of air tour overflights on park resources (FAA n.d.). This planning effort will inform future planning and soundscape management activities in various areas of the park (FAA 2006). Sound level measurements were conducted at 22 site locations from October 23, 2002, to June 1, 2003. Ultimately, 10 acoustic sampling areas were identified to acoustically represent regions of the park. The acoustic sampling areas largely reflect the natural ecological zones of the park. The baseline data representative of the various acoustic sampling areas and acoustic modeling of aircraft overflights will be used to further characterize soundscapes and determine potential impacts to park soundscapes from overflights as the ATMP/EIS planning process progresses. The results of these surveys are shown in table 11. While non-native ungulate management can occur anywhere throughout the park, these actions occur more frequently in zones 4 (Kahuku and ʻŌlaʻa), 5 (Kahuku) and 10 (Kahuku) (see table 11 and figure 10). It should be noted that sound measurements were not performed in the Kahuku Ranch Unit. Information collected from other sections of the park was used to extrapolate the natural

ambient sound levels in Kahuku based on similarity of vegetation and terrain. These zones are shown in figure 10. Appendix D contains further information regarding the 10 acoustic sampling areas. The term L_{50} refers to the noise level exceeded for 50 percent of the day.

TABLE 11: MEASURED L_{50} NATURAL AMBIENT SOUND LEVELS

Acoustic Sampling Area[1]	Measurement Site	L50 Natural Ambient Sound Level (dBA)
Zone 1 (Shoreline)	1A	54.2
	1B	46.6
Zone 2 (Coastal Lowlands)	2A	28.3
	2B	32.7
	2C	29.1
Zone 3 (Sparsely Vegetated)	3A	31.4
	3B	29.1
	3C	32.7
	3D	20.4
Zone 4 (Montane Rain Forest)	4A	33.5
Zone 5 (Mauna Loa Montane/Subalpine)	5A	35.0
	5B	22.1
	5C	27.5
Zone 6 (Dry ʻŌhiʻa Woodlands)	6A	28.0
	6B	28.0
	6C	32.7
Zone 7 (Mauna Loa Alpine)[2]	no data	no data
Zone 8 (Lowland Rain Forest)	8A	42.6
	8B	38.2
	8C	29.7
Zone 9 (New Lava Flows)	9A	28.6
	9B	28.6
	9C	25.4
Zone 10 (Kahuku Pastures)	no data	no data

Source: FAA 2006.

[1]Kahuku was acquired subsequent to the measurement study, so no data were collected. Measurements conducted in older Hawaiʻi Volcanoes National Park units were extrapolated to Kahuku based on similar vegetation type and elevation.

[2]Weather and accessibility to Zone 7 prevented the ability to take measurements in this zone. However, sound levels for these zones were characterized based on the similarity in attributes when compared to Zone 3.

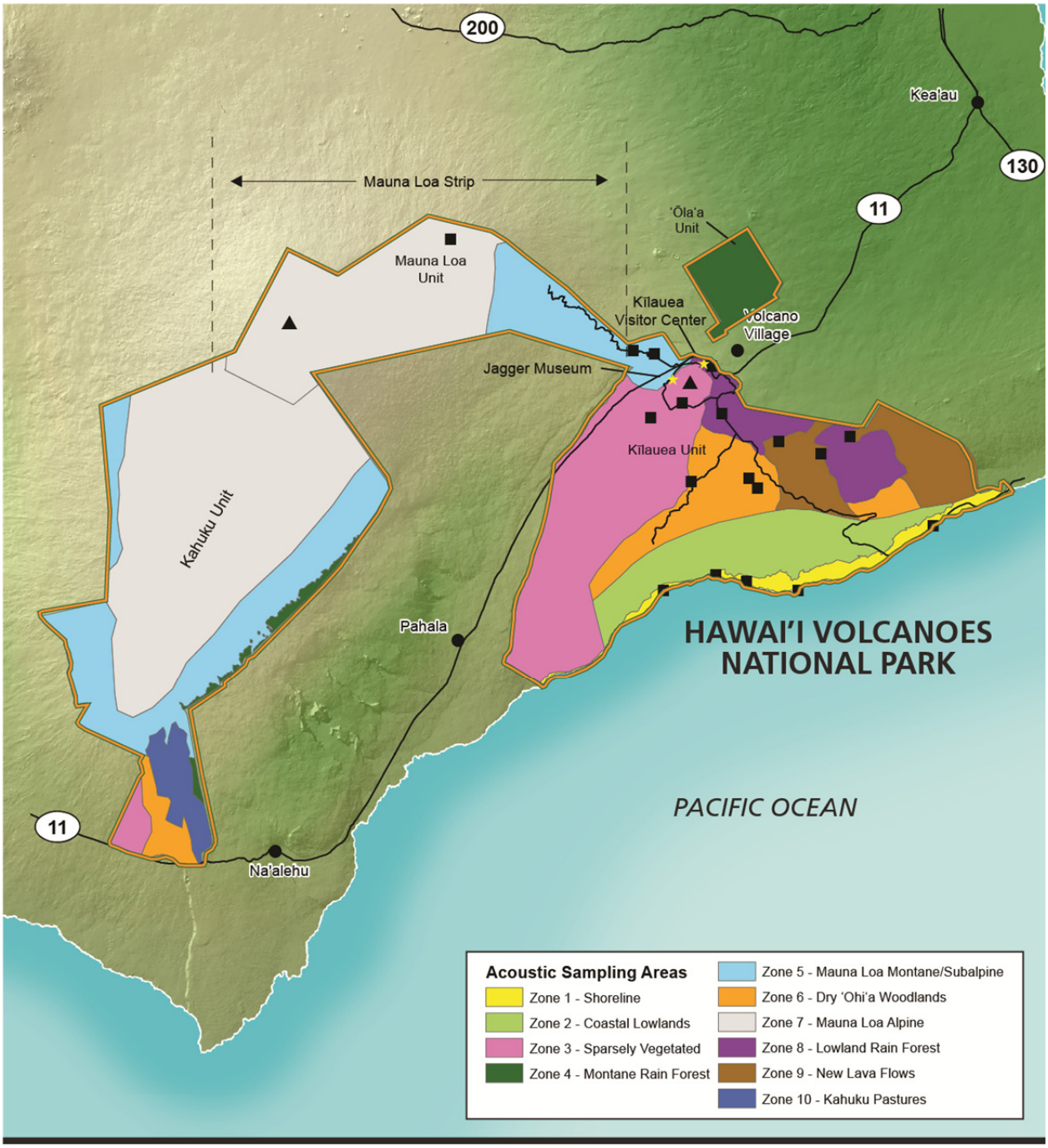


FIGURE 10:
Acoustic Sites & Sampling Areas

LAND MANAGEMENT ADJACENT TO THE PARK

As described in "Chapter 1: Purpose of and Need for Action," Hawai'i Volcanoes National Park is surrounded by other federal, state, and privately held land. Many of the agencies and organizations that own these lands, which include Hawai'i, Kamehameha Schools, and TNC, have specific management goals related to feral ungulates and are part of the TMA watershed partnership. The management of these lands, along with those owned by other landowners, has the potential to be affected by non-native ungulate management at Hawai'i Volcanoes National Park.

STATE OF HAWAI'I

The state manages natural area reserves, forest reserves, and game management areas on the Island of Hawai'i, several of which share boundaries with or are located near Hawai'i Volcanoes National Park. Areas in the state system have different management objectives. Protection of native ecosystems is the primary objective of natural area reserves, while game management is the primary objective in game management areas. Forest reserves balance several objectives that include providing mixed recreational use (including hunting) and protecting native plant communities and watersheds. The state is responsible for administering public hunting programs on these lands, as well as implementing additional non-native ungulate control.

