Chapter 4. Refuge Biology and Habitat

This chapter addresses the biological environment of James Campbell NWR; however, it is not an exhaustive overview of all species 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 conservation targets designated under the CCP. The information presented was used when the CCP team developed goals and objectives for each of the conservation targets.

4.1 Biological Integrity Analysis

The Administration Act directs the Service to ensure that the biological integrity, diversity, and environmental health (BIDEH) of the Refuge System are maintained for the benefit of present and future generations of Americans. The Service's policy on BIDEH (601 FW 3) also provides guidance on 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.

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.

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 purpose(s), Refuge System mission, and landscape scales. Where practical, we support the return of extirpated native species in the context of surrounding landscapes. The BIDEH for James Campbell NWR is characterized in Table 4.1.

Table 4.1. Biological Integrity, Diversity, and Environmental Health Characteristics

Habitats	Population/Habitat Attributes	Natural processes responsible for these conditions	Limiting Factors
Emergent wetland	Seasonal, semi-permanent, permanent Potential conservation species: endangered waterbirds, migratory waterfowl, and shorebirds	Natural springs; surface runoff; periodic flooding; seasonal fluctuations/drying, but more permanent water situations than typical seasonal wetlands	Diked impoundments, human development, disrupted flow patterns, climate change, SLR, and pest species including California grass, California bulrush, marsh fleabane, *Batis*, water hyssop, and mangrove
Dry coastal shrub/scrub community	Mixed shrub and grassland Potential conservation species: endangered waterbirds, shorebirds, and seabirds	Exposed coral shelf due to ancient sea level subsidence, low annual precipitation, subsurface sea water (tidal) influence	Invasive species: kiawe, marsh fleabane, buffel grass, *Verbesina*, and koa haole
Coastal dunes	Beach strand/dune communities Potential conservation species: seabirds, shorebirds, endangered ʻīlio-holo-i- ka-uaua, threatened honu	Onshore winds, salt spray, sandy soil, wave and tidal action	Pest species: tree heliotrope, silverhead, spiny amaranth, mongooses, rats, cats, dogs, and pigs; livestock grazing; human development and disturbance; and marine debris
Exposed coral shelf and anchialine pools	Coastal areas; shallow, poorly developed soil with a coral base; eroded vertical sinkholes occur Potential conservation species: *Metabeteaus lohena*, pinapinao	Sea level subsidence, subterranean sea water influence, dry conditions, low amounts of surface organic matter	Pest species: kiawe, marsh fleabane, Chinese violet, buffel grass, and koa haole

4.2 Conservation Targets

Conservation targets are those species or habitats that are most important to the management of the Refuge. Management for these focal species and habitats that support them will benefit other native species that are present on the Refuge. Table 4.2 identifies the priority resources of concern for James Campbell NWR. As native species are referenced by their Hawaiian names, Appendix A contains a list of all scientific, English, and Hawaiian names.

Nesting ʻalae ʻula Mike Silbernagle/USFWS

Table 4.2. Priority Resources of Concern.

Focal Species	Habitat Type	Habitat Structure	Life-history Requirements	Other Benefiting Species
ʻAlae keʻokeʻo	Flooded wetlands	Open water (< 18 in. depth)	Foraging, loafing	Migratory waterfowl, shorebirds, ʻalae ʻula, aeʻo, and koloa maoli
	Emergent wetland	Hemi-marsh with kaluhā sedge	Nesting, brood rearing	
	Mudflats	Moist-saturated soil	Foraging, loafing	
	Levees	Ground cover vegetation	Foraging, loafing	
ʻAlae ʻula	Flooded wetlands	Open water (< 18 in. depth)	Foraging, loafing	Migratory waterfowl, shorebirds, ʻalae keʻokeʻo, aeʻo, and koloa maoli
	Emergent wetland	Hemi- to permanent marsh with sedge, cattail, and bulrush	Nesting, brood rearing	
	Mudflats	Moist to saturated soil	Foraging, brood rearing, loafing	
	Levees	Ground cover vegetation	Foraging, loafing	
Aeʻo	Flooded wetland	Shallow water (< 7 in. depth)	Foraging, loafing	Migratory waterfowl, shorebirds, ʻalae ʻula, ʻalae keʻokeʻo, and koloa maoli
	Mudflats	Adjacent vegetation (cover) and shallow water	Nesting, brood rearing	

