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Chapter 4. Refuge Biology and Habitats

This chapter addresses the biological resources and habitats of Kīlauea Point NWR; however, it is not an exhaustive overview of all species and habitats occurring within the Refuge. The chapter begins with a discussion of biological integrity; we then focus on the presentation of pertinent background information for the priority resources of concern and other benefitting species designated under the CCP. Background information includes descriptions, locations, conditions, trends, key ecological attributes, and threats (stresses and sources of stress) to the habitats and/or associated resources of concern. The information presented was used to develop goals and objectives for the CCP (see Chapter 2).

4.1 Biological Integrity, Diversity, and Environmental Health

The Improvement Act directs the Service to ensure that the biological integrity, diversity, and environmental health (BIDEH) of the Refuge System is maintained for the benefit of present and future generations of Americans. The Service’s policy on BIDEH (601 FW 3) also provides guidance for consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges and associated ecosystems that represent BIDEH on each refuge. The Refuge Administration Act, as amended by the Improvement Act, clearly establishes that wildlife conservation is the singular Refuge System mission. House Report 105-106 accompanying the Improvement Act states “...the fundamental mission of our System is wildlife conservation: wildlife and wildlife conservation must come first.” BIDEH is a critical component of wildlife conservation.

BIDEH policy defines *biological integrity* as “the biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities.” *Biological diversity* is defined as “the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and communities and ecosystems in which they occur.” *Environmental health* is defined as the “composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment.” In simplistic terms, elements of BIDEH are represented by native fish, wildlife, plants, and their habitats, as well as those ecological processes that support them.

Biological integrity lies along a continuum from a completely natural system to a biological system extensively altered by considerable human impacts to the landscape. No modern landscape retains complete BIDEH. However, we strive to prevent the further loss of natural biological features and processes. Maintaining or restoring biological integrity is not the same as maximizing biological diversity. Maintaining biological integrity may entail managing for a single species or community at some refuges and combinations of species or communities at other refuges. Maintaining critical habitat for a specific endangered species, even though it may reduce biological diversity at the refuge scale, helps maintain biological integrity and diversity at the ecosystem or national landscape scale.

Historically, migratory and nonmigratory native birds and native coastal plant communities may have thrived in the Kīlauea Point area in some or most years and on multiple islands on much larger landscapes. This is supported by fossil and subfossil records of species in lowlands, previously thought to be restricted to higher elevations or other islands, including, ‘a‘o, ‘ua‘u, and nēnē (Burney et al. 2001). Native coastal ecosystems are among the most threatened ecosystems in the Hawaiian

Islands due to the long-term presence of humans and the negative effects of their actions—specifically, development, agriculture, fire, and the introduction of invasive species. Therefore, to conserve native plant and animal populations at larger landscape scales to support long-term regional conservation goals, we may manage habitats at the Refuge to maintain higher densities of native species than those that may have occurred historically at the Refuge level because of loss and degradation of surrounding habitat.

On refuges, we typically focus our evaluations of biological diversity at the refuge scale; however, these refuge evaluations can contribute to assessments at larger landscape scales. We strive to maintain populations of breeding individuals that are genetically viable and functional. Evaluations of biological diversity begin with population surveys and studies of flora and fauna. The Refuge System's focus is on native species and natural communities such as those found under historical conditions.

We evaluate environmental health by examining the extent to which environmental composition, structure, and function have been altered from historic conditions. Environmental composition refers to abiotic components, such as air, water, and soils, all of which are generally interwoven with biotic components (e.g., decomposers live in soils). Environmental structure refers to the organization of abiotic components, such as atmospheric layering, aquifer structure, and topography. Environmental function refers to the processes undergone by abiotic components, such as wind, tidal regimes, evaporation, and erosion. A diversity of abiotic composition, structure, and function tends to support a diversity of biological composition, structure, and function.

We strive to manage in a holistic manner the combination of BIDEH. We balance all three by considering refuge purposes, Refuge System mission, and landscape scales. Where practical, we support the return of extirpated native species in the context of surrounding landscapes. The elements of BIDEH for Kīlauea Point NWR are summarized in Table 4.1 below.

Table 4-1. Biological Integrity, Diversity, and Environmental Health.

Habitats	Historic habitat attributes	Historic natural processes responsible for these conditions	Current limiting factors
Coastal mixed woodland-grassland	Native-dominated coastal dry-mesic shrubland, mixed shrub and grassland, and mixed shrubland and forest communities with <45° slope. <i>Potential conservation species: nēnē, pueo, seabirds including mōlī, ka‘upu, ‘a‘o, and rare native coastal plant communities supporting threatened and endangered plants and endemic insects.</i>	Shallow, well-drained, highly erodible, saline, phosphorus-rich soils (e.g., guano); wind and water erosion; low annual precipitation; and grazing (geese).	Invasive species: ironwood, Christmasberry, lantana, haole koa, introduced mammalian and avian predators and scavengers and insect pests; ungulate rooting and grazing; climate change; human development; vehicular and human traffic.

Sea cliff	Native-dominated coastal dry-mesic shrubland, mixed shrub and grassland, and mixed shrubland and forest communities with >45° slope. <i>Potential conservation species: seabirds including ‘iwa, ‘ā, ‘ua‘u kani, koa‘e kea and rare native coastal plant communities supporting threatened and endangered plants and endemic insects.</i>	Shallow, well-drained, highly erodible, saline, phosphorus-rich soils; wind, wave, and water erosion; and low annual precipitation.	Invasive species: ironwood, Christmasberry, lantana, haole koa, introduced mammalian and avian predators and scavengers and insect pests; climate change; human development; human trespass
Beach strand	Bare sand, gravel, or rock within or just above the tidal zone; sparsely vegetated by native- dominated coastal dry herbland and mixed communities. <i>Potential conservation species: ‘ilio-holo-i-ka-uaua, honu, migratory shorebirds, ‘iwa, ‘ā, and rare native coastal plant communities.</i>	Well-drained, sandy to rocky substrates; wind and water erosion; wave inundation; saline environment; low annual precipitation.	Invasive species: ironwood, Christmasberry, lantana, haole koa, introduced mammalian and avian predators and scavengers and insect pests; climate change; human trespass

4.2 Priority Resources of Concern

4.2.1 Analysis of Resources of Concern

In identifying resources of concern (ROCs), the team followed the process outlined in the Service’s draft Identifying Refuge Resources of Concern and Management Priorities: A Handbook (USFWS 2010). As defined in the Service’s Policy on Habitat Management Plans (620 FW 1), ROCs are:

“all plant and/or animal species, species groups, or communities specifically identified in refuge purpose(s), System mission, or international, national, regional, state, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a refuge whose purpose is to protect ‘migrating waterfowl and shorebirds.’ Federal or State threatened and endangered species on that same refuge are also a resource of concern under terms of the respective endangered species acts (620 FW 1.4G)...”

Habitats or plant communities are ROCs when they are specifically identified in refuge purposes, when they support species or species groups identified in refuge purposes, when they support Refuge System ROCs, and/or when they are important in the maintenance or restoration of BIDEH.

As a result of this information gathering and review process, a comprehensive list of potential resources of concern was developed (Appendix E).

4.2.2 Selection of Priority Resources of Concern

Early in the planning process, the planning team cooperatively identified ROCs for the Refuge. Negative features of the landscape, such as invasive plants, may demand a large part of the Refuge management effort, but are not designated as ROCs. The step-by-step process to prioritize ROCs and management priorities for a refuge are displayed in Figure 4-1. The team then selected priority ROCs from the ROC list. The main criteria for selecting priority ROCs included the following requirements:

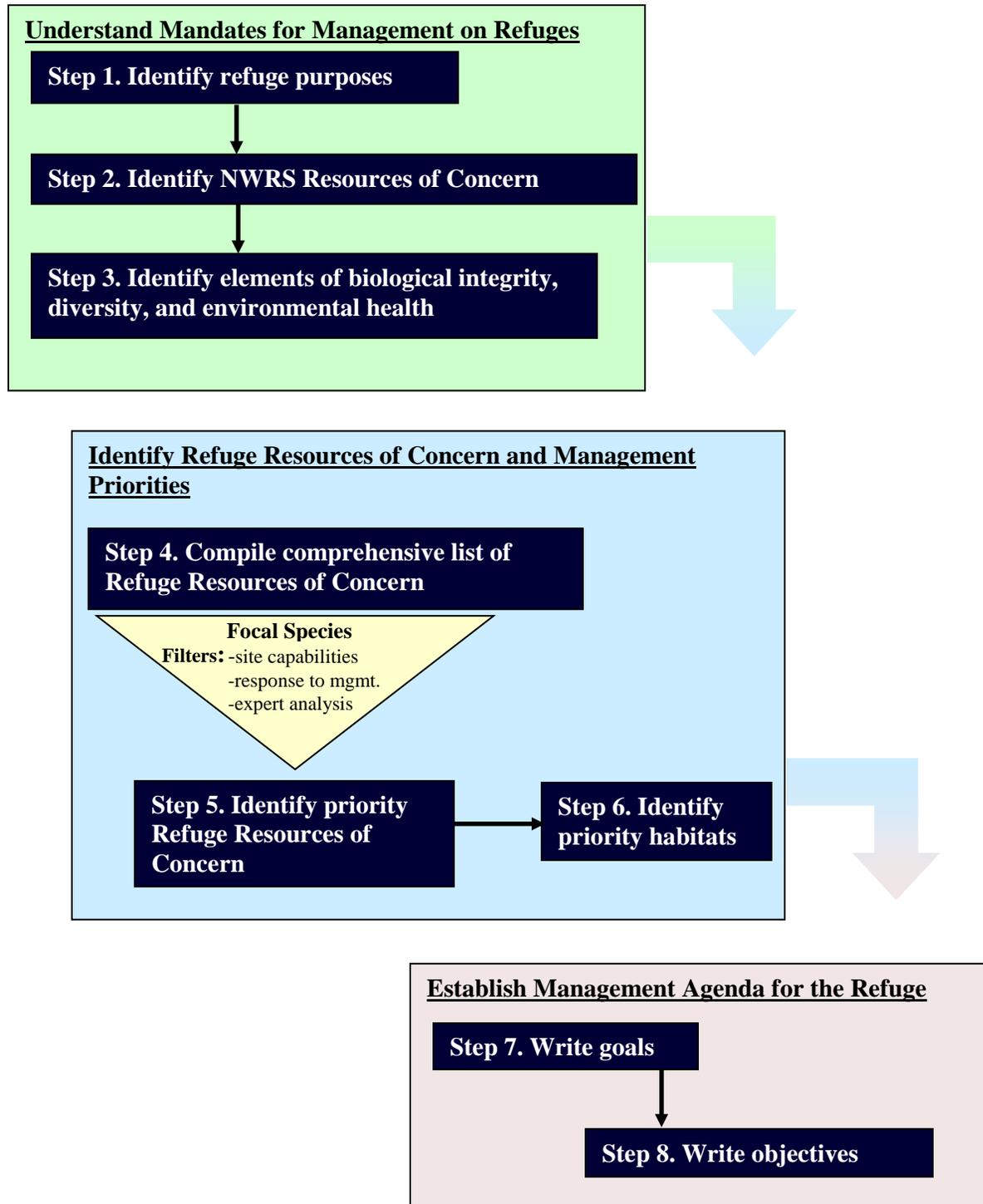
- The resource must be reflective of the Refuge’s establishing purposes and the Refuge System mission;
- The resource must include the main natural habitat types found at the Refuge;
- The resource must be recommended as a conservation priority in the Wildlife and Habitat Management Review; or
- The resource must be federally or state-listed, a candidate for listing, or a species of concern.

Other criteria that were considered in the selection of priority ROCs included the following:

- Species groups and/or Refuge features of special management concern;
- Species contributing to the BIDEH of the ecosystem;
- Species where it is feasible to estimate abundance and distribution (needed for future monitoring and adaptive management).

In developing its listing of priority ROCs, the planning team selected not only species mentioned in establishing documents for the Refuge, but also species that captured the ecological attributes of habitats required by larger suites of species. The ecological attributes of habitats should meet the life history requirements of ROCs, and are therefore important to sustain the long-term viability of the priority ROC and other benefitting species. Ecological attributes of habitats include vegetation structure, species composition, age class, patch size, and contiguity with other habitats; hydrologic regime; and disturbance events. These provide measurable indicators that strongly correlate with the ability of a habitat to support a given species. Tables listing the desired conditions for habitat types found on the Refuge incorporate “desired” conditions that were based on scientific literature review and team members’ professional judgment. These desired conditions for specific ecological attributes were then used to help design habitat goals and objectives, as presented in Chapter 2. However, not all ecological attributes or indicators were deemed ultimately feasible or necessary to design an objective around. Other factors, such as the Refuge’s ability to reasonably influence or measure certain indicators, played a role in determining the ultimate parameters chosen for each habitat objective. Thus, ecological attributes should be viewed as a step in the planning process.

Figure 4-1. Overview of the process to prioritize resources of concern and management priorities for a refuge (USFWS 2010)



Limiting factors were also considered in developing objectives. A limiting factor is a threat to, or an impairment or degradation of, the natural processes responsible for creating and maintaining plant and animal communities. In developing objectives and strategies, the team gave priority to mitigating or abating limiting factors that presented high risk to ROCs. In many cases, limiting factors occur on a regional or landscape scale and are beyond the control of individual refuges. Therefore, objectives and strategies may seek to mimic, rather than restore, natural processes. For example, mowing may be used to maintain a desirable vegetation structure, when restoring native grassland communities may be impractical. Through the consideration of BIDEH, the Refuge will provide for or maintain all appropriate native habitats and species. Refuge management priorities may change over time, and because the CCP is designed to be a living, flexible document, changes will be made at appropriate times.

In the following sections, information is provided on the ecological processes of formation and maintenance, regional distribution, condition and threats, key species supported, and management activities for each priority ROC. A similar analysis is presented for focal resources following the analysis for Priority ROCs.