In the late 1890s, the sugar industry and the growing population of Hawai'i realized that their abundant supply of high-quality water was threatened by the destruction of the forested mountain watersheds. Act 44, approved by the Territorial Legislature on April 25, 1903, created Hawai'i's forest reserve system, which became the largest public–private partnership in the history of the state (Buck 2003). During the early decades of the 20th century, public and private interests waged a massive campaign of fence building and feral animal removal to protect remaining native forests on Hawai'i. Fire control and large-scale tree-planting programs were implemented, and eventually more than 1.2 million acres would be included in the new forest reserve system (TNC 2003). Management activities, such as protective zoning, fencing, removal or control of feral animals, reforestation, and fire protection have reduced excessive erosion and loss of vegetative cover (Buck 2003).

Hawai'i County sponsors a feral pig pilot program. The program is overseen by the USDA Animal and Plant Health Inspection Service's (APHIS's) Wildlife Services and assists residents in getting rid of feral pigs that cause destruction on their properties. An *Environmental Assessment of Feral Swine Damage Management in Hawai'i County* was completed in 2008 (USDA-APHIS 2008).

NATURAL AREA RESERVES

The natural area reserves system was established in 1971 to "preserve and protect, in perpetuity, examples of Hawai'i's unique terrestrial and aquatic natural resources, in order that present and future generations may be able to learn about and appreciate these natural assets" (Natural Area Reserves System Commission 1997). The DLNR is mandated to protect these lands so that the natural resources remain as unmodified as possible. As a result, the natural area reserves system was also created to serve as a baseline to measure changes to other native ecosystems (Natural Area Reserves System Commission 1997).

According to the *Management Policies of the Natural Area Reserves System* (Natural Area Reserves System Commission 1997), the highest priority for these lands is conservation of natural resources, and the removal of feral non-native ungulates is an overriding consideration in the management of natural area reserves. In general, strategies are employed on these lands that reduce populations of non-native animals to the lowest possible level. The *Management Policies of the Natural Area Reserve System* states

that sustained yield management of animals for hunting is not consistent with the intent of the natural area reserves, but where practicable, regulated public hunting could be used. Other control methods, including fencing, trapping, snaring, and aerial shooting, are also available if public hunting does not provide adequate control to meet objectives specified in the management plans for each natural area reserve (Natural Area Reserves System Commission 1997).

There are four natural area reserves adjacent to Hawai‘i Volcanoes National Park: Kahauale‘a, Pu‘u Maka‘ala, Kīpāhoehoe, and Manukā. The Kahauale‘a Natural Area Reserve is located near the eastern boundary of the park and occupies 16,726 acres from 1,400 to almost 3,900 feet (427 to almost 1,189 meters) in elevation near the Kīlauea Iki Crater (HDLNR 1992a). The plan for this reserve identifies goals and actions for non-native ungulate control that are aimed at reducing non-native ungulate populations (primarily pigs and cattle) to the lowest level possible in areas dominated by native species (HDLNR 1992a). To achieve this objective, the state recommends fencing followed by public hunting supplemented by staff hunting, either on the ground with dogs or aerially (recommended in areas with cattle). Public hunting is a well-established activity in the Kahauale’a Natural Area Reserve (HDLNR 1992a, 2003b). The plan, which has yet to be implemented, also identifies the use of snares for effective pig control, but notes that it is not compatible with intensive public use or hunting with dogs (HDLNR 1992a).

The plan for this reserve identifies goals and actions for non-native ungulate control that are aimed at reducing non-native ungulate populations (primarily pigs and cattle) to the lowest level possible in areas dominated by native species (HDLNR 1992a).

The Pu‘u Maka‘ala Natural Area Reserve was established in 1981 and includes 12,000 acres ranging from 2,800 to 5,500 feet (853 to 1,676 meters) in elevation. The reserve surrounds three sides of the ‘Ōla‘a Forest Unit of Hawai‘i Volcanoes National Park, and the plan for Pu‘u Maka‘ala identifies feral pigs as the most severe threat to natural resources (HDLNR 1989). This plan identifies the non-native ungulate control program as the first priority for long-term management of the reserve. Recommendations include fencing approximately 4,560 acres of the reserve followed by intensive snaring, trapping, and staff hunting to reduce feral pig populations to remnant levels in the enclosed areas. In the remaining areas, public hunting is used to control pig populations, with the intent of reducing the pig population to remnant levels, not sustained yield hunting (HDLNR 1989). Since implementation of the plan, approximately 3,000 acres has been controlled to remnant numbers of pigs, and efforts are underway in additional units.

The Kīpāhoehoe Natural Area Reserve is located in the South Kona district on the Island of Hawai‘i. The reserve encompasses a 5,583-acre wedge-shaped section of the southwestern slope of Mauna Loa. The parcel includes roughly 2 miles of shoreline, and narrows to less than a mile across the top of the reserve, at an elevation of 5,600 feet (1,707 meters). The *Kīpāhoehoe Natural Area Reserve Management Plan* states that the primary threat to the native ecosystem in the upper portion of the reserve is the continuing uncontrolled disturbance and damage to vegetation caused by feral pigs, goats, cattle, and sheep (HDLNR 2002). The management plan identifies game drives, hunting with dogs (using public hunters whenever possible), fencing, and snaring as recommended management actions to prevent further destruction from these non-native ungulates (HDLNR 2002).

The Manukā Natural Area Reserve was established on the Island of Hawai‘i in 1983, and occupies 25,550 acres on the southwest slope of Mauna Loa (HDLNR 1992b). The reserve protects 18 different natural communities, including dry and mesic forests, subalpine shrublands and forests, lowland and coastal shrublands and grasslands, anchialine pools, pioneer vegetation on lava flows, and lava tubes. The *Manukā Natural Area Reserve Management Plan* identifies reducing feral pig and goat damage as a primary goal of the reserve. In the management plan, fencing was proposed along the northwestern

boundary and around the Kīpuka management unit. Furthermore, both public and staff hunting efforts were proposed to remove non-native ungulates (HDLNR 1992b).

FOREST RESERVES AND GAME MANAGEMENT AREAS

There are several forest reserves and game management areas in the vicinity of Hawai‘i Volcanoes National Park, including the Mauna Loa Forest Reserve and Game Management Area, Kapāpala Forest Reserve, Kapāpala (Cooperative) Game Management Area, Ka‘ū Forest Reserve, ‘Ōla‘a Forest Reserve, and Upper Waiakea Forest Reserve. Multiple management goals within forest reserves and game management include providing public recreational opportunities, protecting forest watersheds, supporting sustainable forest industry, and maintaining biological integrity of native ecosystems. According to the *Division of Fish and Wildlife Management Guidelines* (HDLNR n.d.a), game animal management in these areas falls into one of two categories for feral pigs, sheep, and goat: (1) control: mixed game and other uses, and (2) game control (public). In the first category, game management is an objective integrated with other uses. Under game control (public), the emphasis is on protecting native plant communities and watersheds through the use of public hunting. The Mauna Loa Forest Reserve and Game Management Area and the Waiakea Forest Reserve are designated mixed game and other uses for sheep and goats, and designated game control (public) for pigs. The Kapāpala (Cooperative) Game Management Area and Ōla‘a Forest Reserve are designated mixed game and other uses for pigs, goats and sheep while the Ka‘ū and Kapāpala forest reserves are designated as game control (public) for all three animals (HDLNR n.d.c).