Focal Species	Habitat Type	Habitat Structure	Life-history Requirements	Other Benefiting Species
Koloa maoli	Low disturbance flooded/ emergent wetlands	Open water < 8 in. depth supporting seed-bearing plants and invertebrates for food	Foraging, loafing, and chick rearing yearlong	Migratory waterfowl, shorebirds, ‘alae ‘ula, ae‘o, and ‘alae ke‘oke‘o
	Low disturbance grassy upland adjacent to/in wetlands	Dry land with vegetative concealment cover	Nesting, yearlong major period March-June	Migratory waterfowl, shorebirds
‘Īlio-holo-i-ka-uaua	Beach areas; sand spits and islets, including all beach crest vegetation; lagoon waters; inner reef waters; and open ocean	Sandy shoreline, rocky areas, and emergent reefs; as well as vegetated areas for shelter	Pupping, nursing, resting, and molting	Honu, shorebirds, and seabirds
Honu	Shallow, protected water with abundant aquatic vegetation; coral reefs; beach areas; sand spits and islets; and open ocean	Open beaches with a sloping platform and minimal disturbance are required for nesting	Basking and nesting	‘Īlio-holo-i- ka-uaua, shorebirds, and seabirds

4.3 Endangered Hawaiian Waterbirds

James Campbell NWR was established to provide protected managed habitat for four of Hawai‘i’s endangered waterbirds. According to the Draft Revised Recovery Plan for Hawaiian Waterbirds, the Refuge is designated as a core wetland, which is an area essential to the recovery and delisting of all four waterbird species. This Refuge is one of the five core wetland complexes located on O‘ahu that are continually managed for endangered waterbirds (USFWS 2005).

The primary causes of Statewide population decline for these four endangered waterbirds include loss of wetland habitat, predation by introduced animals, altered hydrology, habitat alteration by pest plants, and disease. Environmental contaminants may threaten populations in certain areas. The general recovery objectives are: stabilize or increase species population to greater than 2,000 individuals; establish multiple self-sustaining breeding populations throughout their historical ranges; protect and manage core and supporting wetlands Statewide; eliminate or control the threat of introduced predators, diseases, and contaminants; and remove the threat of koloa maoli hybridizing with non-migratory mallards.