Tables describing focal resources associated with a particular habitat type are included at the end of each Priority ROC section in this chapter. Definitions for the column headings are as follows:

- **Focal Resources:** Species or species groups selected as representatives or indicators for the overall condition of the priority ROC. In situations where the conservation target may include a broad variety of habitat structures and plant associations, several different conservation focal resources may be listed. In addition, species with specific “niche” ecological requirements may be listed as a focal resource. Management will be focused on attaining conditions required by the focal resource. Other species utilizing the associated habitat type will generally be expected to benefit as a result of management for the focal resource.
- **Habitat Type:** The priority resource of concern utilized by the focal resource.
- **Desired Habitat Characteristics:** The specific and measurable habitat attributes considered feasible on the Refuge and necessary to support the focal resource.
- **Life History Requirement:** The general season of use for the focal resource.
- **Other Benefiting Species:** Other species that are expected to benefit from management for the selected focal resource. The list is not comprehensive.

Table 4-2 identifies the priority resources of concern for Kīlauea Point NWR. As native species are referenced by their Hawaiian names, Appendix K contains a list of all scientific, English, and Hawaiian names.

Table 4-2. Priority Resources of Concern

Focal Resources	Habitat Type	Habitat Structure	Life History Requirements	Other Benefiting Species
Mōlī/ka‘upu (albatrosses)	Coastal mixed woodland-grassland	Variable. Large windward sandy, grassy, or shrubby areas with open runways for take-off and landing.	Breeding, prospecting	‘Ua‘u kani, nēnē, koa‘e ‘ula, ‘ā, ‘iwa, kōlea and other shorebirds, associated native plant and insect communities
‘A‘o/‘ua‘u kani (shearwaters)	Coastal mixed woodland-grassland and sea cliff	Substrates with good soil or root structure, or sub-canopy layer for burrowing, rock and root crevices, with open flight corridors.	Breeding, prospecting	Nēnē, koa‘e ‘ula, koa‘e kea, ‘a, ‘iwa, ‘ou, associated native plant and insect communities
‘Ā/‘iwa (red-footed booby and frigatebird)	Coastal mixed woodland-grassland, sea cliff, and beach strand	Variable. Woody vegetation >1.5–3 ft tall	Breeding, roosting, prospecting	Koa‘e ‘ula, koa‘e kea, ‘a, ‘iwa, ‘ou, ‘a‘o, ‘ua‘u kani, associated native plant and insect communities
Nēnē/pueo	Coastal mixed woodland-grassland, sea cliff	Sward-forming grass-legume mix with high moisture content, managed <6 inches tall. Shrublands with an open understory, forage value, adjacent to grasslands.	Breeding, roosting, foraging	‘Ua‘u kani, koa‘e ‘ula, mōlī, ka‘upu, kōlea, kioea, and other shorebirds, associated native plant and insect communities

Focal Resources	Habitat Type	Habitat Structure	Life History Requirements	Other Benefiting Species
‘Ilio-holo-i-ka-uaua/ honu	Beach strand	Protected, un-vegetated, or sparsely vegetated beaches with little to no human activity.	Hauling out and nursing (‘ilio-holo-i-ka-uaua), basking (honu)	Migratory shorebirds, ‘iwa, ‘ā, and rare native coastal plant communities.

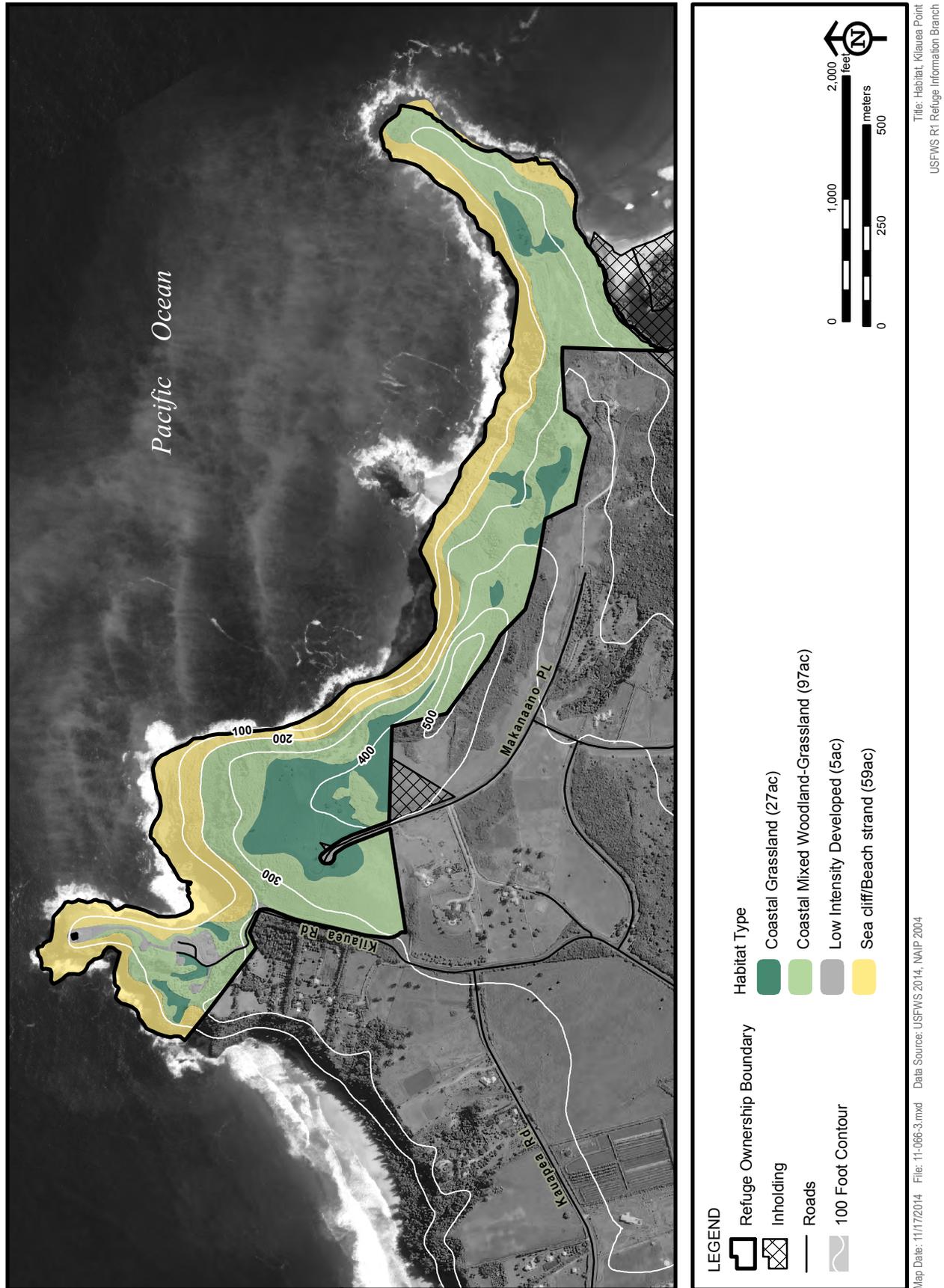
4.3 Primary Habitats

Plants that grow in the coastal zone and low elevation forests are rare in Hawai‘i as a result of development, agriculture, fire, and the introduction of pest species. Only 11 percent of lowland mesic and dry native plant communities remain intact on Kaua‘i, compared to 22 percent for all of the Hawaiian Islands combined.

Coastal habitats are designated as lands between sea level and 1,500 feet in elevation that are typically vegetated with salt-tolerant species and dispersed by wind, currents, and waves, but less capable of terrestrial migration. Strand species are highly influenced by the sea due to their location on the shoreline and adjacent areas. Strand environments can be harsh due to salt spray, constant wind, low rainfall, intense sunlight, high evaporation, high temperatures, and unstable sands. As a result, strand plants have developed a variety of adaptations to deal with these conditions, including moist stems, prostrate growth forms, thick cuticles, and small leaves that are succulent, hairy, or rosette. Because of these harsh conditions, species diversity is usually low in this habitat (Char and Balakrishna 1979, Tabata 1980, Wagner et al. 1999).

The Refuge consists of three primary habitats: coastal mixed woodland-grassland, sea cliff, and beach strand (Figure 4-2). Threats to these habitats include introduced mammalian predators and insect pests, invasive plants, ungulate rooting and grazing, climate change, human development, unregulated vehicular and human traffic, and trespassers.

Figure 4-2. Habitat, Kīlauea Point NWR.



The back sides of maps are blank to improve readability.

4.3.1 Coastal Mixed Woodland-Grassland

The coastal mixed woodland-grassland habitat consists of flats and bluffs with a $<45^\circ$ slope dominated by low-growing trees and shrubs and perennial herbs adapted for salt, wind, and low precipitation. The area contains shallow, well-drained, highly erodible, saline, phosphorus-rich soils. This habitat type is found along the entire length of the Refuge. Historically, this habitat probably consisted of native-dominated coast dry-mesic shrubland, mixed shrub and grassland, and mixed shrubland and forest communities. Currently, this area is important breeding habitat for all six species of breeding seabirds on the Refuge (mōlī, ‘ua‘u kani, ‘a‘o, koa‘e ‘ula, koa‘e kea, ‘ā), breeding and flocking habitat for endangered nēnē, wintering or stopover habitat for migratory shorebirds, and probably foraging and breeding habitat for pueo. Woody vegetation is dominated by ironwood, Christmasberry, and haole koa intermixed with patches of hala, naupaka kahakai, ‘akoko, ‘ilima, pōhinahina, and pā‘ūohi‘iaka. Grasslands are dominated by introduced species such as Kikuyu grass, Guinea grass, and lantana. These are areas that were historically grazed by livestock and now serve as managed grasslands for nēnē. The coastal mixed woodland-grassland habitat has the greatest potential to be stabilized, restored, and managed to benefit native plant and animal communities, including threatened and endangered species.

4.3.2 Sea Cliff

Sea cliff habitat is characterized by nearly vertical or vertical cliff faces with $>45^\circ$ slope and rocky, shallow, highly erodible substrates exposed to wind, rain, and sea. This habitat type is found along the coastline of the Refuge. Historically, this habitat probably consisted of native-dominated coastal dry-mesic shrubland, mixed shrub and grassland, and mixed shrubland and forest communities. Given the vertical topography and substrate of these areas, access is very difficult to hazardous. Because of its steep topography, the area appears to provide a refugium for seabirds and other native species from large mammalian predators and human disturbance. Currently, this area is important breeding habitat for ‘ua‘u kani, koa‘e ‘ula, koa‘e kea, and ‘ā and roosting habitat for ‘iwa, ‘ā (brown boobies and red-footed boobies) and endangered nēnē. The sea cliffs are sparsely vegetated with ironwood, Christmasberry, and lantana with patches of hala, naupaka kahakai, ‘akoko, ‘ilima, and pōhinahina.

4.3.3 Beach Strand

Beach strand habitat, consisting of small areas of sand, gravel, or rock within or just above the tidal zone, provides protected basking habitat for the critically endangered ‘īlio-holo-i-kauaua and potentially the threatened honu, foraging habitat for migratory shorebirds such as ‘ūlili, akekeke, kōlea, and marine fauna, and roosting habitat for ‘iwa and ‘ā (brown boobies and red-footed boobies). Beach strand communities are strongly influenced by the marine environment including wind and water erosion, wave inundation, and salt spray. Historically, this habitat probably consisted of native-dominated coastal dry herbland and mixed communities. Currently, vegetation is sparse, but consists of low shrubs and perennial herbs, such as naupaka kahakai, ‘ilima, and other prostrate native vegetation such as pōhinahina. Invasive species found in this environment include ironwood, Christmasberry, lantana, and haole koa. This habitat type is most vulnerable to climate change because of its low elevation.

4.4 Threatened and Endangered and Other Native Wildlife

4.4.1 ‘A‘o (*Puffinus auricularis newelli*) or Newell’s Shearwater

‘A‘o is a threatened endemic subspecies of the nominate species, the Townsend’s Shearwater of the eastern Pacific. It is a medium-sized shearwater, dark, sooty black above with a white belly, throat, and underwings. When compared to ‘ua‘u kani, it has shorter, broader wings and a shorter body and tail. Its flight pattern is distinctive with rapid stiff wing beats interspersed with glides versus the banking and gliding of ‘ua‘u kani. ‘A‘o is a pelagic bird that forages over deep waters east and south of Hawai‘i following predatory fish, particularly yellowfin tuna that chase squid and other prey to the ocean surface (Joyce et al. 2010). The total population of ‘a‘o is estimated to be 84,000 birds, including 14,600 breeding pairs (Ainley et al. 1997). From 1983 to 2008, there has been an alarming 75 percent decline in population indices (Day et al. 2003). Probable causes of the decline include predation by introduced predators, habitat loss and degradation, urbanization including collisions with powerlines, and attraction to urban lights and subsequent disorientation and fallout, and natural catastrophes (Ainley et al. 1997).

At least 90 percent of the subspecies breeds from April to November on Kaua‘i (Ainley et al. 1997), with the remainder breeding on Hawai‘i, Maui, and Moloka‘i. Age at first breeding is six years old. A single egg is laid in a burrow or on the ground in most years. The incubation and chick-rearing period is 62 and 92 days, respectively. Most ‘a‘o breed in steep mountainsides of Kaua‘i in ‘ōhi‘a forest with an uluhe fern-thicket understory. However, between 1978 and 1980, 65 and 25 ‘a‘o eggs were translocated to Kīlauea Point and Moku‘ae‘ae Island, respectively, and cross-fostered by ‘ua‘u kani pairs. Seventy-nine percent of these eggs hatched and ninety-four percent of the chicks fledged (Byrd et al. 1984). The current breeding habitat at Kīlauea Point is characterized by open-canopy hala forest with a naupaka understory, which supports at least 11 breeding or prospecting pairs, some presumably the fledglings of the translocated eggs or their progeny. Between 2002 and 2012, 2–5 chicks probably fledged each year from the Refuge. Three chicks hatched and banded on-Refuge in 1997, 2006, and 2009 have returned as successful breeders or prospectors.