NATIONAL WILDLIFE REFUGES

In 2008, the USFWS developed an environmental assessment to evaluate the potential environmental effects of building about 88,500 feet (27,000 meters) of fencing enclosing approximately 2,145 hectares (5,300 acres) of land in the Kona Forest Unit of the Hakalau Forest National Wildlife Refuge (USFWS 2008e). The fencing, which is not yet under construction, is intended to keep non-native ungulates and other mammals out of the area. The native forests of the Kona Forest Unit support four species of endangered forest birds, the endangered Hawaiian hoary bat, and a high diversity of native plant species, several of which are threatened or endangered. Until 2002, the Kona Forest Unit supported the last remaining ‘alalā (Hawaiian crows) in the wild. In the future, the area may serve as a place for their reintroduction into the wild.

KAMEHAMEHA SCHOOLS

Kamehameha Schools (Bishop Estate) is the largest private landowner in Hawai‘i. These lands were inherited by Princess Bernice Pauahi Bishop as the last royal descendant of the Kamehameha line and today total 365,800 acres of land throughout the state. In her will, she left her estate to Kamehameha Schools and mandated that her real estate be leased, sold, or managed to help generate revenue that would support the schools’ educational programs and services (Kamehameha Schools n.d.). Today, these lands are managed to derive an overall balance of economic, educational, cultural, environmental, and community returns as well as to protect and enhance native ecosystems (TMA 2007). As part of their involvement with the TMA, Kamehameha Schools is involved in fencing and non-native ungulate removal. In 2003, they ceased cattle operations and removed feral non-native ungulates from portions of the Keauhou Ranch designated for native forest restoration. The Keauhou Ranch is adjacent to the park.

THE NATURE CONSERVANCY

TNC's mission is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive (TMA 2007). TNC of Hawai'i partners with indigenous communities, businesses, governments, multilateral institutions, and other nonprofits to address threats, including climate change, fire, and non-native species, to conservation of freshwater, forests, and marine ecosystems (TNC 2009).

On the Island of Hawai'i, TNC owns and manages two preserves: the Kona Hema Preserve (8,061 acres in three contiguous units) and the Ka'ū Preserve (3,548 acres in four noncontiguous units) (TNC 2006). TNC is involved with fencing and non-native ungulate removal on their lands. For example, the Kona Hema Units are fenced and approaching non-native ungulate–free status (TNC n.d.). In the Ka'ū Preserve, TNC is managing the land to reduce populations of non-native animals and prevent new weed invasions. They are also working with neighboring landowners, local communities, state agencies, the NPS, and neighboring private landowners to protect the larger Ka'ū forest (TNC 2009).

SOCIOECONOMICS

Hawai'i Volcanoes National Park hosts an average of over 1.3 million visitors annually (see the "Visitor Use and Experience" section in this chapter). In 2007, there were 1.47 million visitors using the park for recreational and nonrecreational purposes. Over 95 percent of the spending associated with park visitation is from nonlocal visitors (Stynes 2008). Tourists primarily come to see volcanoes, rainforests, and the natural plant and animal life at the park. The uses of the park include viewing and understanding volcanic processes, seeing the park's natural and cultural resources, practicing traditional cultural activities, and experiencing the relative solitude of the park's backcountry.

Over 95 percent of the spending associated with park visitation is from nonlocal visitors (Stynes 2008). Tourists primarily come to see volcanoes, rainforests, and the natural plant and animal life at the park.

This socioeconomics section describes the more recent socioeconomic and demographic conditions and trends, the economic contribution of Hawai'i Volcanoes National Park payroll and nonlocal visitation to the local economies, and the social benefits that the Volunteer Ungulate Control Program provides to the local community. As described in detail in chapter 1, although environmental justice populations of concern have been identified, there would be nominal to no impacts on these populations. Therefore, this issue is not discussed further in this chapter.

SOCIOECONOMIC CONDITIONS AND TRENDS

Since Hawai'i Volcanoes National Park experiences such a large portion of nonlocal visitation, it is likely that visitors stay in communities (and spend money) across the Island of Hawai'i. The socioeconomic study area therefore was chosen to be Hawai'i County, which encompasses Hawai'i Volcanoes National Park and includes the entire Island of Hawai'i.

DEMOGRAPHIC AND ECONOMIC OVERVIEW

With an area of 4,028 square miles (10,432 square kilometers), the Island of Hawai'i (or Hawai'i County) is larger than all the other Hawaiian Islands combined and is the largest island in the United States. Fruits, nuts, and coffee are the island's principal agricultural products. The Kona district in the western part of Hawai'i is the coffee belt of the United States and is also known for its health resorts and offshore deep-

sea fishing (Columbia Encyclopedia 2003). Hilo, on the east coast, is the island's largest city, chief port, and the county seat. In 2007, Hilo had a population of 50,289, comprising more than a quarter of the island's population (U.S. Census Bureau 2007a). All the coastal towns are linked by the Hawai'i Belt Road, which encircles the island.

Hawai'i County had an estimated population of 173,057 during 2007; the population has increased an average of 2.2 percent annually since 2000 (U.S. Census Bureau 2009b) for a total of 16 percent during this time period. The Island of Hawai'i is quite rural in nature, with 37 people per square mile. This can be compared with the state (189 people per square mile), Oahu (1,460), Maui (110), and Kaua'i (94) (U.S. Census Bureau 2000c). Table 12 summarizes a number of demographic and economic characteristics for Hawai'i County, Hawai'i, and the nation. In 2007, Hawai'i County and the state had slightly older populations than those of the nation. Poverty rates in the county are similar to those of the nation but higher compared to those of the state. The percentage of the population with bachelor's degrees is similar across the county, state, and nation.

TABLE 12: DEMOGRAPHIC CHARACTERISTICS OF HAWAI'I COUNTY, HAWAI'I, AND THE UNITED STATES, 2007

Estimate	HI County	HI State	USA
Demographic, Education, and Poverty Status			
Total population	173,057	1,283,388	301,621,159
Median age	38.6	38.1	36.7
High school education or higher	89.7%	89.4%	84.5%
Bachelor's degree or higher	27.6%	29.2%	27.5%
People below poverty level	12.8%	8.0%	13.0%
Race			
White	49.2%	34.3%	75.8%
Black	0.5%	2.8%	13.1%
American Indian or Alaskan Native	0.8%	0.3%	1.5%
Asian	34.4%	50.0%	5.0%
Native Hawaiian or Pacific Islander	13.3%	10.9%	0.3%
Some other race	1.9%	1.7%	6.7%
Hispanic or Latino	11.0%	8.2%	15.1%
Housing and Families			
Total housing units	63,250	506,751	127,895,430
Average family size	3.06	3.39	3.2
Percentage of households with one or more people under 18 years of age	36%	25%	34%

Source: U.S. Census Bureau 2007b, 2007c, 2007d.

In terms of race, the population of Hawai'i County comprises more white, Native Hawaiian or Pacific Islander, and Latino individuals and fewer Asian individuals than the population of the state. The county's racial percentages generally fall between those of the state and those of the nation, although they are closer to those of the state. Households in Hawai'i County are more apt to have children at home than households in the state or the nation, although the average family size is slightly smaller in the county compared to the state or the nation. This could indicate that there are fewer adults in the county's households, as compared with the state and the nation.

In 2007, Hawai‘i County’s estimated median household income was less than that of the state and only slightly more than that of the nation. Between 2000 and 2007, the island’s median household income grew 14 percent, much higher than the household income growth experienced in the state and the nation. These figures are summarized in table 13.

TABLE 13: REAL MEDIAN HOUSEHOLD INCOME (2007$)

Year	HI County	HI State	USA
2000*	$51,672	$64,673	$50,986
2007	$59,111	$63,746	$50,740
Percentage change, 2000 to 2007	+14%	−1%	0

Source: U.S. Census Bureau 2007b, 2007c, 2007d, 2000b.