4.4.2 Nēnē (*Branta sandvicensis*) or Hawaiian Goose

The endangered nēnē is a member of the waterfowl family (Anatidae) and closely related to the Canada Goose. Though similar in appearance, the gander is usually slightly larger than the goose. It is light gray-brown with a mostly black head, cream-colored neck with distinctive dark furrows, and black tail and feet. Nēnē are browsing grazers, eating the leaves, seeds, fruits, and flowers of grasses, sedges, forbs, and shrubs (Banko et al. 1999). In the 1950s, the nēnē population declined to about 30 birds on Hawai‘i because of introduced predators, overhunting, and habitat loss. In 2011, there were an estimated 2,457–2,547 nēnē on four islands, including growing numbers on Kaua‘i, which supports 1,421–1,511 birds, or 59 percent of the state population (USFWS unpubl.).

Nearly all birds are the result of an aggressive captive propagation and release program which was initiated by the Territorial government in 1949. This program is credited with bringing nēnē back from the brink of extinction; however, despite a comeback, nēnē still face major obstacles on the road to recovery. Current threats include depredation by introduced predators, inadequate nutrition, lack of suitable lowland habitat, human-related disturbance and mortality, behavioral problems, lack of genetic diversity, and disease (USFWS 2004).

Habitat types frequently used by nēnē at Kīlauea Point NWR include grasslands dominated by introduced species (e.g., saltgrass, Kikuyu grass), open-understory shrublands (e.g., naupaka, haole koa), and sea cliffs. Nēnē build nests on the ground usually under woody and herbaceous plants with an open canopy. Nesting habitats range widely but generally are associated with woody vegetation. Species composition varies by availability; for instance, in highlands native shrubs (e.g., ‘a‘ali‘i, ‘ōhelo, pūkiawe, small ‘ōhi‘a) predominate, but in lowlands on Kaua‘i both native (e.g., naupaka, pōhinahina) and nonnative (e.g., lantana, Christmasberry, koa haole, Guinea grass) plants are used.

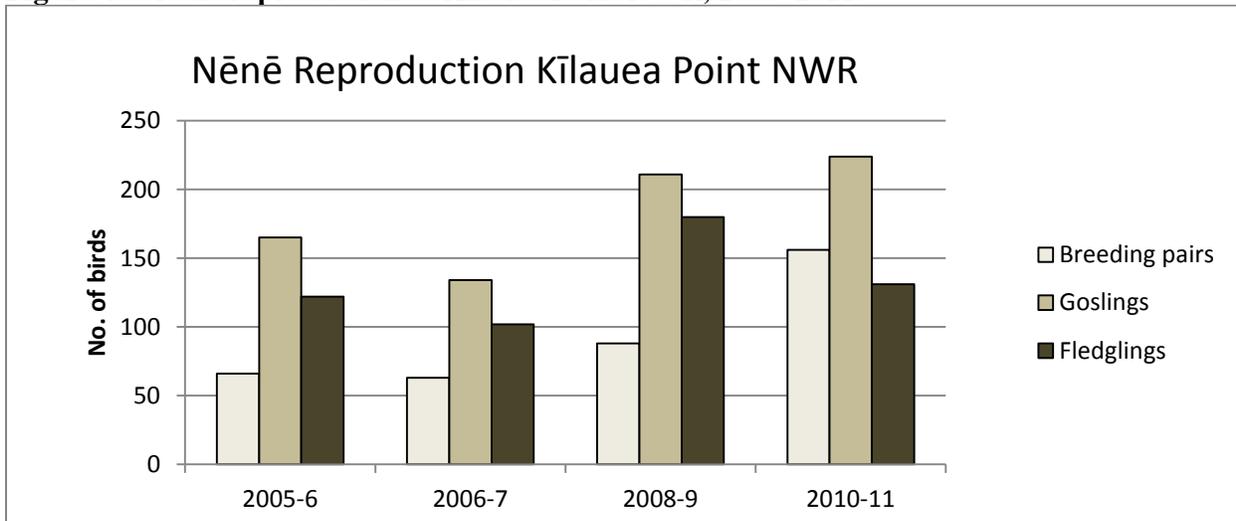
Nēnē mate for life. The average clutch size is 3 eggs (range 1–6), incubation is usually 30 days (range 29–32), and goslings fledge at 10–14 weeks (Banko et al. 1999). Breeding occurs mainly October to March and molting March to June, which is when adults become flightless for 4 to 6 weeks while they grow new flight feathers. During this period, they become secretive, and are extremely vulnerable to attacks by introduced predators. During the rest of the year, from June to September, nēnē disperse or flock with other family groups in nonbreeding areas where young nēnē have opportunities to find mates. Historically, nēnē are believed to have bred and molted in the lowlands during the winter and to have moved to higher elevations in the summer. Today, birds move daily between feeding and roosting areas and seasonally between breeding and nonbreeding areas, but altitudinal patterns are less apparent (USFWS 2004).

Nēnē are browsing grazers, eating the leaves, seeds, fruits, and flowers of grasses, sedges, forbs, and shrubs (Banko et al. 1999), and occasionally climb into or perch in bushes to reach berries (e.g., naupaka, māmaki). In many areas nēnē feed on cultivated grasses. In mid-elevation Hawai‘i, birds select forage with high water and protein content such as the young shoots of a Kikuyu grass–Spanish clover grassland. They prefer sward-forming (turf-like growth) over bunch grasses and short (2–4 inches) over tall grasses and use grasslands less during drought (Woog and Black 2001).

In partnership with the DLNR and USFWS Ecological Service, 38 nēnē were reintroduced to Crater Hill on the Refuge between 1991 and 1994. By 2002, the population was estimated to be 238 birds (USFWS 2004). In 2011, the population estimate for Hanalei, Princeville, and Kīlauea Point was 791–811 birds.

In 2010, the average number of nēnē during the breeding season (Oct–May) and flocking season (Jun–Sep) was 82 and 158, respectively, with a high count of 214 birds in July. During the 2010–2011 breeding season, the Refuge supported a minimum of 156 nēnē breeding pairs, 224 goslings, and 131 fledglings. Of 105 located nests, 85 (81 percent) hatched at least 1 egg. Of 298 eggs of located nests, 215 (72.2 percent) hatched. Of these 215 goslings, 91 (42.3 percent) fledged. However, the fledging rate is biased low because of the difficulty in collecting reliable gosling data on unhabituated, more secretive birds at Crater Hill and Mōkōlea Point.

Figure 4-3. Nēnē reproduction at Kīlauea Point NWR, 2005–2011.



4.4.3 ‘Ōpe‘ape‘a (*Lasiurus cinereus semotus*) or Hawaiian hoary bat

‘Ōpe‘ape‘a is a medium-sized member of the vesper bat family (Vespertilionidae) which consists of nocturnal, mostly insect-eating bats. It is an endemic and endangered subspecies of the North American hoary bat, a solitary tree-rooster. The ‘ōpe‘ape‘a is Hawai‘i’s only native terrestrial mammal. Males and females have a wingspan of about 1 foot, and females are typically larger than males. Both sexes have brown and gray fur. Individual hairs are tipped or frosted with white; “hoary” means frosted. The Hawaiian name refers to a half taro leaf or canoe sail shape; these being similar to the shape of the bat. Fur color, frosted or reddish, may be related to location or age.

The ‘ōpe‘ape‘a is a major predator of night-flying insects such as moths, beetles, and termites. Bats forage in open and wooded landscapes and linear habitats such windbreaks and riparian zones, and roost in trees with dense foliage and with open access for launching into flight. Females are believed to give birth to twins May to August and rear pups May to September. Pups fledge from about July to September, which is a critical time in the reproductive cycle (Menard 2001, Bonaccorso et al. 2008). The population size is unknown. Resident populations occur on Kaua‘i, Maui, and Hawai‘i, and possibly other main islands, with the highest abundance on Kaua‘i and Hawai‘i.

Threats are largely unknown but may include roost disturbance, introduced predators, obstacles to flight (e.g., barbed wire fences, vehicles), and pesticides (USFWS 1998). In fall of 2010, a single ‘ōpe‘ape‘a was sighted flying over Crater Hill at sunset on a calm evening (USFWS unpubl.). Occurrence frequency is unknown; however, forested edges near Kāhili Beach and Kīlauea River mouth likely provide suitable habitat (C. Pinzari pers. comm. USGS, 2010).

4.4.4 ‘Ilio-holo-i-ka-uaua (*Monachus schauinslandi*) or Hawaiian monk seal

The ‘ilio-holo-i-ka-uaua or Hawaiian monk seal is among the most critically endangered mammals in the world. Approximately 1,200 seals remain today with the majority in the Northwestern Hawaiian Islands (NWHI), but there is a small and potentially growing population of seals in the main Hawaiian Islands (MHI) where a 2005 survey documented 76 individuals. Its Hawaiian name means “the dog that runs in the rough seas.” Seals frequently haul out on shorelines to rest and molt and

females may haul out on shore for up to 7 weeks to give birth and nurse their pups. Pups and moms stay ashore until weaned. Gestation is approximately 1 year and pupping occurs in late winter and spring.

‘Ilio-holo-i-ka-uaua can live up to 25 years. They feed on reef fishes, he‘e (octopus), squid, and lobsters down to depths of 1,000 feet. Food seems to be a limiting factor for population growth at this time. ‘Ilio-holo-i-ka-uaua are usually solitary except when on preferred beaches when they may be close together and interact. Populations have been decreasing recently in the NWHI, possibly due to sea levels rising above some islands, competition for food resources, and predation on pups. Terrestrial habitat is used about one-third of the time and requirements include haul-out areas for pupping, nursing, and resting, primarily on sandy beaches, but virtually all substrates are used. Beachside vegetation is used for protection from wind and rain. ‘Ilio-holo-i-ka-uaua are particularly vulnerable to climate change because of their limited global range and breeding distributions which are restricted primarily to the low-lying NWHI (Reynolds et al. 2012).

Conflicts and interactions with a variety of ocean and beach users are becoming more frequent and significant in the MHI. Dogs have attacked ‘ilio-holo-i-ka-uaua and carry diseases that are potentially lethal to the critically endangered seal, such as canine distemper virus. Human disturbance, especially of mothers with pups, may be a threat. Guidelines recommend people remain 50 yards from ‘ilio-holo-i-ka-uaua and other marine mammals. ‘Ilio-holo-i-ka-uaua can be observed during most months of the year at the Refuge, most often in the cove below the Kīlauea Road Overlook.

4.4.5 Pueo (*Asio flammeus sandwichensis*) or Hawaiian Short-eared Owl

The pueo is an endemic subspecies of the short-eared owl. The adult is brown and buffy white and ventrally streaked with darker brown. The eyes are yellow and the bill is black. Unlike most owls, pueo are diurnal, though nocturnal or crepuscular activity has been documented. Pueo are commonly seen hovering or soaring over open areas. It is listed by the State of Hawai‘i as an endangered species on the island of O‘ahu.

The pueo is found on all the MHI from sea level to 8,000 feet elevation. There have been no surveys to estimate the pueo population. The species was widespread at the end of the 19th century but is thought to be declining (Mostello 1996, Mitchell et al. 2005). Pueo occupy a variety of habitats, including wet and dry forests, but are most common in open habitats such as grasslands, shrublands, and montane parklands, including urban areas and those actively managed for conservation (Mitchell et al. 2005). Their relatively recent establishment on Hawai‘i (<1,200 years) may have been tied to the rats that Polynesians brought to the islands. In Hawai‘i, pellet analyses indicate that rodents, birds, and insects are their most common prey. Birds depredated by pueo have included passerines, seabirds, and shorebirds.

Little is known about the breeding biology of the ground-nesting pueo, but nests have been found throughout the year. Nests are constructed by females and are composed of simple scrapes in the ground lined with grasses and feather down. Females also perform all incubating and brooding, while males feed females and defend nests. The young may fledge from nests on foot before they are able to fly, and they depend on their parents for approximately 2 months (Mitchell et al. 2005). Pueo can be sighted roosting on and soaring over Crater Hill and Mōkōlea Point. Little is known about Hawai‘i’s only native owl.

Similar to other native Hawaiian birds, loss and degradation of habitat, predation by mammals, and disease threaten pueo. Pueo appear particularly sensitive to habitat loss and fragmentation, as they require relatively large tracts of grassland and are ground nesters. Ground nesters are more susceptible to the increased predation pressure that is typical within fragmented habitats and near rural developments (Wiggins et al. 2006). These nesting habits make them increasingly vulnerable to predation by rats, cats, and Indian mongooses (Mostello 1996, Mitchell et al. 2005).

Mortality of pueo on Kaua‘i has been attributed to the “sick owl syndrome,” which may be related to pesticide poisoning or food shortages. They may be vulnerable to the ingestion of poisoned rodents. However, in the one study conducted, there was no evidence that organochlorine, organophosphorus, or carbamate pesticides caused mortality in pueo. Other causes of death on Maui, O‘ahu, and Kaua‘i have been attributed to trauma (apparently vehicular collisions), emaciation, and infectious disease (pasteurellosis; Work and Hale 1996). However, their persistence in lowland, nonnative, and rangeland habitats suggests that they may be less vulnerable to extinction than other native birds, especially because they may be resistant to avian malaria and avian pox (Mitchell et al. 2005).

4.4.6 Honu (*Chelonia mydas*) or Green Turtle

Honu, also known as the green turtle, is a large sea turtle of the family Cheloniidae. Honu may be seen in waters adjacent to the Refuge. Mature males are distinguished from females by their longer, thicker tails.

Historically, honu most likely inhabited the waters around the all Hawaiian Islands. Today, they still live and forage around all the Hawaiian Islands. Honu are most often found in shallow, protected, or semi-protected water around coral reefs and coastal areas. These habitats contain critical foraging areas consisting of sea grasses and algae and they provide some shelter from predators such as tiger sharks. However, although nesting occurs on all islands, 90 percent occurs on French Frigate Shoals of the NWHI. Evidence shows that Hawaiian turtles migrate only throughout the 1,500-mile expanse of the Hawaiian Archipelago, and so make up a discrete population. Post-hatchlings and juveniles live in pelagic waters, but little is known of their specific distribution.

Little information exists on the feeding behavior of post-hatchlings and juveniles living in pelagic habitats, but most likely they are exclusively carnivorous (e.g., soft-bodied invertebrates, jellyfish, and fish eggs). Subadult and adult turtles residing in nearshore benthic environments are almost completely herbivorous, feeding primarily on select macroalgae and sea grasses. The common name “green sea turtle” is derived from the color of their body fat, which is green from the limu (algae) they eat. Adult honu can weigh up to 500 pounds and are often found living near coral reefs and rocky shorelines where limu is plentiful. Hawaiian honu display slow growth rates, even compared to other populations, with an average annual growth rate of approximately ½-2 inches per year. Turtles often reach sexual maturity at 35–40 years (Mitchell et al. 2005).

Threats to honu include the tumor disease Fibropapilloma; alien seaweeds that displace important foraging, resting, and cleaning habitats of the turtles; indirect take of adult and juvenile turtles as fisheries bycatch; predation, particularly of hatchlings in the open ocean; impacts from snorkeling and other human recreational activities; marine debris that entangles turtles or is ingested by them; and the loss or degradation of foraging habitats along coastal areas due to development, sedimentation, soil erosion, or sewage; nest predation; and boat collisions. Honu can be observed offshore during most months of the year at the Refuge.

4.5 Breeding Seabirds

4.5.1 Mōlī (*Phoebastria immutabilis*) or Laysan Albatross

The mōlī or Laysan albatross is a large seabird (Family: Diomedidae) whose breeding range is centered in the NWHI. Adults are sexually monomorphic and mostly white with black wings and tail; the upperwings are entirely dark, and the underwings are mostly white with variable amounts of black especially along leading and trailing edges. The bill is pink with a gray, hooked tip; legs and feet are light pink. Mōlī are accomplished fliers using dynamic soaring to cover great distances; they mainly feed at night and often far from their breeding colony (1,100 miles; 1,770 km). In Hawai‘i, their diet consists primarily of squid, deep-water crustaceans, fish, and flying fish eggs (Awkerman et al. 2009).

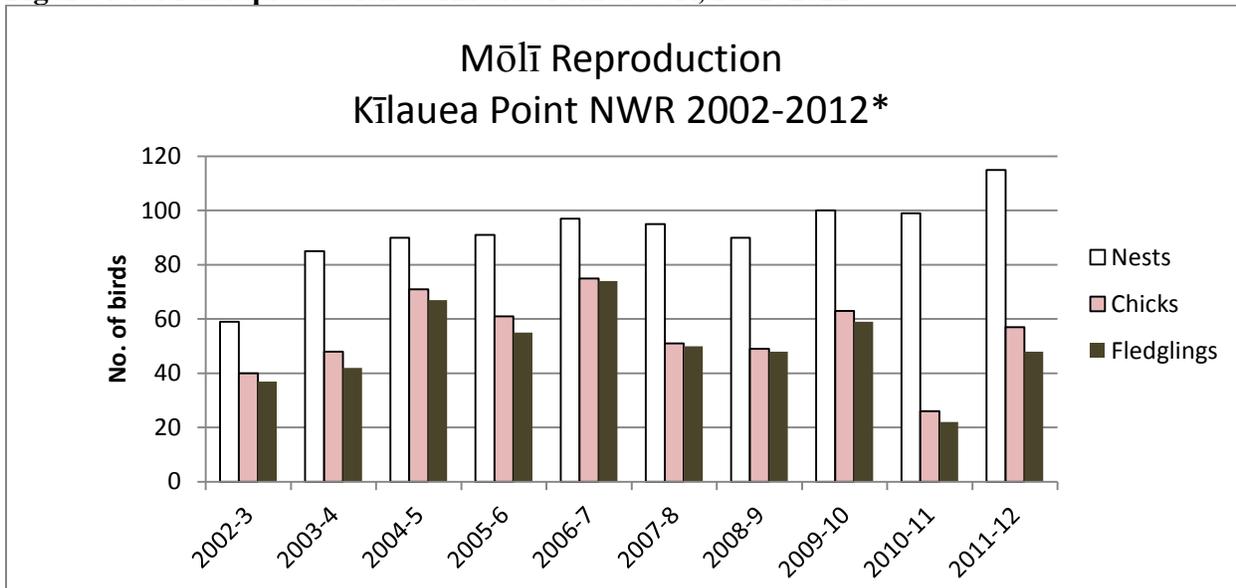
Like most seabirds, mōlī breed in colonies, have long-term pair bonds and high site fidelity, lay only one egg per season, and both parents participate in all aspects of raising young. Pairs engage in long, noisy, ritualized courtship dances. Typically they select nest sites close to vegetation and nests vary from a scrape to a ring-like structure composed of sand, vegetation, and debris. Eggs are laid between November and December and chicks fledge in July; no post-fledgling care is provided by parents. Young birds do not return to land until their third year after fledging. These birds do not breed, but dance, build nests, and prospect for mates. Birds first breed between 8 and 9 years old, and the oldest known individual is currently 63 years old (Awkerman et al. 2009; USFWS unpubl.).

Mōlī breed throughout the NWHI and on the MHI of Kaua‘i and O‘ahu and Lehua Island off Ni‘ihau. Outside of Hawai‘i, mōlī breed on islands off Japan and Mexico. Outside the breeding season, mōlī disperse widely throughout the North Pacific (Young et al. 2009a). In the Hawaiian Archipelago, the population is estimated at more than 590,000 pairs with largest colonies occurring on Midway Atoll (441,000 pairs) and Laysan (145,000 pairs). Total population of all MHI colonies is less than 500 pairs; worldwide population is estimated at 630,000 breeding pairs (Arata et al. 2009).

Historical threats include feather and egg harvesting and military operations on Midway Atoll in the NWHI. Current threats to mōlī include bycatch in fisheries operations, contaminants ingestion, sea level rise in the NWHI, and predation on breeding colonies in the MHI. Mōlī are vulnerable to climate change because of their limited global range and breeding distributions which are predominantly located in the low-lying NWHI (Reynolds et al. 2012).

The first three mōlī chicks fledged from Mōlī Hill on the Refuge in 1986 (KPNHA 1986). Currently, mōlī are found in the densest concentrations on Mōlī Hill (55 breeding pairs in 2011–2012 season), and the rest are distributed on the eastern third of the Refuge towards Mōkōlea Point for a total of 115 pairs in the 2011–2012 season. From 2002–2012 the number of breeding pairs appears to be steadily increasing each year as a result of predator control, natural recruitment, and immigration from other breeding sites; the number of chicks and fledglings appears to be stable or slightly decreasing. Over the past decade, the Refuge has fledged 50 mōlī per year, on average.

Figure 4-4. Mōlī reproduction at Kīlauea Point NWR, 2002–2012.



*Includes supplemental eggs. The Pacific Range Missile Facility’s BASH program, 2005-2012.

4.5.2 ‘Ua‘u kani (*Puffinus pacificus*) or Wedge-tailed Shearwater

The ‘ua‘u kani or wedge-tailed shearwater is a large, abundant seabird (Family: Procellariidae) that produces a variety of wails and moans that inspired this bird’s Hawaiian name, which means “calling or moaning petrel.” Individuals have long sleek wings, a wedge-shaped tail, and a hooked bill. ‘Ua‘u kani are polymorphic, having two color phases, dark or light, and sexes are similar; approximately 90 percent of the birds breeding in Hawai‘i are light-phase. Light-phase adults are grayish brown above with white underparts except for dark trailing edges of wings and tail. Dark-phase adults are uniformly sooty brown. Flight is similar to that of albatross but wings flap with greater frequency (Whittow 1997).

‘Ua‘u kani often forage in large, mixed species flocks associated with schools of large predatory fishes (such as ahi and mahi mahi) which drive smaller prey species to the surface. ‘Ua‘u kani use a variety of foraging techniques: most frequently they plunge their heads into water while on the wing, they seize prey while sitting on the water, and often they follow fishing vessels. In Hawai‘i, their diet primarily consists of larval goatfish, flyingfish, squirrelfish, and flying squid. Like most seabirds, ‘ua‘u kani breed in their natal colonies, form long-term pair bonds, have high site fidelity, lay only one egg per season, and both parents participate in all aspects of raising young. ‘Ua‘u kani nest in excavated burrows or rock crevices or under vegetation.

In Hawai‘i, breeding is synchronous, and most eggs are laid in June with most young fledging in November. Birds first breed at four years, and the oldest known individual was 29 years old (Whittow 1997). At the Refuge, ‘ua‘u kani typically arrive in late February and early March. The first eggs are laid in early June, with peak laying in mid-June, and most egg laying completed by the end of June. Hatching begins in late July with most chicks hatched by mid-August. Fledging begins in early November peaking in mid- to late November. The average incubation period onsite is 53 days, and nestling period is 103–115 days (Byrd et al. 1983).

Ua‘u kani breed on low, flat islands and sand spits with little or no vegetation, but also excavate burrows on the slopes of extinct volcanoes and in old volcanic craters. Burrows require firm soil or plant roots to stabilize loose soil; generally nesting habitat is devoid of tall woody plants. In locations where nest sites are scarce or the ground is too hard to excavate burrows, individuals will nest in rock crevices or above ground. ‘Ua‘u kani breed throughout the NWHI and on offshore islets of most of the MHI. Outside Hawai‘i, ‘ua‘u kani breed on islands throughout the tropical and subtropical Indian and Pacific oceans.

Outside the breeding season, ‘ua‘u kani migrate to the eastern Pacific. In Hawai‘i, population is estimated at 270,000 breeding pairs, with approximately 210,000 of those occurring in the NWHI. The population in the MHI is estimated at between 40,000 and 60,000 breeding pairs with the largest colonies occurring on the offshore islands of Mānana (10,000–20,000 pairs), Moku Loa (10,000–20,000 pairs), Lehua (23,000 pairs), Kīlauea Point NWR (ca. 10,000 pairs), and Ka‘ula (1,500–2,500 pairs). Smaller populations occur on Moku Manu, Moku‘auia, Kāpapa, Molokini, Mōkapu Peninsula, and Ka‘ena Point Natural Area Reserve on O‘ahu. Worldwide population is estimated at over one million breeding pairs (USFWS 2005b).

Threats to ua‘u kani include food reduction through overfishing of the large predatory fishes (ahi) that bring their prey to the surface, depredation by introduced predators in MHI breeding colonies, light attraction, and human disturbance. A pilot study on stress hormone levels and chick sizes in relation to their proximity to the Refuge’s lighthouse trail suggested ‘ua‘u kani chicks near the trail (e.g., <12 feet) may be exposed to higher chronic levels stress from visitation (Kitaysky et al. 2004). In 2010 at the Refuge, more than 75 adult ‘ua‘u kani were found preyed upon by owls (compared with about 5 in 2009), and carcass recoveries subsided after removal of 4 introduced barn owls (USFWS unpubl.). Ongoing losses from depredation could affect local populations because adult survival is an important factor regulating seabird populations.

Ua‘u kani is the most abundant bird species on the Refuge with dense concentrations on Mōlī Hill, near the lighthouse, Crater Hill, and Mōkōlea Point, where habitat is suitable. Byrd et al. (1983) estimated that between 1978 and 1981, 520 fledglings from 700 breeding pairs fledged annually from the accessible 10–45 degree slopes of Kīlauea Point peninsula. In 2004, average hatching success of 10 plots was 73 percent (range 20–100 percent) and nest density was 0.36 nests per square yard (range 0.09–0.86) (Zaun 2004). Although the number of breeders and prospectors is unknown, the Refuge probably supports roughly 8,000–15,000 breeding pairs.

4.5.3 Koa‘e kea (*Phaethon lepturus*) or White-tailed Tropicbird

Koa‘e kea are mostly white birds with a pair of narrow, elongated inner tail feathers. Male and female birds are similar in appearance. The adult is 29 inches long from bill to end of tail, and the tail is about about half that length. Its wingspan is 37 inches, and the bird weighs 11 ounces. The feathers are mostly white, but it has black markings on the upper wings, and a black eye-stripe. It has a long white tail with a black stripe on top and a decurved bill that is usually yellow. Variations in bill color include yellowish-green, orange, and red-orange. It has short legs and its feet are webbed. Since legs of the tropicbird are set far back on its body, it is a good swimmer, but awkward on land (Lee and Walsh-McGehee 1998).

Koa‘e kea usually forage alone, but occasionally with conspecifics, most often far from land and will often follow ships. Koa‘e kea captures prey by plunge-diving from 50–65 feet above the water. Their

diet is poorly known, but includes flyingfish and is likely similar to koa'e ula. Koa'e kea breed in colonies, and pairs remain together for years. At the beginning of the breeding season, pairs engage in complex aerial displays. Nests are placed in hard to reach locations on cliffs, as well as in caves and tree hollows; nests have little if any material. In Hawai'i, breeding occurs March through October and a single egg is laid per season. Both parents incubate the egg, and brood and feed the chick. No post-fledging care is provided. Based on few data, age at first breeding is likely after fourth year; no data on longevity has been collected (Lee and Walsh-McGehee 1998).

In Hawai'i, the population is estimated at 1,800 breeding pairs with most occurring in the MHI. The worldwide population is estimated at less than 200,000 breeding pairs. Threats to koa'e kea are primarily predation on the breeding colonies (USFWS 2005b).

Koa'e kea can be observed at the Refuge year-round, but appear to be less common in the winter. Nesting appears to be year-round, but peaks occur from March to October. In 2005, four nests were monitored on the Refuge, all four were in rock crevices on steep-sided cliff faces, and only one was accessible. Chicks successfully fledged from two nests and the outcome of the other two was unknown (Zaun 2005).