*2000 household income figures for Hawai‘i County and the state were inflated with Bureau of Labor Statistics, Honolulu County Consumer Price Index, while the nation’s household income was inflated with the U.S. Bureau of Labor Statistics, West Region’s Consumer Price Index (U.S. Bureau of Labor Statistics 2009a, 2009b).

More recently, the economic downturn in the economy has likely reduced this income growth considerably. Less tourism, construction, and retail sales activities have been impacting economies of both the Island of Hawai‘i and Hawai‘i as a whole. One source indicated that the Island of Hawai‘i experienced an 8.8 percent drop in visitor arrivals in the first half of 2008, and visitor spending was down 2.2 percent over this same time period (Laney 2008).

In 2007, estimated average annual per capita personal income for Hawai‘i County was considerably lower than that of the nation and the state. Nominal personal income in the county has increased considerably between 2001 and 2007; however, once the inflation and cost of living increases have been removed, the income growth was 8 percent from 2001 to 2007, or on average, 1 percent annually. This growth is similar to that of the nation. Table 14 summarizes these personal income figures, which likely do not reflect the recent economic downturn affecting the national and state economies.

TABLE 14: REAL PER CAPITA PERSONAL INCOME FOR HAWAI‘I COUNTY, HAWAI‘I, AND THE UNITED STATES (2007$)*

Year	2001	2002	2003	2004	2005	2006	2007	% Change 2001–2007
Hawai‘i County	$27,502	$28,353	$28,368	$29,222	$30,128	$30,031	$29,702	+8%
Hawai‘i	$35,480	$36,080	$36,361	$37,755	$38,716	$38,913	$39,242	+11%
USA	$35,819	$35,434	$35,480	$36,291	$37,015	$37,962	$38,615	+8%

Source: Bureau of Economic Analysis 2009a, 2009b, 2009c.

*Personal income figures for Hawai‘i County and the state were inflated with U.S. Bureau of Labor Statistics, Honolulu County Consumer Price Index, while the nation’s household income was inflated with the U.S. Bureau of Labor Statistics, West Region’s Consumer Price Index (U.S. Bureau of Labor Statistics 2009a, 2009b).

Employment in Hawai‘i County has increased by 18 percent between 2000 and 2009. Hawai‘i has experienced more moderate job growth over this period of 10 percent. Although there has been employment growth since 2000 in Hawai‘i County, between April 2008 and April 2009 there has been a loss of almost 4,000 jobs, or over 6 percent of all jobs (State of Hawai‘i Department of Business, Economic Development, and Tourism 2009). Additionally, in April 2009, the unemployment rate in the

county was estimated to be 9.7 percent (up from 2.9 percent in April 2007), compared with 6.8 percent in the state, and 8.9 percent in the nation (State of Hawai‘i Department of Business, Economic Development, and Tourism 2009; U.S. Bureau of Labor Statistics 2009c).

Major sources of employment in Hawai‘i County include accommodations and food services (17 percent), retail trade (14 percent), various government services (20 percent), and health care (10 percent). In 2009, agriculture accounted for 3 percent of the employment on the island. Between 2001 and 2009, educational services, other services, the arts, entertainment, recreation, and construction industries and activities have been driving the increase in employment. Employment declines over this time period were in manufacturing, accommodations, information, and agriculture. These employment-by-industry figures are summarized in table 15.

TABLE 15: TOTAL EMPLOYMENT BY INDUSTRY—HAWAI‘I COUNTY

Industry	1990		2000		2009		% Change* 1990–2009	% Change* 2000–2009
	Number	%	Number	%	Number	%		
Natural resources, mining, construction	3,500	7%	3,000	5%	4,500	7%	29%	50%
Manufacturing	2,400	5%	1,600	3%	1,450	2%	−40%	−9%
Wholesale trade	1,200	3%	1,300	2%	1,700	3%	42%	31%
Retail trade	6,700	14%	7,800	14%	9,150	14%	37%	17%
Transportation, warehousing, and utilities	2,400	5%	2,200	4%	2,650	4%	10%	20%
Information	600	1%	700	1%	650	1%	8%	−7%
Financial activities	2,300	5%	2,100	4%	2,750	4%	20%	31%
Professional & business services	2,500	5%	4,100	7%	4,700	7%	88%	15%
Educational services	300	1%	500	1%	1,200	2%	300%	140%
Health care & social assistance	2,500	5%	4,700	8%	6,350	10%	154%	35%
Arts, entertainment, & recreation	600	1%	1,100	2%	1,750	3%	192%	59%
Accommodations	6,200	13%	7,300	13%	6,150	9%	−1%	−16%
Food services & drinking places	3,900	8%	4,300	8%	5,100	8%	31%	19%
Other services	1,300	3%	1,200	2%	2,200	3%	69%	83%
Government	8,400	18%	11,200	20%	13,050	20%	55%	17%
Federal	800	2%	1,100	2%	1,300	2%	63%	18%
State	5,600	12%	7,800	14%	9,000	14%	61%	15%
Local	2,000	4%	2,300	4%	2,750	4%	38%	20%
Agriculture	3,200	7%	2,200	4%	2,100	3%	−34%	−5%
Total employment	48,000	100%	55,300	100%	65,350	100%	36%	18%

Source: State of Hawai‘i Department of Business, Economic Development, and Tourism 2009.

*Percentage change is positive unless marked negative.

PARK ECONOMIC CONTRIBUTIONS TO LOCAL ECONOMIES

Hawai‘i Volcanoes National Park contributes to the local economy in several ways. First, it provides jobs to park employees, including seasonal, term, and permanent full- or part-time positions (see the "Park Management and Operations" section of this chapter for more detail). Park employees spend their income and wages in the local economies, which support additional jobs and income. In 2007 Hawai‘i Volcanoes National Park employed 144 employees, who supported an additional 59 jobs in the local economy, for a total of 203 jobs.[1] This payroll spending contributes to the value added,[2] or the island's gross regional product, by an estimated $10.9 million. These park payroll benefits are summarized in table 16. The park may also support the local economy if local vendors are used; for example, through contracted lawn maintenance services or purchases of office supplies. These figures are not assessed in this socioeconomics section.

TABLE 16: 2007 HAWAI‘I VOLCANOES NATIONAL PARK PAYROLL SPENDING IMPACTS

NPS Payroll and Impacts	NPS	Total (NPS and Supporting Jobs and Income)
Jobs	144	203
Labor income (includes payroll and benefits)	$7,803,000	$9,541,000
Total value added (i.e., gross regional product)	NA	$10,907,000

Source: Stynes 2008.

NA = not applicable.

Second, Hawai‘i Volcanoes National Park attracts a large number of visitors from around the world. These visitors consume from local businesses such as restaurants, hotels, and retail outlets during their time in Hawai‘i County, contributing to the local economy. The economic contribution of the visitor spending is a function of how many visitors arrive and how much money they spend while visiting. Visitor spending benefits for Hawai‘i Volcanoes National Park have been estimated by Stynes (2008) and are summarized in table 17.

[1] The local economy or local regions are defined as a 50-mile radius around the park, which is the primary impact region around most parks. Economic multipliers are based on regions or areas defined as groupings of counties to approximate a 50-mile radius of the park (Stynes 2008).

[2] *Value added* is defined as gross output (sales or receipts and other operating income, plus inventory change) minus intermediate inputs (consumption of goods and services purchased from other industries or imported). Value added consists of compensation of employees, taxes on production and imports less subsidies (formerly indirect business taxes and nontax payments), and gross operating surplus.