4.5.4 Koa'e 'ula (*Phaethon rubricauda*) or Red-tailed Tropicbird

The koa'e 'ula or red-tailed tropicbird is a showy, white seabird (Family: Phaethontidae) related to boobies and frigatebirds. Adult males and females are mostly white, although they develop a pale pinkish wash when breeding, except for a partial black eye ring and short eye line, black flanks, and black shafts of outer primaries; both sexes have long, narrow, tail feathers with red shafts. Koa'e 'ula have large red bills; legs and feet are very small. Flight is characterized by strong flapping interspersed with gliding, and koa'e 'ula are capable of flying long distances. Koa'e 'ula usually forage alone, but occasionally with other species, most often far from land and will often follow ships. Koa'e 'ula capture prey by plunge-diving. In Hawai'i, their diet is mainly composed of flyingfish, but also includes squid, mackerel scads, dolphinfish, truncated sunfish, and balloonfish (Schreiber and Schreiber 1993).

Koa'e 'ula breed mainly on oceanic islands and coral atolls with shrubs, including naupaka and beach heliotrope (*Tournefortia argentea*). Koa'e 'ula nest on the ground, generally in inconspicuous places such as under vegetation or in cliff crevices. Koa'e 'ula breed in colonies and pairs remain together for years. At the beginning of the breeding season, pairs engage in complex aerial displays. Nests are placed on the ground, and generally are a simple scrape lined with some vegetation. In Hawai'i, breeding can occur throughout the year, but most breeding occurs between February and June. A single egg is laid per season, and both parents incubate the egg, and brood and feed the chick. The incubation period is 39–51 days, and the nestling period is 73–123 days. No post-fledgling care is provided. Age at first breeding is between 2 and 4 years, and the oldest known individual was 23 years old (Schreiber and Schreiber 1993).

Koa'e 'ula breed throughout the NWHI and at a limited number of sites on MHI, mostly on offshore islets. Outside of Hawai'i, koa'e 'ula breed on oceanic islands in the Indian and Pacific oceans. Outside the breeding season, adults are solitary and pelagic, and their range is poorly known. In Hawai'i, population is estimated at between 9,000 and 12,000 breeding pairs, with the largest populations occurring on Midway Atoll and Laysan. The worldwide population is estimated at

17,000 to 21,000 breeding pairs, with the majority residing in the Pacific Ocean. Primary threats include predation on the breeding colonies (USFWS 2005b).

Koa'e 'ula can be observed at the Refuge year-round, but are more common February to September. Nesting generally occurs from March to August, and birds nest in rock crevices and on benches on steep cliff faces and windswept slopes and under woody vegetation such as naupaka. In 2005, 191 nests were monitored on the Refuge; of these, 145 nests were accessible on flats and slopes of Kīlauea Point, Crater Hill, and Mōkōlea Point. The dates for egg-laying spanned approximately March 8 to August 18. The dates for chick fledging ranged approximately July 9 to November 13. Hatching success and fledging success was 77 percent and 81 percent, respectively. Mate fidelity and nest site fidelity for years 2004–2005 was 85 percent and 76 percent, respectively (Zaun 2005).

4.5.5 'Ā (*Sula sula*) or Red-footed Booby

The 'ā or red-footed booby is the smallest booby (Family: Sulidae), and has a pantropical distribution. Individuals have long pointed wings and a relatively long, wedge-shaped tail. Several color phases exist, ranging from all brown to all white; almost all Hawaiian birds are white. Adult male and females are overall white, except for brownish black primary and secondary wing feathers; females are larger than males. Feet and legs are orange to red, bill bluish except for base of lower mandible which is pinkish, and facial skin around bill ranges from pink to red and blue. Flight is characterized by strong flapping interspersed with gliding and they may glide for long distances depending on wind conditions (Schreiber et al. 1996).

'Ā forage alone or in mixed species feeding flocks, generally feeding farther from land than their congeners. 'Ā capture prey by plunge-diving generally from 13 to 26 feet over the water. In Hawai'i, their diet is mainly composed of flying fish and squid, but also includes mackerel, scads, saury, and anchovies (Schreiber et al. 1996).

'Ā breed on small islands or islets, both on low-lying coralline sand islands and high volcanic islands. They tend to nest in bushes or trees, including beach naupaka and beach heliotrope. They will occasionally nest on deserted man-made structures, on bare ground, or on low piles of vegetation. 'Ā build nests of twigs, grass, and other vegetation. 'Ā breed in colonies ranging from 10 to 10,000 pairs, and pairs generally retain mates throughout several breeding seasons. In Hawai'i, breeding season is synchronous, but can occur throughout the year. Egg laying peaks in February through April, and most young fledge by September. Both parents incubate egg, and brood and feed chick. Adults continue to feed young up to 4 months after fledging. Birds first breed at 3 to 4 years of age and the oldest known individual was 22 years old (Schreiber et al. 1996).

'Ā breed throughout the NWHI and at a limited number of sites on MHI, including Kīlauea Point NWR, the cliffs of Ulupa'u Head at the Kāne'ohe Bay Marine Corps Base on O'ahu, and offshore islets including Moku Manu and Lehua. Outside of Hawai'i, 'ā breed on islands in the tropical waters of the Pacific, Indian, and Atlantic oceans, Caribbean Sea, and seas north of Australia. Little is known about the movements of the 'ā outside nesting season, but birds in Hawai'i appear to disperse eastward and move between islands (USFWS 2005b).

Threats include poaching of eggs, chicks, and adults for food, degradation of habitat from human development of coastal zones and introduced sheep, goats, and pigs, and disturbance at nest sites. 'Ā have been described as sensitive to human activities, including eco-tourism (Burger and Gochfeld

1993). This species may tolerate short-term, infrequent human disturbance, but typically does not breed in proximity to humans (Schreiber et al. 1996). Up until the mid-1960s, hundreds of ‘ā nested around Kīlauea Point peninsula (by the lighthouse), and it is suspected that the colony shifted to its current Crater Hill location because of threats from large mammalian predators (G. Smith, pers. comm). Kīlauea Point peninsula has been free of large mammalian predator for about two decades, however, the ‘ā have not returned to nest there.

In Hawai‘i, the population is estimated at between 7,000 and 10,500 breeding pairs. The worldwide population is estimated at less than 300,000 breeding pairs, with the majority residing in the eastern Pacific (USFWS 2005b). ‘Ā occur year-round at the Refuge, but breeding has been documented only between the months of February and October. Currently, breeding occurs only on the windward slopes of Crater Hill where birds build nests in ironwood and Christmasberry trees. Between 2004 and 2008, the Refuge supported an annual average of 1,882 breeding pairs of ‘ā.

Table 4-3. Spring surveys of ‘ā breeding pairs, Kīlauea Point NWR (USFWS files)

Survey date	Crater Hill			Total
	West	Central	East	
5/07/2004	1214	350	250	1814
5/18/2005	1422	209	133	1764
5/24/2006	1866	360	310	2536
5/22/2008	1243	65	107	1415
Average (SD)				1882 (470.6)



‘Ā at the Refuge in 1964 adjacent to the lighthouse. Gary Smith

4.6 Other Seabirds

Other nonbreeding seabirds that use the Refuge for roosting and prospecting include ka‘upu (black-footed albatross, *Phoebastria nigripes*), ‘ā (brown booby, *Sula leucogaster*) and ‘iwa (great frigatebird, *Fregata minor*).

Ka‘upu are closely related to mōlī, and are approximately the same size, but with a dark chocolate brown coloring throughout the body, and small amounts of white around the bill, eye, and around the tail. The species has a federal status as a “bird of conservation concern” and State of Hawai‘i status of threatened, and was recently petitioned but declined for federal listing. The world breeding

population is estimated at 61,700 pairs, with a trend that is stable in the long-term and declining in the short-term (Naughton et al. 2007). More recent analyses identify ka'upu as particularly vulnerable to climate change because of their limited global range and breeding distributions which are restricted primarily to the low-lying NWHI (Reynolds et al. 2012). They primarily visit the Refuge in February where they can be seen flying offshore or landing on Moku'ae'ae.

Similarly, 'ā (brown booby), are also closely related to 'ā (red-footed booby) and are occasionally spotted roosting on the Refuge, and fly by frequently. These 'ā are all brown on top and on their breasts, and have contrasting white coloration underneath and yellow feet. Unlike red-footed boobies though, brown boobies nest on the ground on relatively flat surfaces. This species is very susceptible to human disturbance and will flush from their nests easily.

'Iwa are large, graceful seabirds related to tropicbirds and boobies that are almost entirely black with varying amounts of white underneath on females and juveniles. Males have a large, red gular pouch which they inflate for courtship displays. 'Iwa can be recognized from other seabirds on the Refuge by their large size, deeply forked tail, long bill and tendency to harass and chase both species of 'ā in an attempt to steal their food. They can be found roosting along the sea cliffs of Crater Hill and Mōkōlea Point in addition to being frequent aerial visitors of the Refuge.

4.7 Migratory Waterfowl and Shorebirds

For hundreds of thousands of years, migratory waterfowl, shorebirds, and other waterbirds have wintered on the Hawaiian Islands from September to May. Of the nearly 30 species of migratory ducks and geese using the islands, the most common winter migrants observed on the Refuge include cackling geese, snow geese, and white-fronted geese. Of the approximately 50 species of migratory shorebirds that have been recorded in the Hawaiian Islands (Pyle and Pyle 2009), the most common shorebirds on the Refuge are kōlea (Pacific golden-plovers), 'akekeke (ruddy turnstones), and 'ulili (wandering tattlers), and occasionally hunakai (sanderlings) and kioea (bristle-thighed curlews).

Shorebirds primarily utilize wetlands and tidal flats; however, estuaries and uplands are also important habitats. Golf courses on O'ahu support an estimated 1,900 kōlea during the winter, and this species has even been observed roosting on urban rooftops (Engilis and Naughton 2004). On the Refuge, short-grass habitat and shorelines are used by shorebirds, with kōlea being the most abundant.

The Pacific Islands region functions as an essential migratory habitat for maintaining global shorebird populations. The Service developed the U.S. Pacific Islands Regional Shorebird Conservation Plan over concerns of declining shorebird populations and loss of habitat. Threats to shorebirds in the Pacific Islands include habitat loss, nonnative plants, nonnative animals (e.g., predation, disease, competition), human disturbance, and environmental contaminants. Population estimates and conservation status for shorebirds are provided in Table 4-4. The kōlea is the most common shorebird in the Pacific Islands region, with Hawai'i supporting a substantial portion of the Alaskan breeding population during winter. The kioea is the only migratory species that exclusively winters in the Pacific. Thus, the Pacific Islands region is considered to be a critical area for supporting hemispheric populations of both these species (Engilis and Naughton 2004).

Table 4-4. Shorebirds of primary conservation importance in the Pacific islands region (Engilis and Naughton 2004).

Species	Hawai‘i Winter Population	Regional Trend	Conservation Category
Kōlea	15,000–20,000	Unknown	High Concern
Ae‘o	1,200–1,600	Unknown	Highly Imperiled
Kioea	800	Unknown	High Concern
‘Ulili	1,000	Unknown	Moderate Concern
‘Akekeke	5,000–7,000	Unknown	Low Concern

4.8 Threatened and Endangered Plants

With nearly 300 species of plants listed as threatened or endangered, nearly one-third of Hawai‘i’s remaining native flora is threatened with extinction. Over 100 species of plants now listed as threatened or endangered occur, or historically occurred, on the island of Kaua‘i; 49 species are found only on Kaua‘i. Plants that grow in coastal shrublands and low elevation forests are particularly rare due to the long-term presence of humans and the negative effects of their actions, specifically, development, agriculture, fire, and the introduction of pest species. Only 11 percent of lowland mesic and dry native plant communities remain intact on Kaua‘i, compared to 22 percent for all of the Hawaiian Islands combined (The Nature Conservancy 1998).

Small numbers of the following listed species have been introduced on the Refuge.

4.8.1 Pokulakalaka (*Munroidendron racemosum*)

Munroidendron racemosum, commonly known as pokulakalaka, is a monotypic genus and an extremely rare flowering plant in the Araliaceae or ginseng family. It is endemic to Kaua‘i, and occurs in coastal mesic and mixed mesic forests from 390 to 1,300 feet, typically on exposed cliffs and ridges. It is primarily found in three locations on Kaua‘i: Nounou Mountain, Napali cliffs, and Ha‘upu Ridge near Nawilili Bay. Pokulakalaka is a 25-foot tall tree with a straight trunk and spreading branches. It has smooth, gray bark. The 12-inch long leaves are made up of many oval leaflets, each of which is over 3 inches long. These trees drop most of their leaves during their summer blooming season. The small, pale yellow flowers hang in long, loose bunches (Wagner et al. 1999). Flowering season for pokulakalaka is variable, having been observed in both spring and fall, and fruits mature in about 75 days. Self-pollination is assumed to occur since isolated individuals have produced viable seeds. Pollinators have not been observed, but insect pollination is likely. Dispersal mechanisms are unknown (USFWS 1995).

Threats to pokulakalaka include competition with pest plant species, such as kukui, guava, lantana, and koa haole. Other threats include habitat degradation by feral goats, fire, and fruit depredation by rats. Because each naturally occurring population of this species contains only a small number of individuals, the species is also under threat of extinction from catastrophic events, such as landslides or hurricanes.

4.8.2 Alula (*Brighamia insignis*)

Brighamia insignis, commonly known as ‘ōlulu or alula in Hawaiian, or colloquially as cabbage on a stick, is a critically endangered species of Hawaiian lobelioid in the bellflower family, Campanulaceae. It is native to the islands of Kaua‘i and Ni‘ihau and is found on sea cliffs on the Napali Coast and Ha‘upu Ridge. This short-lived perennial species is a member of a unique endemic Hawaiian genus with only one other species. In 1994, the Service reported 5 populations totaling 45 to 65 individuals, and listed the plant as an endangered species.

Alula is a potentially branched plant with a succulent stem that is bulbous at the bottom and tapers toward the top, ending in a compact rosette of fleshy leaves. The stem is usually 3.3–6.6 feet in height, but can reach 16 feet. The plant blooms from September through November. It has clusters of fragrant yellow flowers in groups of three to eight in the leaf axils and the fruit is a capsule 0.51 to 0.75 inches long containing numerous seeds.

Alula is found at elevations from sea level to 1,570 feet in mesic shrublands and dry forests that receive less than 67 inches of annual rainfall. It grows on rocky ledges with little soil and steep sea cliffs. Its only pollinator was a now-extinct sphingid moth. This has made it all but impossible for alula to reproduce on its own. Therefore, individuals only produce seed when artificially pollinated by humans who go to great lengths (e.g., rappelling over steep cliff edges) to exchange pollen among plants and to collect seeds that can be grown and stored in botanical gardens and seed banks. Despite its rarity in the wild, it is not hard to cultivate in a nursery, and it has come into use as a novel ornamental plant.

4.8.3 Dwarf Naupaka (*Scaevola coriacea*)

Scaevola coriacea, the dwarf naupaka, is a species of flowering plant in the Goodenia family, Goodeniaceae, that is endemic to Hawai‘i. It is a low, flat-lying perennial herb. Its older stems are somewhat woody, and the succulent leaves are oval-shaped, relatively far apart, and smooth or somewhat scaly with rounded tips. Flowers occur in branched inflorescences from the point of leaf attachment in groups of one to three.

Dwarf naupaka usually occurs in relatively hot dry coastal sites on low, consolidated sand dunes near sea level (Wagner et al. 1999). This species is salt-tolerant, relatively long-lived, and flowers year-round. Currently, dwarf naupaka exists naturally only on Maui and two offshore islets. Historically, it could be found on six islands and has since been outplanted on several other main islands. The total population is less than 300 plants, making dwarf naupaka an endangered species. Threats to dwarf naupaka include human development, livestock grazing, and pest plants.

4.8.4 Lo‘ulu (*Pritchardia aylmer-robinsonii*)

Pritchardia aylmer-robinsonii is a fan-leaved tree about 23–50 feet tall with a trunk approximately 8–12 inches in diameter. The upper and lower leaf surfaces are green and hairless, and leaf segments are rather thin and drooping. The lower surfaces of the petiole and the leaf ribs are covered with dense, tan wool. The branched, hairless flower clusters are located among the leaves and are no longer than the petioles. Each flower is composed of a cup-shaped, three-lobed calyx, three petals, six stamens, and a three-lobed stigma. The spherical, hard, black fruit is 0.7–0.8 inches in diameter. This species is distinguished from others of the genus by the thin leaf texture and drooping leaf

segments, the tan woolly hairs on the underside of the petiole and the leaf blade base, the stout hairless flower clusters that do not extend beyond the fan-shaped leaves, and the smaller spherical fruit (Read and Hodel 1990).

Historically, this species of lo‘ulu was found at three sites in the eastern and central portions of the island of Ni‘ihau. Trees were found on Kaali Cliff and in Mokouia and Haaō Valleys at elevations between 230 and 890 feet. The most recent observations indicate two plants still remain on Kaali Cliff. Originally a component of the Coastal Dry Forest, this species now occurs only in a rugged and steep area where it receives some protection from grazing animals (Read and Hodel 1990).

Hawaiian land practices prior to European contact probably destroyed most of the forest on Ni‘ihau. Grazing animals were introduced to the island beginning in the 1700s. Cattle, goats, sheep, and pigs have decreased available habitat for lo‘ulu as well as directly damaging trees, seedlings, and seeds (Wagner et al. 1999).

Although approximately 200 immature individuals have been cultivated on Ni‘ihau and Kaua‘i, extinction from naturally occurring events or reduced reproductive vigor due to the small number of reproductive plants are major threats. Because palms take many years to mature, it is not known whether the immature plants now in cultivation are capable of reproducing and sustaining a viable population. Roof rats are a threat to this species since they eat the seeds of some lo‘ulu species (Wagner et al. 1999).

4.8.5 Lo‘ulu (*P. napaliensis*)

Pritchardia napaliensis, or lo‘ulu (the common name for all plants in this genus) is a species of palm tree that is endemic to the island of Kaua‘i. It inhabits gulch slopes in coastal mesic forests on the Nā Pali coastline, especially in the vicinity of Ho‘oluu Valley. *P. napaliensis* reaches a height of 13–20 feet and has a trunk diameter of 7.1–7.9 inches. As with *P. aylmer-robinsonii*, feral ungulate browsing, seed depredation by rats, erosion, and habitat destruction are all threats.

4.9 Native Plant Communities

Native Hawaiian plants arrived to the archipelago via natural means such as wind, water, or birds. According to Wagner et al. (1999), the native Hawaiian flora is composed of roughly 956 species within 87 families. Approximately 89 percent of these species are endemic (found only in Hawai‘i), while the remainder are indigenous (naturally found in Hawai‘i and elsewhere). Since their establishment, native Hawaiian plant communities have greatly declined since humans arrived in the islands. Few native plants have escaped the impacts of urbanization and agriculture on the coastal and lowland habitats. As a result, recent surveys conclude that 75 percent of the native plant communities in these habitats are considered to be rare. Coastal alterations, such as agriculture, residential developments, recreational parks, military installations, golf courses, and roads have permanently displaced much of the native flora.

Over 30 native coastal and lowland plant species are appropriate for re-establishment at the Refuge, in addition to those already existing. Of these species, approximately one-third could be established as dominant members of the communities, while the remaining two-thirds would be integrated as sub-dominants and associated species. Populations of eight species of endangered plants could be established within these restored habitats, thereby contributing to their statewide recovery. Beginning

in 1980, approximately 13 acres on the Point and portions of Crater Hill’s west slope were restored with hala, ‘akoko, ‘ilima, naupaka kahakai, ‘āweoweo, and pōhinahina, which are now the dominant native plant communities on the Refuge.

4.9.1 Naupaka Kahakai (*Scaevola sericea*) or Beach Naupaka

Naupaka is an indigenous shrub that grows from 3–10 feet tall along coasts throughout the tropical Pacific and Indian oceans. It has bright green succulent leaves and fragrant white flowers that appear to have split in half with five petals remaining on one side. As a dominant member of the coastal mixed woodland-grassland habitat, naupaka provides cover and nesting substrate for native birds, most notably as nesting sites for two listed species, nēnē and ‘a‘o. It is abundant and naturally occurring on the Refuge. It has also been outplanted on the Refuge. This species is the only nonendemic naupaka, and the only one to produce white fruit in the Hawaiian Islands. The pulpy marble-sized fruits tolerate salt water and float on the ocean currents for dispersal to other islands and are a food source for nēnē. Mixed with salt, the fruit or root bark of naupaka kahakai was used for cuts, skin diseases, and wounds.

4.9.2 ‘Ilima (*Sida fallax*) or Yellow Ilima

A common native species found in Hawaiian coastal areas, ‘ilima have yellow-orange flowers with five petals. The ground-hugging plant has heart-shaped, one-inch-long silvery-green leaves. Individual plants of this species vary greatly in height, density of hairs, leaf size and shape, and flower color and size. The Refuge anticipates expansion of the species into additional areas of the Refuge as projects to remove pest plants for habitat restoration are implemented.

The yellow ‘ilima is the official flower of the island of O‘ahu; about 1,000 blooms are used to create a single lei. Hawaiians also used the plant for medicinal properties. Pregnant women consumed its juice and flowers prior to giving birth. The root bark mixed with the plant’s blooms was used as an asthma remedy (Walther 2004).

4.9.3 Hala (*Pandanus tectorius*) or Screw-pine

Hala is a small tree growing 20–30 feet in height and from 15–35 feet in diameter. The trunk is stout and the branches grow at wide angles to it. It has distinctive long, blade-like leaves (lau hala) about 2 inches wide and over 2 feet long. Most varieties have spines along the edges and on the midribs of the leaves. The leaves are spirally arranged toward the ends of the branches and leave a spiral pattern on the trunk when they fall. These trees develop aerial prop roots (ule hala) at the base of the trunk and sometimes along the branches. It occurs in coastal sites and on the low elevation slopes of mesic valleys further inland to 2,000 feet elevation. Hala has been identified as a potential roosting site for ‘ōpe‘ape‘a. On the Refuge, hala leaf litter and debris immediately under mature trees serve as nesting sites for ‘a‘o.

Female hala produce a large, segmented fruit somewhat resembling a pineapple. Male trees produce large clusters of tiny, fragrant flowers surrounded by white to cream-colored bracts. There are four types of hala based on color of fruit: common hala is yellow, hala ‘ula is orange, hala lihilihi ‘ula is red fading to yellow, and hala pia is small and pale yellow. Men from Kahuku were identified by lei of the orange hala fruit which they wore by order of their chief when they left their ahupua‘a (Wilcox 1975, Hensley et al. 1997, Wagner et al. 1999).

4.9.4 ‘Akoko (*Chamaesyce celastroides*)

Chamaesyce celastroides is by far the most variable and widespread of all Hawaiian ‘akoko and is separated into eight varieties (Wagner et al. 1999), two of which occur on the Refuge. It grows as a shrub or small tree that has compact lateral branches and grows in coastal dry shrublands on windward talus slopes at an elevation of 30 to 2,100 feet. Its flowers can be found tucked close or in the leaf axis. It has been observed flowering and fruiting throughout the year, probably in response to precipitation. Fruits mature in 3 to 4 weeks and plants live from 5 to 10 years.

The varieties found on the Refuge exist on windswept cliffs and ledges above the ocean on Ni‘ihau, Ka‘ula Islet, Kaua‘i (Kīlauea Point), Moloka‘i, and Kaho‘olawe. Threats to this plant include competition with alien plants, fire, and negative effects of recreational activities. ‘Akoko is common throughout the Refuge and can be found in all habitat types.

4.9.5 Pōhinahina (*Vitex rotundifolia*)

Pōhinahina is a sprawling shrub that is 8 feet in diameter and 6 inches to 2 feet tall, but reaching 4 feet in height and 12 feet in width when protected from wind and salt spray. The round leaves are gray-green to silvery and 1–2 inches long and have a sage-like aroma when crushed. The 1-inch flowers are bluish purple and are produced in small clusters at the ends of the branches throughout the year. The round fruits are about 1/4 inch in diameter and bluish purple to black when ripe. Pōhinahina is a widespread strand plant; its natural range spans from China, Taiwan, and Japan south to Malaysia, India, Sri Lanka, Mauritius, Australia, Pacific Islands, and Hawai‘i. In Hawai‘i, pōhinahina grows along the coast on sandy beaches, dunes, and rocky shorelines. It occurs naturally up to elevations of 50 feet on all the main islands except Kaho‘olawe, but it can grow at higher elevations. It is drought and salt spray tolerant and spreads by runners, and as a result, it is a popular ornamental plant in Hawai‘i.

4.10 Invasive Species

For the purpose of this CCP, “invasive” is a subset of nonnative species. An invasive species is defined as a species whose migration and growth within a new range is causing detrimental effects on the native biota in that range. Mammals, amphibians, invertebrates, and plants can all be considered invasive. These species become invasive because their population and growth are no longer balanced by natural predators or biological processes that kept them in balance in their native ecosystems. In the absence of these restraints, invasive species have the potential to compete with native species for limited resources, alter or destroy habitats, shift ecological relationships, and transmit diseases.

Invasive species are one of the most serious problems in conserving and managing natural resources. In particular, the ecological integrity of Pacific Island environments is greatly threatened by invasive species. Hawai‘i, which existed in isolation for millions of years, is an exceptionally ideal environment for invasive species. Most native species lost their natural defense mechanisms and are more vulnerable to introduced species (Meffe and Carroll 1997, National Invasive Species Council 2008).

4.10.1 Mammals

Rat (*Rattus* spp.)

Three nonnative rat species are found throughout the Hawaiian Islands. Polynesian rats arrived from the central Pacific approximately 1,500 years ago with the Polynesians who settled Hawai‘i; Norway rats reached the Hawaiian Islands after the arrival of Captain Cook in the 1770s; and black or roof rats most likely arrived in the 1870s. It is estimated that these three species have populated nearly 82 percent of the major islands and island chains throughout the globe. Black and Polynesian rats have a large distribution and can be found from sea level to 10,000 feet. Norway rats are restricted to areas below 6,000 feet. Polynesian rats and Norway rats nest exclusively in terrestrial habitats, while black rats are arboreal nesters. This nesting difference may contribute to a larger population of black rats in Hawai‘i due to the presence of nonarboreal mongoose predators (Tomich 1986, Tobin and Sugihara 1992, Hays and Conant 2007).

Globally, introduced *Rattus* species have caused the decline, extirpation, or extinction of numerous insular bird species. In the main Hawaiian Islands, Atkinson (1977) suggested that black rats caused the accelerated decline or extinction of many native forest birds between 1870 and 1930. Polynesian rats are speculated to have been a contributing factor in the large-scale extinctions of Hawaiian bird species during Polynesian settlement prior to European contact. Rats continue to be a major threat to waterbirds, seabirds, and forest birds in the Hawaiian Islands. All three species of introduced rats in Hawai‘i are known predators of eggs, nestlings, young, and occasionally adults of endangered waterbirds, seabirds, migratory shorebirds, and forest birds. Ground- and burrow-nesting seabirds are particularly vulnerable to rat predation, even by the arboreal black rat. Rats also consume plants, insects, mollusks, herpetofauna, and other invertebrates. Because these species are also eaten by birds, a reduction in these populations may indirectly affect avian populations (Olson and James 1982, USFWS 2004, 2005a, 2005b, Mitchell et al. 2005).