TABLE 17: NONLOCAL VISITOR SPENDING AND IMPACTS AT HAWAIʻI VOLCANOES NATIONAL PARK, 2007

Type of Impact	Nonlocal Spending and Associated Impacts
Visitor spending	$109,329,000
Total labor income	$43,661,000
Value added or gross regional product	$67,577,000
Jobs supported	2,199

Source: Stynes 2008.

During 2007, the park experienced a total of 1,467,779 recreational visitor days, primarily from nonlocal visitors. Total spending associated with Hawaiʻi Volcanoes National Park was estimated to be $114 million, of which $109 million was spent by nonlocal visitors. The total labor income generated by this spending was almost $43 million, and the gross regional product was over $67 million. This economic activity supports 2,199 jobs in the local economy (Stynes 2008).

Total impacts of Hawaiʻi Volcanoes National Park associated with payroll and visitor spending are summarized in table 18. In April 2007, there were 69,100 jobs in Hawaiʻi County, of which 2,402 or 3.5 percent are estimated to be supported by Hawaiʻi Volcanoes National Park payroll and visitation spending.

TABLE 18: TOTAL ECONOMIC CONTRIBUTION ASSOCIATED WITH PAYROLL SPENDING AND PARK VISITATION AT HAWAIʻI VOLCANOES NATIONAL PARK

	Total Payroll Impacts	Total Nonlocal Visitor Spending Impacts	Total
Spending	$7,803,000	$109,329,000	$117,132,000
Total labor income	$9,541,000	$43,661,000	$53,202,000
Total value added	$10,907,000	$67,577,000	$78,484,000
Jobs	203	2,199	2,402

Sources: Stynes 2008.

SOCIAL BENEFITS OF THE VOLUNTEER UNGULATE CONTROL PROGRAM

Hawaiʻi Volcanoes National Park currently provides a Volunteer Ungulate Control Program to aid in managing the numbers of ungulates at the parks (see the alternative A discussion in chapter 2 for more details about this program). The program, which is open to the public, provides volunteers the opportunity to participate in ground shooting efforts for ungulate control in Kahuku. Volunteers, who are accompanied by park staff, are allowed to bring one guest.

In fiscal year 2007, 68 volunteers donated more than 950 hours to the program over 25 days; 1,130 hours of park staff time were required as well. During this year, 605 mouflon sheep and 3 feral pigs were removed from the park through the Volunteer Ungulate Control Program. Currently, the volunteers are allowed to keep the meat from the animals they shoot. The program continues to attracted high volunteer interest, and previous volunteers are enthusiastic about returning (NPS 2007b).

The majority of volunteers are from the Island of Hawai‘i, while some are from communities adjacent to the park. This program allows these local residents access to the park for recreation; provides interaction with the park staff, which supports social connectedness and public–federal relations; promotes communications among landowners of the region; and also allows local residents to assist in helping protect park resources (i.e., park stewardship).

VISITOR USE AND EXPERIENCE

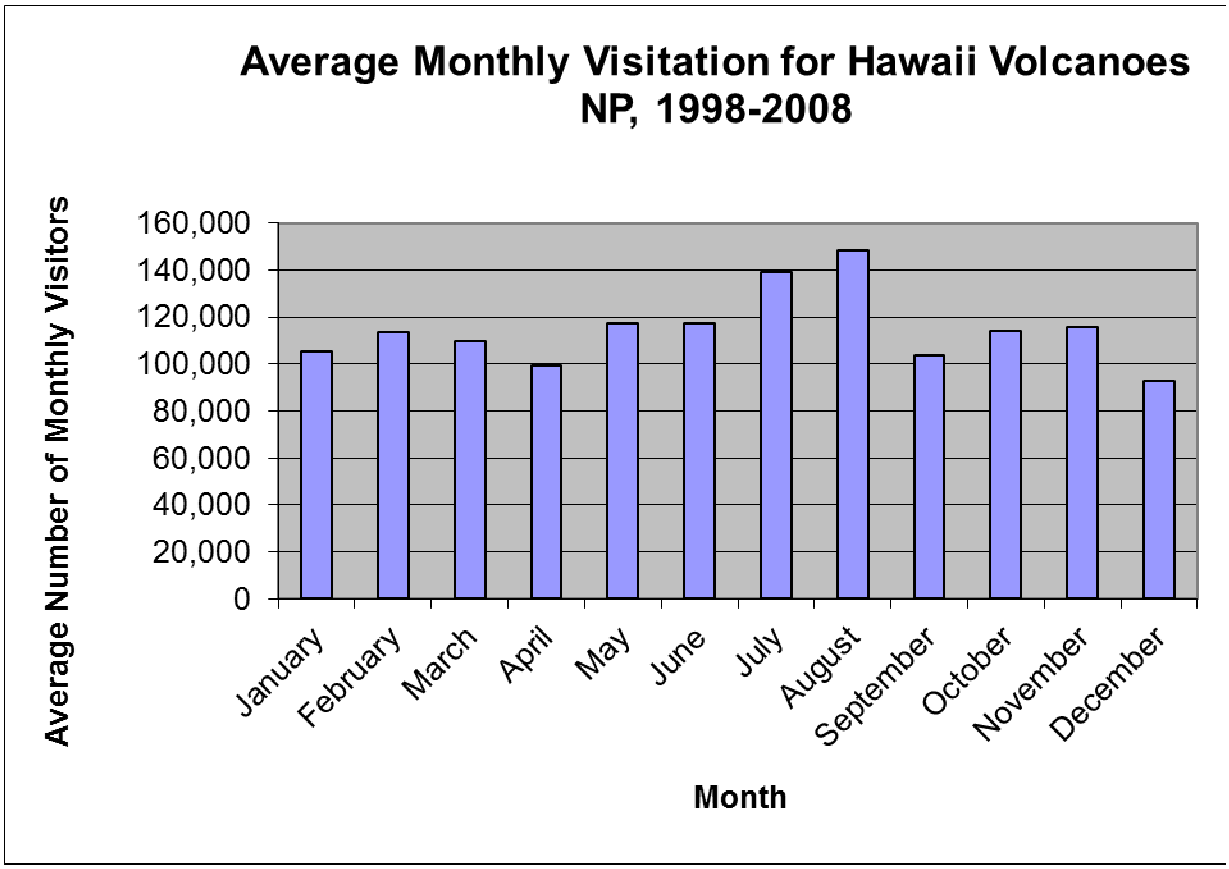
VISITATION

Visitors to Hawai‘i Volcanoes National Park have the opportunity to visit two of the world's most active volcanoes, take in views of volcanic landscapes, and learn about the geologic origins of the Hawaiian Islands, the native plants and animals unique to the area, and the distinct Native Hawaiian culture (NPS 2009a). During each year between 1998 and 2007, an average of 1,375,925 people visited the park (see table 19). Over this time, the largest decline in visitation was experienced from 2001 to 2002, when the annual number of visitors decreased by 17 percent. By contrast, the largest increase in visitation was experienced from 2003 to 2004, when the annual number of visitors increased by 32 percent. From 1998 to 2008, an average of approximately 115,000 people visited the park per month (figure 11). July and August represent slightly busier months overall, with over 140,000 visitors. December is, on average, the lightest month in terms of park visitation, with roughly 90,000 visitors to the park (NPS 2009b).

TABLE 19: VISITOR USE STATISTICS FOR HAWAI‘I VOLCANOES NATIONAL PARK, 1998–2008

Year	Visitation	Percentage Change from Previous Year
1998	1,352,373	—
1999	1,502,855	+11%
2000	1,514,636	+<1%
2001	1,343,286	−11%
2002	1,110,998	−17%
2003	991,875	−11%
2004	1,307,391	+32%
2005	1,661,196	+27%
2006	1,612,246	−3%
2007	1,467,779	−9%
2008	1,270,538	−13%
Average	**1,375,925**	

Source: NPS 2009b.