The use of snap traps and ground-based application of diphacinone rodenticide to control rats in the main Hawaiian Islands has shown a positive effect in native bird survival (VanderWerf 2008). Using these two treatments, rodent abundance dropped 58–90 percent within one month of treatments for 3 years in a row at Hakalau Forest NWR on the island of Hawai‘i. The estimated cost for a 247-acre (1 km²) grid was \$7,000 in year one and \$2,000 per year in years two and three (Nelson et al. 2002). At the Refuge, rats are controlled year-round through the use of live-trapping and rodenticides approved for conservation of endangered species (e.g., 0.005 percent diphacinone) in tamper-proof bait stations concentrated in key management areas, such as high density nesting habitat for endangered birds. There are 40–80 bait stations on the Refuge, bait stations are replenished every 2 weeks, and the amount of bait used is recorded and reported. Applicators of rodenticides operate under the State Department of Agriculture’s Pesticide Applicator Certification Program.

Cat (*Felis catus*)

Cats in the United States kill more than one million birds per day on average (Dauphine and Cooper 2011) and are recognized by the Union for Conservation of Nature as one of the “world’s worst” invasive species (Lowe et al. 2000). Cats have a universally damaging effect on island forest birds, breeding seabirds, resident waterbirds, and migratory shorebirds and waterfowl (Smucker et al. 2000, USFWS 2004, 2005a, 2005b, Mitchell et al. 2005). Cats are found on all the main Hawaiian Islands from sea level to 10,000 feet. Food habits of feral cats in Hawai‘i include insects, centipedes, marine

crustaceans, lizards, mice, rats, bird eggs, birds (young and adults), ‘ōpe‘ape‘a, grasses, and seeds. Cats have a universally damaging effect on insular forest birds and nesting seabirds. In Hawai‘i, cats can prey on waterbirds, migratory shorebirds, nesting seabirds, and forest birds (Smucker et al. 2000, USFWS 2004, USFWS 2005a, Mitchell et al. 2005).

On remote lands of Mauna Kea on the island of Hawai‘i, feral cats prey on about 11 percent of endangered palila nests (finch-billed Hawaiian honeycreeper) annually, and radio-collared male cats can range up to 8 square miles. Cats are most active at night when birds are roosting or incubating eggs and more vulnerable to predation (Hess 2011). In addition, cats are reservoirs of diseases that can be transmitted to birds and other mammals, including humans. Felids including feral and domestic cats are the definitive hosts for an infectious parasite called *Toxoplasmosis gondii*, which reproduces in cat intestines and is shed in cat feces. *T. gondii* has been linked to deaths of ‘ā (red-footed booby), endangered nēnē, critically endangered ‘alalā (Hawaiian crow) (Work et al. 2000, 2002), and critically endangered ‘īlio-holo-i-kauaua on the coast of Kaua‘i (Honnold et al. 2005).

There are many “managed” feral cat colonies on O‘ahu with 19,786 feral cats sterilized and released between 1993 and 2002. Cat colonies near seabird colonies have been very detrimental to nesting birds with the loss of adult and chicks of ua‘u kani on Maui and O‘ahu (Smith et al. 2002, Young et al. 2009b). There is ongoing evidence of cats threatening and/or killing mōlī, ‘ua‘u kani, threatened ‘a‘o, and endangered nēnē. In 2009, a cat was captured on video attacking a nēnē nest (USFWS unpubl.). There is an ongoing influx of feral cats, particularly from Kāhili Beach southeast of the Refuge. Due to the threats adjacent to the Refuge and the presence of free-roaming cats across Kaua‘i, cat control is conducted year-round.

Cats captured with collars and domesticated behavior are transported to the Kaua‘i Humane Society. Feral cats are controlled using live-trapping and euthanasia or shooting. Trap cycles last from 2–7 days with 15–25 traps active on a bi-monthly basis. In addition, cats are trapped opportunistically when there are fresh carcasses of endangered or migratory birds showing evidence of cat depredation or there are other detections of cats in the area. Shooting follows protocols for humane dispatch (AVMA 2007) and is only performed by highly skilled personnel trained and federally certified in the safe use of firearms. Trapping success varies widely depending on many factors (e.g., cat’s condition, food availability, methods, techniques). From November 2006 to July 2007, 16 cats (2,419 trap nights) were removed from KNWRC. From December 2007 to April 2008, 11 cats (79 trap nights) were removed from Kīlauea Point NWR. From 2007 to 2010, 129 feral cats were removed from KNWRC, with a high of 81 feral cats removed in 2008 (USFWS unpubl.).

Dog (*Canis lupus familiaris*)

The dog is a domesticated form of the gray wolf, a member of the Canidae family of the order Carnivora. Abandoned, escaped, or pet dogs allowed to run loose can cause great harm to native species and ecosystems. Dogs have caused terrible damage to native ground-nesting seabird colonies. In 2008, almost 90 ‘ua‘u kani birds were killed by a pack of dogs at the Kahuku Golf Course and in 2006, dogs killed nearly 180 ‘ua‘u kani chicks at Ka‘ena Point, both sites on O‘ahu. Dogs typically attack a large number of birds in a single incident by grabbing and shaking the birds around with their mouths and leaving them for dead before heading to another nest or burrow. Dog entry through the perimeter hogwire fence surrounding portions of the Refuge may occur through holes from vandalism or degradation, allowing sporadic and random dog presence within the Refuge. In 2010, dogs entering the Refuge at the unfenced end of Mōkōlea Point killed at least nine adult ‘ua‘u kani

on the Refuge. In 2014, 26 mōlī were killed by dogs on unfenced private lands on Kauai's North Shore.

Small Indian mongoose (*Herpestes javanicus*)

The Indian mongoose was intentionally introduced to numerous island ecosystems during the 1800s and 1900s and has since expanded to large portions of Asia, Africa, Europe, Oceania, and the Americas. In 1883, the species was introduced to the main Hawaiian Islands as a biocontrol agent against rats in sugarcane fields. The mongoose inhabits all habitat types from sea level to nearly 10,000 feet on the islands of Hawai'i, Maui, O'ahu, and Moloka'i. In other areas of the world, mongooses appear to avoid wet areas; however, in Hawai'i, dense populations of mongooses are concentrated in wet habitats. The mean home range of a female in Hawai'i is approximately 3.5 acres, and the main reproductive period occurs February through August. The high density of mongooses in the Hawaiian Islands is due to abundant food and the lack of natural predators (Tomich 1986, Hays and Conant 2007).

Mongooses are voracious omnivores, consuming insects, reptiles, mammals, amphibians, crabs, plants, and birds. In Hawai'i, mongooses are diurnal predators that primarily eat invertebrates and small mammals, as well as plants, birds, reptiles, and amphibians. They are a major threat to any ground-dwelling and -nesting species in Hawai'i. These mammals are known to eat eggs, young, and adults of endangered Hawaiian birds, various seabirds, and migratory shorebirds. In addition, mongooses are known to consume young sea turtles (Mitchell et al. 2005, Hays and Conant 2007).

Until recent years, Kaua'i was thought to be mongoose-free. On May 23 and June 29, 2012, two live mongooses were captured in Līhue and Nāwiwili Port, confirming presence of mongooses on Kaua'i. Previously, the only hard evidence of mongooses on the island was a Kalaheo roadkill in 1976 of a lactating female. Other evidence included 160 credible sightings including more than 70 within the last 10 years with sightings concentrated near Nāwiwili Port and Port Allen. Credible mongoose sightings occurred in 2012–2013 all over Kaua'i, from Polihale to Lihu'e to Kīlauea, indicating that mongoose could eventually be detected within the Refuge.

Mongooses have been detrimental to native ground-nesting birds on other Hawaiian Islands, and the effects are expected to be even more detrimental on Kaua'i, as the island is the last stronghold for several endangered species. The Refuge will continue to work in partnership with the Kaua'i Invasive Species Committee and DLNR to gain information on the status and control and, if possible, eradicate or contain mongooses.

Feral pig (*Sus scrofa*)

Feral pigs that occur in Hawai'i are likely to be hybrids descended from two ancestral types introduced on separate occasions. Polynesians first brought pigs to the islands as a food source around 1,500 years ago. Captain Cook subsequently brought European pigs to the islands in 1778 (Tomich 1986). Pigs descended from European strains were generally larger, more fecund, and more nomadic than their Polynesian counterparts (Van Driesche and Van Driesche 2000). Although pigs have been eradicated from numerous islands worldwide, these animals remain highly abundant in Hawaiian island ecosystems (Courchamp et al. 2003, Cruz et al. 2005) and occupy every main island in the Hawaiian archipelago (Tomich 1986). Pigs are long and narrow in shape and predominately black in color and are generally hairy. They measure 3.5–4.5 feet in length and average 2 feet in

height. Pigs are elusive animals. They have been reported to be highly active in the early morning and late afternoon in tropical climates (Diong 1982). The reproductive potential of pigs contributes to their invasive potential. These animals are polyestrous meaning that adult females have more than one estrus cycle (21 days) in a breeding season. Pregnancy can occur year-round with peaks between January and March. The average sow in Hawai‘i has 1.1 litters per year (Caley 1997). Reproductive rates peak between 2 and 4 years, but breeding has occurred by 10-month-old sows (Hess et al. 2006).

Pigs are an omnivorous species that consume fruits, seeds, plant material, invertebrates, and opportunistically, the eggs and young of ground-nesting birds. In Hawai‘i, pigs consume and damage plant material in both wet and dry habitats and in agricultural and natural areas. They root and trample native vegetation, digging up the soil for earthworms, as well as underground plant parts such as rhizomes and tubers. Pigs act as vectors for invasive plant species, dispersing alien plants such as strawberry guava and banana poka (LaRosa 1992, Stone et al. 1992). Other ecosystem effects can be attributed to pig activity. Rooting and compaction can deplete the soil of needed oxygen (Van Driesche and Van Driesche 2000). The behavior of pigs causes erosion of cliff and stream banks. As a result, the quality of both fresh and brackish water system can be degraded. Since the Refuge is fenced, it is usually free of pigs. However, breaches in the aging perimeter fences may result in the need for periodic pig trapping.

4.10.2 Birds

Cattle egret (*Bubulcus ibis*)

Cattle egrets were introduced to Hawai‘i from Florida in 1959. The release was sponsored by local ranchers and the Hawai‘i State Board of Agriculture to control pasture insects. Nearly 150 birds were released on all the main islands except Kaho‘olawe. After one year, successful breeding was recorded on O‘ahu, where egrets were quick to establish. On Kaua‘i, egret numbers remained low until 1975, when the population exploded. By 1982, Kaua‘i had 3 active roost sites totaling approximately 8,000 birds, including a rookery of 4,000 birds at Crater Hill in Kīlauea. By the mid-1980s cattle egrets were well-established on five of the main islands.

Cattle egrets are highly adaptable, and generally found foraging in grasslands and shallow wetlands, but will also feed in roadside ditches and landfills. Roosts in the Hawaiian Islands are usually on level lowland areas near water bodies, often in trees less than 30 feet high. It is the only species in the family Ardeidae (Herons) that can breed at 1 year. Reproduction in the Hawaiian Islands occurs year-round. Clutch size averages three eggs (range 2–6); (Paton et al. 1986), chicks, known as “branchers,” begin wandering on branches at 14–21 days and fledge at 25–30 days. Some birds in Hawai‘i may breed twice per year (Telfair 2006).

Cattle egrets are opportunistic feeders. In addition to pest insects, they consume a variety of native and nonnative invertebrates and small vertebrates such as fishes, skinks, frogs, beneficial insects, and seabird and endangered Hawaiian waterbird chicks (USFWS 2005a). Cattle egrets are the subject of localized control at airports to avert bird strikes and at wildlife sanctuaries to protect endangered species (Paton et al. 1986). From 2007 to 2010, 291 cattle egrets were removed from KNWRC, an average of about 100 individuals per year (USFWS unpubl.). Techniques for cattle egret removal including shooting and hazing and are regulated under the Migratory Bird Treaty Act and Migratory Bird Depredation permits.

Barn Owls (*Tyto alba*)

The barn owl native to North America is found throughout the main Hawaiian Islands, including offshore islets such as Lehua near Kaua‘i, where they were introduced in 1958 for rodent control. They have light grey underparts with numerous fine dark lines and scattered pale spots on the feathers. There are buff markings on wings and back. Feathering on the lower legs may be sparse. The heart-shaped facial disc is white with a brownish edge, with brown marks at the front of the eyes, which have a black iris. Its beak is off-white and the feet are yellowish-white to brownish. Males and females are similar in size and color; females and juveniles are generally more densely spotted. Barn owls can be distinguished from pueo by their primarily nocturnal habits, rounder faces, and lighter coloring.

In their native environment, barn owls specialize in hunting small ground mammals, and the vast majority of their food consists of small rodents. However, in the Hawaiian Islands they are known to be serious predators of seabirds, including the endangered ‘a‘o, in addition to other seabird species, such as ‘ua‘u kani. On the Refuge, barn owls have been documented killing ‘a‘o, ‘ua‘u, and large numbers of ‘ua‘u kani. Because barn owls will breed at any time during the year, and depending on food supply, they can reproduce up to 2 times per year, they are able to increase rapidly in a relatively short period of time. Barn owls likely compete with the native pueo for introduced rats and mice and could potentially be limiting their population. Techniques for barn owl removal including trapping and shooting and are regulated under the Migratory Bird Treaty Act and Migratory Bird Depredation permits.

4.10.3 Amphibians

Nonnative amphibians also have a negative effect on native Hawaiian species. Recent radio transmitter studies at James Campbell NWR on O‘ahu (Eizenga USFWS unpubl.) provide conclusive evidence that introduced bullfrogs (*Rana catesbeiana*) are key predators of Hawaiian waterbird chicks. While evidence of native bird depredation by cane toads has not been documented, it is possible given the species behavior that they do on occasion eat native ground-nesting birds or their chicks.

Cane toad (*Bufo marinus*)

Cane toads, or Pacific giant toads, which are native to Latin America, have a broad geographic range that includes a majority of the Pacific region. The toads were brought to the Hawaiian Islands in 1932 to control insect pests. The adults require only water for breeding, which results in thousands of eggs per mating occurrence. Cane toads are active at night and primarily feed on cockroaches, crickets, grasshoppers, grubs, earthworms, slugs, spiders, centipedes, and snails. In addition, these highly invasive amphibians could be a potential predator of eggs and young of ground-nesting birds (Yamamoto and Tagawa 2000, Kishinami 2001).

Coqui (*Eleutherodactylus coqui*)

Coqui frogs, which are native to Puerto Rico, were accidentally introduced to the Hawaiian Islands in the late 1980s through eggs or frogs in nursery plants. They are small, nocturnally active, brown frogs approximately 1 inch in length. Their habitat includes moist leaf bases of foliage and leaf litter from the coastal zone to 4,000 feet elevation or higher. Coqui are a human health and quality of life

nuisance because of the male's loud, high-pitched, two-note call "co-kee," heard primarily at night. They eat large number of small insects, in native and nonnative habitats, posing a threat to native insects and insectivores (Kishinami 2001). Coqui have occurred on five of the main Hawaiian Islands including the Island of Kaua'i. In 2001, a breeding population was discovered in Lawai, but after extensive eradication efforts by the Kaua'i Invasive Species Committee (KISC) and partners, Kaua'i was declared "coqui-free" in June 2012. Coqui are not known to occur on the Refuge. However, in May 2014 KISC responded to a report of coqui on the northshore of Kaua'i (KISC 2014).

4.10.4 Invertebrates

Although the Hawaiian Islands support a large number of native invertebrates, a wide array of nonnative invertebrates has invaded Hawaiian ecosystems. While numerous species exist on the Refuge, the only group documented to be a threat to native wildlife is ants.

Ants

Hawai'i is one of the few places on Earth believed to lack any native ant species. Today, at least 47 ant species in 7 subfamilies and 24 genera have become established. Ants are a growing concern since they can have negative effects on native and endangered plants and animals. Ants are also implicated in having negative effects on native and endangered plants by farming scales and other insect pests. Ants are known to attack, injure, or kill young birds. The Service is currently studying the efficacy of various baits and approved toxins on pest ants on O'ahu and Johnston Atoll.

On offshore islets on O'ahu and on Kure Atoll, several species of ants have been documented to harass and potentially kill nesting seabird chicks, primarily 'ua'u kani chicks, by attacking their mucus membranes, removing their down, eating the webbing off their feet, and irritating the chicks so much that they leave their burrows and become separated from their parents (Plentovich et al. 2009).

At the Refuge, long-legged ants (*Anoplolepis gracilipes*) have been observed on koa'e 'ula adults with watery, irritated, swollen eyes. Long-legged ants subdue their prey by spraying formic acid. Ants have also been observed attacking koa'e 'ula chicks to the point where they lose their down and part of the webbing on their feet. Chick foot injuries are typical of those caused by big-headed ants (*Pheidole megacephala*) (Zaun 2005).

4.10.5 Plants

Invasive species are recognized as a major threat to native ecosystems and to the survival of threatened and endangered species. At the ecosystem level, invasive plants have been shown to be capable of changing fire regimes, altering nutrient cycling patterns, and modifying the surface runoff of water. Invasive plants can physically displace native species, and/or supersede them by competition for water, nutrients, or other limited resources. Nonnative plants can also be vectors and hosts for introduced pests and diseases to which the native species lack natural defenses. Furthermore, compared to native plants, nonnative plants lack their natural enemies in the introduced range, which again gives them a competitive edge over native species. Invasive plants are also reported to be faster growing and can therefore easily and quickly colonize, establish, and displace native species (Vitousek 1990, D'Antonio and Vitousek 1992, Blossey and Notzold 1995).

Almost half the flora of the Hawaiian Islands is composed of naturalized nonnative plants, approximately 1,100 species. Invasive plants are successful in island ecosystems due to a multitude of traits. According to Staples et al. (2000), invasive plants in Hawai‘i share the following biological and reproductive characteristics:

- Adaptable to and capable of thriving in different habitats
- Tolerant of variable conditions (such as light, temperature, moisture)
- Fast-growing
- Tolerant of disturbance
- Easily dispersible to new localities by seeds, fruits, spores, or vegetative parts
- Produce small seeds/spores early in life
- Long reproductive periods
- Dispersed by animals and with no special germination requirements

The control and eradication of pest plants has been the top priority of natural resource managers in Hawai‘i. In the wetland habitats of the Refuge, invasive plant species can drastically reduce the value of wetland habitat to native species. Nonnative species out-compete more desirable plant species here, as well as smother open water and mudflat habitats. In addition, the high biomass characteristic of invasive grasses produces a high amount of fuel for fire and become threats to nearby residential, commercial, and military land uses. In Hawai‘i, plants grow year-round; thus, the Service has a full-time task of maintaining the habitat by nonnative plant control. At Kīlauea Point NWR, a combination of control techniques are employed for invasive plant removal including chemical, mechanical (hand and tractor), and water level manipulations.

California grass (*Urochloa mutica*)

California grass (Family–Poaceae) is a sprawling perennial with culms up to 20 feet long and rooting at the nodes. Stolons and leaf sheaths are densely hairy. It occurs pantropically as a pasture grass and its native range is unknown, although it is suspected to have originated in sub-Saharan Africa.

California grass occurs in aquatic environments such as the openings of wet forests, marshes, and other open water areas. It is also known to invade drier, disturbed areas. It is reported to be well-adapted to a wide range of soil conditions (sandy to clay) and tolerates moderate shade but prefers full sun (Wagner et al. 1999).



Monotypic stand of California grass
USFWS

In Hawai‘i, California grass occurs between sea level and 3,445 feet on the five main Hawaiian Islands. The grass can form monotypic stands reaching 5 feet in height, with rooting runners up to 18 feet in length. Throughout the state it has been reported to grow in a wide range of moisture conditions. It grows prolifically in wet swampy habitats, but it can also withstand severe drought. The Hawai‘i-Pacific Weed Risk Assessment is a research project conducted by University of Hawai‘i and the USDA Forest Service (USFS) to identify plants that pose a high risk in Hawai‘i and other Pacific Islands. The assessment score of 12 for California grass reflects its invasion potential. It also designates the

species as H (Hawai‘i), meaning the species is “documented to cause significant ecological or economic harm in Hawai‘i” (Motooka et al. 2003). Techniques used to control California grass on

the Refuges include an integrated system of mowing, disking, tilling, hand-pulling, and application of herbicides.

***Pluchea* spp**

Pluchea spp. (Family–Asteraceae) is comprised of two shrub species in Hawai‘i—Indian fleabane (*P. indica*) and sourbush (*P. carolinensis*)—and a hybrid species. *Pluchea indica* readily hybridizes with *P. carolinensis* to form the intermediate plant *P. x fosbergii*. The leaves of this hybrid species are usually more similar to *P. indica*, while the inflorescence more closely resembles *P. carolinensis*. *P. x fosbergii* can be found where the two species occur together (Wagner et al. 1999).

P. carolinensis is an erect, aromatic shrub native to parts of North and South America. The species has naturalized in Hawai‘i, Guam, Taiwan, Africa, and other tropical and Pacific areas. It can grow in poor soil conditions; however, it cannot withstand shade and severe competition from brush and grass. In dry habitats, the fast-growing shrub can form thickets. In Hawai‘i, *P. carolinensis* has spread to all the main islands since its arrival in the 1930s. This shrub is able to grow in a wide array of habitats, ranging in distribution from dry coastal areas to open forests at 2,953 feet elevation. The plant seeds prolifically and the seeds are easily dispersed by wind (Mueller-Dombois and Fosberg 1998, Wagner et al. 1999).

Pluchea will out-compete native plants on the Refuge, reducing forage and nesting habitats for birds. *Pluchea* tend to harbor huge nests of paper wasps, which are a hazard to Refuge staff and the public. Techniques used to control *Pluchea* spp. on the Refuges include an integrated system of manual removal and application of herbicides.

Christmasberry (*Schinus terebinthifolius*)

Christmasberry is an aggressive, rapidly spreading plant native to Argentina, Brazil, and Paraguay. It can grow as a tree or shrub up to 23 feet in height. Christmasberry has become naturalized in mesic, disturbed, and coastal areas throughout the Hawaiian Islands, where it can form dense thickets on steep slopes (Wagner et al. 1999).

Christmasberry is considered a pioneer species because it quickly colonizes disturbed areas. The invasive attributes of Christmasberry include a large number of fruits, bird dispersal, and a tolerance to shade, fire, and drought. Furthermore, the species is believed to have allelopathic properties, which increases its competitive ability with neighboring plants (Hight et al. 2003). Due to these characteristics, this species is recognized as a noxious weed by the Hawai‘i Department of Agriculture.

Three biocontrol insects have been released in the Hawaiian Islands to control this species. This includes a seed-feeding beetle in 1960, a leaf-rolling moth in 1954–1956, and a stem-galling moth in 1961–1962 (Hight et al. 2003). An accidentally introduced seed-feeding wasp has also been found attacking seeds of Christmasberry. A foliage-feeding sawfly was tested as a potential biological control agent for Christmasberry; however, this species was not introduced due to its risk to the native ‘ohe kuku‘o (*Reynoldsia sandwicensis*) (Hight et al. 2003).

Kikuyu Grass (*Pennisetum clandestinum*)

Kikuyu grass is a fast-growing grass species that forms mats and spreads by rhizomes and stolons. It was introduced to Hawai'i for cattle forage. Kikuyu grass is native to eastern Africa, but has spread throughout the tropics and subtropics (Holm et al. 1972). It occurs primarily in cool fertile areas (Scowcroft and Jeffrey 1999) between sea level and 6,600 feet elevation. It propagates vegetatively because the small, inflorescences rarely produce seeds (Holm et al. 1972). It is shade-tolerant, and the root morphology may also be altered in shaded areas (USFWS 1996).

Kikuyu grass is a particular management concern in many habitats because the species forms dense mats, preventing the establishment of native seedlings. It competes with native seedlings for nutrients, light, and water (Scowcroft 1992), it increases the frequency and intensity of fire (Smith and Tunison 1992), and has been reported to possess allelopathic substances (Smith 1985). For these reasons, it is a federally listed noxious weed, and according to the USFS and DOFAW it is considered a high-risk weed species for creating ecological and economic harm in Hawai'i.

Although Kikuyu grass is considered an aggressive pest, the species appears to be less aggressive in the coastal zone and provides valuable forage habitat for nēnē on the Refuge. Currently, there are no known native grasslands that could be restored to provide the same nutrition as Kikuyu-legume grasslands. Approximately 27 acres of Kikuyu grasslands are managed for nēnē at Crater Hill year-round.

Ironwood (*Casuarina equisetifolia*)

Ironwood is native to the tropical and subtropical seacoasts from Malaysia to Australia, Micronesia, Melanesia, the Philippine Islands, and Polynesia, but is not native to the Hawaiian Islands. The common name refers to any of a number of closely related species that have also been called “she-oak,” or “beefwood.” The tree reaches heights of 80 to 100 feet and diameters up to 18 inches. The wood is dark brown, very tough and dense, and grows rapidly.

Ironwood was first introduced to Hawai'i on the island of on Kaua'i in 1882. More than 70,000 trees were planted on the forest reserves of the island and many others were planted on private lands for windbreaks and in depleted soils or sandy areas requiring a salt-tolerant tree. Since that time, ironwood has not only spread to all the main Hawaiian Islands, but has also established on some of the small atolls in the NWHI.

At the Refuge, it is a common weed and poses a threat to native plants and seabirds. For example, rapid growth of ironwood trees at the base of Mōlī Hill creates obstacles within primary mōlī flight corridors. In 2010, a mōlī fledgling taking its first flight crashed into an ironwood tree and was grounded cliff-side for a day, an annual occurrence if ironwoods are not maintained. As a result, ironwood is controlled on the Refuge in key areas using chainsaws, handsaws, herbicides and, rarely, heavy equipment.

Haole Koa (*Leucaena leucocephala*)

Koa haole, haole koa (foreign koa), or leucaena, is a vigorous shrub or small tree native to southeastern Mexico. This naturalized deciduous species is characterized by twice pinnate leaves with numerous small gray green leaflets, many flowers in whitish round balls 3/4–1 inch across the

spreading threadlike stamens, and many clustered dark brown flat pods. It is a rapidly growing small tree 20–30 feet tall and 4 inches in trunk diameter

This species was unknown in Hawai‘i in 1864, but reported as frequent 20 years later. It is reported that seeds were broadcast from airplanes to provide a charcoal source. It is now an abundant weed in the dry lowlands throughout Hawai‘i and will form dense thickets in lowlands and lower mountain slopes to 2,500 feet altitude.

Haole koa is common throughout the Refuge, but is found in highest concentration in Crater Hill and Mōkōlea Point where it can crowd out nesting seabirds. As a result, haole koa is controlled on the Refuge in key areas using power or hand tools and herbicides.

Lantana (*Lantana camara*)

Lantana is a perennial, erect or prostrate shrub growing to 6 feet or more in height. Leaves are ovate in shape, oppositely arranged, commonly 6 inches long and 2.5 inches wide. Lantana reproduces vegetatively and via seed, flowers are produced year-round and are able to self- and cross-pollinate. Lantana is an extremely prolific seed producer with approximately 12,000 fruits per plant.

Lantana is a thorny shrub and noxious weed native to the West Indies that was brought to Hawai‘i as an ornamental plant for gardens. It can form an impenetrable thicket which crowds out other plants and is dispersed by pest and frugivorous birds. It is capable of surviving all but the hottest fires, regenerating from basal shoots. Allelopathic substances are produced by shoots and roots. Lantana is found up to 1,970 feet on all islands, principally in dry areas, but has also infested both mesic and wet habitats as well. Lantana is found throughout the Refuge. It is controlled using power or hand tools and herbicides.

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