Source: NPS 2009b.

FIGURE 11: AVERAGE MONTHLY VISITATION FOR HAWAIʻI VOLCANOES NATIONAL PARK, 1998–2008

VISITOR ACTIVITIES

The park provides ample opportunity for lava and wildlife viewing via scenic drives along the two popular main roads: Crater Rim Drive and Chain of Craters Road. Other popular activities include hiking, bicycling, camping, visiting the visitor centers, and taking part in various ranger-led programmed activities. These activities are available year-round (NPS 2009a).

An important park experience is created by the interplay of natural forces, including volcanism, weather, wildlife, vegetation, vistas, smells, color and shape of landform, air quality, and varied light. Volcanic activity continues to create spectacular formations and provides opportunities for visual interpretation of the volcanic processes. The varied landscape in the park contains the active caldera of Kīlauea Volcano, fragile lava features, deserts, rain forests, craters, rift zones, rare plants, and archeological sites.

Lava at the End of Chain of Craters Road

The park's seven ecological zones harbor distinct plant and animal communities. Hawai'i Volcanoes National Park also shelters an array of Hawaiian native species, including birds, carnivorous caterpillars, the largest dragonfly in the United States, crickets that inhabit new lava flows, endangered sea turtles, and the Hawaiian hoary bat. It is home to many engaging creatures (such as happy-face spiders, carnivorous caterpillars, lava crickets, picture wing flies, and honeycreepers), and a refuge for many endangered species (such as the Hawaiian goose, dark-rumped petrel, and Hawaiian hoary bat).The Hawaiian Islands are renowned in the scientific world for having evolved the most spectacular land bird assemblage on a remote oceanic archipelago (NPS 2009a). While visitor activities are generally available at all times of the year, the park superintendent may restrict use of any area or trail in order to protect visitors and the park's resources. Volcanic eruptions and high levels of volcanic gases may also warrant closing an area or the entire park.

Primary Interpretive Themes

Primary interpretive themes describe what needs to be interpreted to provide visitors with opportunities to understand and appreciate the park's purpose and significance. Identification of primary themes is part of a park's basic foundation statement. Primary interpretive themes are derived from, and reflect, park significance. Additional perspectives may be obtained from the identification and analysis of fundamental and other important resources and values. It is anticipated that the primary interpretive themes may be revised through development of the park's future Comprehensive Interpretive Plan.

The following primary interpretive themes have been developed for Hawai‘i Volcanoes National Park (NPS 2010a):

- Monitoring the daily pulse of Hawai‘i’s active volcanoes leads to new discoveries and advances understanding of volcanic eruptions and hazard monitoring.
- The approachable active volcanoes of Mauna Loa and Kīlauea allow first-hand discovery and connection with one of the most fundamental forces in our world, in both its creative and destructive roles.
- In Hawai‘i, active volcanism created an isolated home for a few immigrant species and gave rise to a rich, yet fragile, endemic biota. Due to the accelerating change brought about by human actions and introduced plants and animals, much of that unique heritage is being lost to extinction, challenging all of us to learn from the past and work together to preserve and restore the remaining native plants and animals.
- The park’s designation as a World Heritage Site and International Biosphere Reserve attests to the compelling values that the park’s unique geologic resources and island biota hold for people worldwide and its global importance as a benchmark for monitoring environmental change.
- Hawai‘i Volcanoes National Park protects a diverse wilderness that stretches from rich coastline to stark alpine summit, providing visitors with opportunities to connect with nature’s challenges, remote solitude, and wild spirit.
- Kīlauea Volcano, the home of Pelehonuamea, and Mauna Loa Volcano are sacred to many Native Hawaiians. The park is a place of birth and the physical representation of many spirits and forces; the active volcanism, the features of the terrain, and the plants and animals that live there are all important to the Native Hawaiian sense of identity, unity, and continuance.
- The journeys of the Hawaiian people, and those who followed, portray cultural clashes, adaptations, and assimilations that provide enduring lessons about human resourcefulness, interdependence, and respect on an active volcanic landscape.

KAHUKU UNIT

The Kahuku Unit is an 115,653-acre addition to Hawai‘i Volcanoes National Park that includes the southwest rift zone of Mauna Loa Volcano. Resource values present at Kahuku are similar to those found in the other portions of Hawai‘i Volcanoes National Park. Consequently, the existing primary interpretive themes of the park would also be used at Kahuku. Based on other planning actions, possible visitor uses in Kahuku could include guided geologic hikes, bird walks, car caravans, bicycle tours, service-based resource management interpretive programs (collection of seeds, sowing and planting of native plants, removal of non-native weeds, and cleanup of trash and other debris) open houses, special events, and paniolo (Hawaiian cowboy) Days (NPS 2006d). The Kahuku Unit is open to the public on weekends from 9:00 a.m. to 3:00 p.m.

VISITOR AND EMPLOYEE SAFETY

Non-native ungulate management actions, including the use of firearms, helicopters, and snaring, can affect the health and safety of visitors and employees. In addition, the presence of ungulates poses hazards, including threats of disease and bodily injury should humans come in direct contact with them. Existing regulations, including the NPS *Management Policies 2006* and several director’s orders address some of these activities (see NPS *Management Policies 2006*, “Policies and Regulations,” section 8) and would be implemented to ensure human health and safety during project implementation. Among other

things, these policies and regulations contain specific language regarding how to ensure public health and safety in areas of NPS jurisdiction and specifying when appropriate certifications related to it are required (e.g., use of firearms and aviation).

HAZARDS ASSOCIATED WITH MANAGEMENT ACTIONS

Firearms—Ground Shooting

The use of firearms during ground shooting potentially poses a threat to the health of visitors and employees. In order to ensure safety, the current volunteer program mandates that volunteers be properly trained through a hunter education course. While conducting ungulate control projects, volunteers are supervised closely throughout the duration of removal efforts. Volunteers are supervised at a 1:2 ratio. Park staff members who are involved with ground shooting have the proper skills in the use of firearms and ensuring volunteer and public safety. Staff members also have experience with the use of firearms for the removal of wildlife.

Helicopter Operations

Helicopters are used in managing non-native ungulates. Health and safety concerns related to the use of helicopters range across a number of issues, including (1) mechanical failure resulting in a crash; (2) contact or entanglement with the main and/or tail rotor; and (3) rotor contact with trees, tall shrubs, power lines, etc., at capture/landing sites or during operation. Personnel involved with these activities have appropriate training, certification, skills, and proficiencies in helicopter operation and in the use of firearms for the removal of wildlife. Helicopter use generally occurs in open canopy areas where skilled shooters can effectively and quickly dispatch animals that briefly appear in open areas. Stringent policies and procedures are in place to ensure the safety of all helicopter operations, particularly ACETA (aerial capture, eradication, and tagging of animals) missions.

Snares

While snares pose hazards to employees or visitors should they come across a pig caught in a snare, they are generally used in remote locations or where there is limited potential for encounters. In addition, snare sites are well signposted to further limit this potential risk.

Other

Wildlife biologists and other field researchers who currently work in the park may come in contact with a variety of physical and biological hazards during the normal conduct of non-native ungulate management. Physical environmental hazards affecting field personnel include sunburn, exposure to weather, uneven terrain for walking or for driving vehicles, etc. Biological hazards include insect bites, plants, animals, parasites, fungi, bacteria, or viruses that may physically harm or cause disease in humans. While handling wildlife, staff and researchers can be kicked or bitten by the animals, causing physical harm to researchers. In addition, staff or researchers immobilizing an animal may be exposed to drugs that are latently dangerous to humans. Diseases may be transmitted from animals to humans, including bacteria and viruses that may enter humans through contact with the skin, eyes, mouth, and/or through inhalation. Park staff and researchers may be exposed to bacteria and virus vectors including mosquitoes.

HAZARDS ASSOCIATED WITH NON-NATIVE UNGULATES

Beyond management actions, the presence of non-native ungulates in Hawai‘i also creates health and safety risks. Park staff and visitor encounters with non-native ungulates can result in injuries, although a

study of visitor incidents from 1992 through 2002 did not document any such injuries (Heggie 2005). In Kahuku, mouflon sheep attract feral dogs to the area, which chase and bring down animals; these animals in turn are a potential risk to visitors and staff. Non-native ungulates have also been known to carry diseases that are transmissible to humans. For example, feral swine can harbor at least 30 significant viral and bacteriological diseases, several of which are transmissible to humans (Seward et al. 2003).

In addition to potentially carrying disease themselves, non-native ungulates such as pigs also create suitable conditions for disease vectors, such as mosquitoes, to flourish.

In addition to potentially carrying disease themselves, non-native ungulates such as pigs also create suitable conditions for disease vectors, such as mosquitoes, to flourish. Wallows created by feral pigs in Hawai‘i catch rain and become habitat for mosquito larvae and other aquatic organisms. Tree fern hollows, which are created by feral pigs when they feed on the interior pulp of the tree, also create similar habitats. In one 2-acre study area at the park, 35 tree fern hollows were found to contain mosquito larvae and another 50-acre area contained five mud wallows that contained larvae. Larvae of four other families of Diptera were found in these wallows and hollows, as well as numerous species of parasitic nematodes (Baker 1975). Mosquitoes have the potential to transmit diseases including but not limited to malaria, West Nile virus, dengue, and encephalitis (Maryland Department of Agriculture 2009).

ACCIDENTS

Based on a review of incident data from 1992 through 2002 (see table 20), the most common visitor injuries included lacerations, abrasions, broken bones, sprains and strains, dehydration, respiratory irritation, allergic reactions, and thermal burns (Heggie 2005). No non-native ungulate–related injuries were documented. However most visitation is in areas that are ungulate free or with very low animal densities. In areas where higher numbers of animals remain (e.g., Kahuku), the presence of these animals could pose a threat to health and safety.

From 2004 to 2008, a total of 95 employee injuries were reported, 48 of which resulted in lost time. Injuries included muscle strains, sprains, bruises, cuts (including abrasions, lacerations, and puncture wounds), stings/bites, broken bones, heat exhaustion, allergic reactions, and chemical exposure, among others. The primary causes of these injuries included falls; lifting/moving equipment, materials, or debris; exposure to plants, insects, or chemicals; hiking, especially on rough terrain; and motor vehicle accidents (NPS 2009g).

TABLE 20: FATAL AND NONFATAL VISITOR INCIDENTS IN HAWAI‘I VOLCANOES NATIONAL PARK, 1992–2002

Classification	Fatal	Serious	Minor	No Injury	Unknown	Total (%)
Aircraft	16	7	18	6	4	50 (30)
Backcountry[a]	10	23	18	0	0	51 (30)
Frontcountry[b]	7	5	16	0	0	28 (17)
Road	6	10	1	19	0	36 (22)
Other (suicide)	1	0	0	0	0	1 (<1)

Source: Heggie 2005.

[a]Backcountry refers to primitive and undeveloped areas of the park where backpacking and wilderness hiking activities are common.

[b]Frontcountry regions are areas in the park within 1 kilometer (0.6 mile) of any park road or highway, where walking short interpretive and educational trails is common.

Of the 95 injuries reported, approximately 20 were associated with non-native ungulate management actions, primarily related to constructing fences or repairing/replacing the fences; 8 of these resulted in lost time. The nature and cause of injuries during these actions were consistent with those that occurred more generally in the park, including sprains/strains, cuts, insect stings, and broken bones from falls; lifting, moving, and/or operating equipment, materials, or debris; hiking; and exposure to plants. One staff member contracted leptospirosis while camping (NPS 2009g). Leptospirosis is a bacterial disease in animals that is considered an occupational hazard for people that work outdoors or with animals. It can be transmitted to humans when they come in contact with water, food, or soil containing urine from infected animals (CDC 2005).

PARK MANAGEMENT AND OPERATIONS

Hawai‘i Volcanoes National Park has seven divisions: Administration, Cultural Resources, Interpretation, Maintenance and Facilities Management, Natural Resources, Resource Protection, and Fire Management (Yoshida 2009a).

The total number of full-time employees was 93 in 2009. The park's operating budget for the fiscal year of 2008 was $6,740,143 (Yoshida 2009b). Approximately 5 percent of this, or $320,000, was committed for non-native ungulate management. When combined with other funding sources, the annual budget for non-native ungulate management activities averaged approximately $922,000 from 2006 to 2008 (Loh, pers. comm., 2009b). Of this, approximately $530,000 went towards labor costs (including fence repair and replacement, animal monitoring and removal), $220,000 for material costs, $143,000 for administrative costs, and $29,000 for the Volunteer Ungulate Control Program.

ADMINISTRATIVE DIVISION

The Administrative Division oversees all human resources, budget operations, contracting, concessions, information technology, property, and cost of collections in the park. The division is responsible for the park's revenues, which are collected in various ways: the entrance station, air tour fees, special use permits, commercial use authorizations, and donations. The division manages contracts that pertain to the acquisition of new areas, such as the newly acquired Kahuku area. Contracting support is also provided by the Pacific West Region's Contracting Officer, with assistance from the Major Acquisition Buying Office, which helps all Pacific Island Network parks. Additionally, the Administrative Division provides support to local parks on the Island of Hawai‘i, including Pacific Island Parks. This includes a newly developed Servicing Human Resources Office at Hawai‘i Volcanoes National Park, which will be assisting all the Pacific Island Network parks with staffing. The division consists of 12 permanent full-time employees, 3 term employees, 2 seasonal employees, and 2 Student Temporary Employment Program employees (Yoshida 2009c). One employee is dedicated to the park's IT system and is responsible for the park's entire telecommunications system.

CULTURAL RESOURCES DIVISION

This division is responsible for compliance with Sections 106 and 110 of the *National Historic Preservation Act*, including surveying the entire park property for archeological and cultural resources. The division also manages the park's museum, which contains approximately 300 library, archeological, natural, and artistic items. The division also manages contracts with individuals who enter the park to work on resource inventory documentation projects.

The Cultural Resources Division has four permanent, full-time employees, including one division chief and one Hawaiian community liaison. There are seven full-time employees on term appointments, whose terms are from 1 to 4 years in length. The division does not have a large number of volunteers, although

the museum program currently has three volunteers. Student interns are rare; however, the division does occasionally use them. The museum curator, one of the division's full-time, permanent employees, is also responsible for acting as the museum curator at several of the other parks on the Island of Hawai'i. In addition, the Cultural Resources Division shares 1 permanent employee with the Natural Resources Division, who is responsible for various administrative tasks (Schuster, pers. comm. 2009).

INTERPRETATION DIVISION

The Interpretation Division is responsible for public communications, outreach, publications, and permitting related to communications. These responsibilities involve conducting interpretation and outreach activities with the goal of conveying science and culture to the visiting public, to school groups, and to the surrounding community. The division conducts its activities via formal ranger interpretation programs, through school environmental education programs, and through informal roving interpretation programs. The Interpretation Division annually initiates new or existing outreach programs that are relevant and meaningful to the underserved communities surrounding the park. Volunteer programs play an integral role in the division's interpretive and educational functions. This division is also responsible for managing film permits in the park, and dispenses between 60 and 100 filming permits per year. The permits ensure that filming operations conducted by park visitors will not adversely impact park resources (Gale 2009a).

The park film, "Born of Fire … Born of the Sea," shown on the hour, conveys a holistic story of the arrival of life and of non-native ungulates and other non-native species, and shows how the NPS takes care of the park. In the Kīlauea visitor center, exhibits tell the story of how generations of park employees have never given up in their fight against non-native species. The history and ecological significance of non-native ungulates in the park is reviewed in most of the park's interpretive programs, such as ranger walks and stewardship walks with the public (Gale 2009b).

The division has nine permanent staff members, two of whom are subject to furlough (temporary layoffs). There are three to four term staff members (on 1- to 4-year appointments) in any given year. There are eight seasonal employees. Volunteer labor provides for the equivalent of 10 additional full-time positions.

MAINTENANCE AND FACILITIES MANAGEMENT DIVISION

The Maintenance and Facilities Management Division provides custodial services and is responsible for the maintenance of buildings and facilities in the park; vehicles and equipment; utilities, water, sewers, and lights; and all trails, including front- and backcountry trails. They are also responsible for maintenance of the park's four cabins and three shelters.

The park's fencing program is managed by the Natural Resources Division (below), and not by the Maintenance and Facilities Management Division, as would be typical in a national park.

The division consists of 24 permanent employees, some of whom are subject to furlough; 17 seasonal or term appointment employees; and 1 employee of the Research Corporation of the University of Hawai'i, acquired through a special agreement between the NPS and the University of Hawai'i. Each seasonal employee provides approximately 1,039 hours per year. In some years, the division acquires a Ford Foundation student to assist on projects (Borne 2009).

NATURAL RESOURCES MANAGEMENT DIVISION

The Natural Resources Management Division is responsible for the protection and perpetuation of native ecosystems and native species, including conducting restoration activities related to protecting native species and perpetuating biological diversity. Many of the division's programs focus on non-native species management, perpetuation of rare species, fire ecology and fire restoration, and habitat restoration for extirpated or at-risk (threatened and endangered) species. The division also assists in wildland firefighting.

There are 12 full-time, permanent staff members, 7 of whom are subject to furlough; 1 additional administrative permanent staff member is shared with the Cultural Resources Division. Depending on the annual availability of special project funds, there are between 10 to 15 nonpermanent staff members (term or seasonal appointments). Volunteers make up an important component of the workforce. In 2008, volunteers contributed the equivalent of 16 full-time positions on various projects related to endangered species monitoring and recovery, habitat restoration, and non-native plant and animal management. Division responsibilities are divided among the following programs:

- The Wildlife Program, which is responsible for non-native ungulate control. The program focuses on fence inspection, repair, and replacement and on monitoring and removal of ingress animals. It is staffed by four permanent, full-time staff members (two of whom are subject to furlough) and by three to six seasonal or term staff members funded by special project funds.
- The Vegetation Management Program, which oversees habitat restoration, monitoring and control of non-native plants, fire ecology, and recovery of rare, threatened, and endangered plant species. The program also oversees the monitoring and control of non-native coqui frogs. This program is staffed by five permanent, full time staff members (four of whom are subject to furlough), three to six seasonal or term staff members funded by special project funds, and additional volunteer staff.
- The Hawaiian Petrel Program, which focuses on monitoring and protecting the endangered Hawaiian petrel. Program actions involve nest protection measures and bird monitoring. The program is staffed by part-time seasonal or term employees funded by special project funds.
- The Endangered Hawksbill Turtle Program, which focuses on monitoring and protecting the endangered hawksbill turtle. Program actions involve nest site protection, protection of hatchlings as they migrate from land to water, turtle monitoring, and informal environmental education. The program is implemented by volunteers directed by part-time seasonal staff who work collaboratively with specialists from the University of Hawai‘i through a cooperative agreement.
- The Nēnē Goose Recovery Program, which focuses on recovering the endangered Hawaiian goose, or nēnē. Program actions involve identification of potential threats to the goose, including protection from predation by non-native pigs, and monitoring of the existing birds and their nests. The program is staffed by 2 permanent employees, subject to furlough staff members, and volunteer staff.
- The Air Quality Monitoring Program, which focuses on the collection of air quality measurements in several sites across the park. Field staff from the NPS and USGS cooperatively maintain instruments and collect data that is analyzed by USGS and the NPS Air Quality Monitoring Program.
- Through a cooperative agreement with the University of Hawai‘i (referred to as the Cooperative Ecosystem Studies Unit or CESU), the Natural Resources Management Division collaborates with approximately 10 part-time or full-time university cooperators who provide technical

assistance with natural resources management programs related to rare species recovery and research on non-native species control (e.g., coqui frog invasion) and habitat restoration. These are nonpermanent positions that end at the completion of a project. The division also coordinates all research (e.g., geology, biology, social science studies) conducted in the park through the web-based NPS Research Permit and Reporting System. Between 30 and 50 permits are issued annually in the park.

The division has several formal and informal partnerships with external institutions. These include the USGS Pacific Islands Ecosystem Research Center (PIERC), and the USDA quarantine facility, all with offices based at the park that provide valuable monitoring and research services; Big Island Invasive Species Council, a partnership among federal, state, and county agencies to coordinate non-native plant management activities on the Island of Hawai‘i; the Friends of Hawai‘i Volcanoes National Park, who contribute volunteers and assist with raising funds for special projects; and the TMA, which coordinates conservation and watershed management activities among several federal and state agencies and private landowners (e.g., Kamehameha Schools, TNC).

PROTECTION DIVISION

The responsibility of the Protection Division is to ensure protection of the visiting public and of park resources. This responsibility involves law enforcement duties, including enforcement of criminal codes, traffic codes, and federal laws. The division also conducts search-and-rescue operations and assists with wildland firefighting. This division has exclusive jurisdiction for all law enforcement in the park. As a result, local, county, or state law enforcement agencies are unable to enter the park and enforce any laws unless they are invited by the Resource Protection Division or are in pursuit of a crime that occurred in their own jurisdiction.

The Protection Division consists of three groups. The first group is called Law Enforcement, and functions as the law enforcement response team for the park. This group currently consists of seven permanent, full-time employees, including the division chief. There are two additional seasonal, full-time employees that work for this group for a maximum of 6 months out of each year.

The second group is called Pacific Area Communications and is responsible for managing communications. They access criminal computer databases, make necessary phone calls, and function as a routine and emergency dispatch center. The group consists of one full-time, permanent supervisor and five full-time, permanent employees.

The third group is called the Eruption Crew. This group consists of four full-time employees who are appointed for a 1- to 4-year term. The crew is responsible for managing public safety as it relates to the unique volcanic hazards in the park. They oversee public safety interpretation as it pertains to volcanic hazards and conduct search-and-rescue operations during emergencies (Magno 2009).

FIRE MANAGEMENT DIVISION

The Fire Management Division is responsible for fire management at all 10 Pacific Island park units. This includes responding to wildland fires, preparing fire management plans, conducting fire management activities, managing hazardous fuels projects, and maintaining the qualification and certification program for wildland firefighters. The division oversees the park’s aviation program, which is a qualification and certification program for aviation personnel, and which uses helicopters leased from an off-site, external entity. The division also maintains seven remote weather stations. The Fire Management Division spends approximately 70 percent of its time in Hawai‘i Volcanoes National Park.

The division consists of 6 full-time, permanent employees, all of whom are qualified to fight wildland fires. During an average year, there might be two wildland fire emergencies. In such situations, the division will draw upon its trained "militia" made up of park staff from the other divisions, and individuals from the surrounding communities. The Hawai'i Volcanoes National Park firefighting militia consists of 45 qualified volunteers, approximately 20 of whom would be called upon during a wildland fire emergency.