4.3.1 Ae‘o (*Himantopus mexicanus knudseni*) or Hawaiian Stilt

Ae‘o pair © Brian Barker

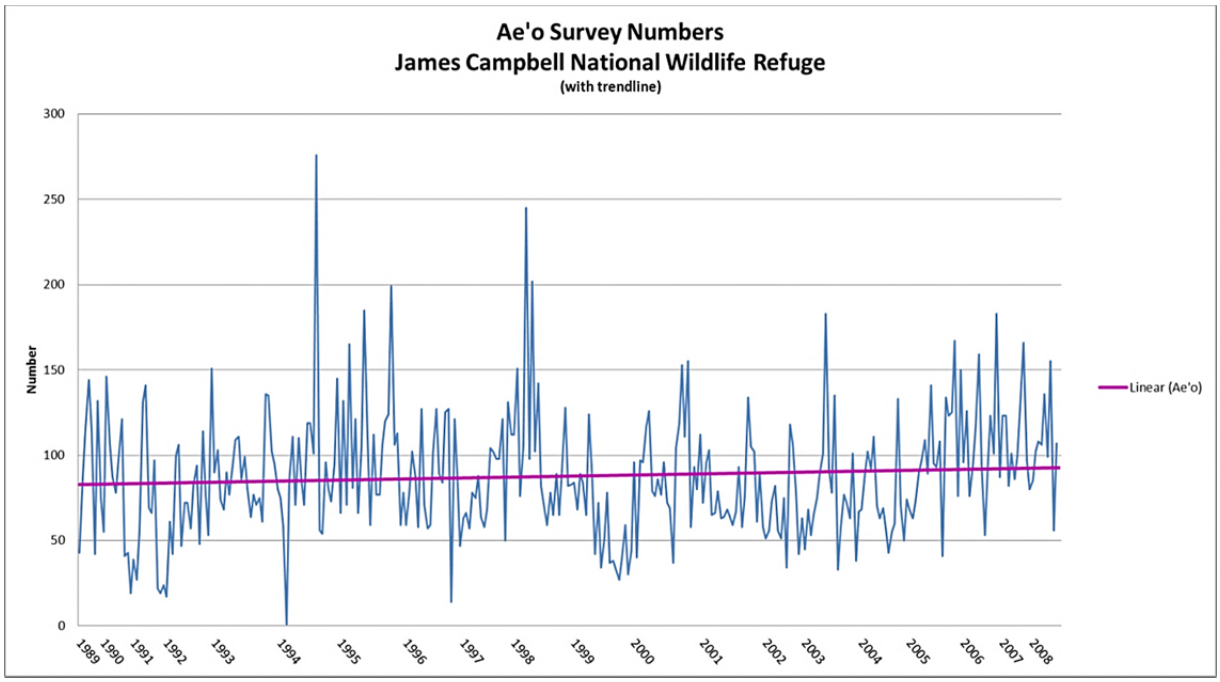
The ae‘o is an endemic subspecies in the Hawaiian Islands, which is part of a superspecies complex of stilts found in various parts of the world. The U.S. Pacific Islands Regional Shorebird Conservation Plan considers the ae‘o as highly imperiled because of its low population level. The ae‘o population has shown a general upward trend Statewide over the past 25 years, although annual summer and winter counts have shown variability from year to year. This fluctuation can be attributed to winter rainfall and successful reproduction. The State population of this resident non-migratory shorebird fluctuates between 1,200-1,500 birds with a 5-year average of 1,350 birds. Adult and juvenile dispersal has been observed both intra- and inter-island (Robinson et al. 1999).

Ae‘o numbers fluctuate seasonally with the overall population trend on the Refuge showing a general decline during the summer months and a general increase during the winter months over the past 30 years. Annual numbers vary with habitat availability for this species. Peak numbers range as high as 276 birds. Ae‘o survey numbers are shown in Figure 4-1. With the addition of new Refuge acreage, increased year-round habitat for ae‘o will become available and will have a positive effect on their numbers.

Ae‘o favor open wetland habitats with minimal vegetative cover and water depths less than 9.4 inches, as well as tidal mudflats. Ae‘o nest from mid-February to late August. Nesting sites consist of simple scrapes on low relief islands or undulating wetland bottom topography within and/or adjacent to ponds. Ae‘o tend to be opportunistic users of ephemeral wetlands to exploit seasonal abundance of food, feeding on small fish, crabs, polychaete worms, terrestrial and aquatic insects, and tadpoles (Robinson et al. 1999, Rauzon and Drigot 2002).

Although ae‘o are considered imperiled, it is believed to have high recovery potential with a moderate degree of threat. Barn owls and pueo (Hawaiian short-eared owl) are known predators of adult ae‘o. Known predators of eggs, nestlings, and young include mongooses, cats, rats, dogs, ‘auku‘u (black-crowned night-heron), cattle egrets, common mynas, ‘akekeke (ruddy turnstone), laughing gulls, American bullfrogs, and large fish. Ongoing threats to foraging and breeding birds on Refuge lands include predation by introduced vertebrates, pest plants, disease, and potential environmental contaminants.

Figure 4.1



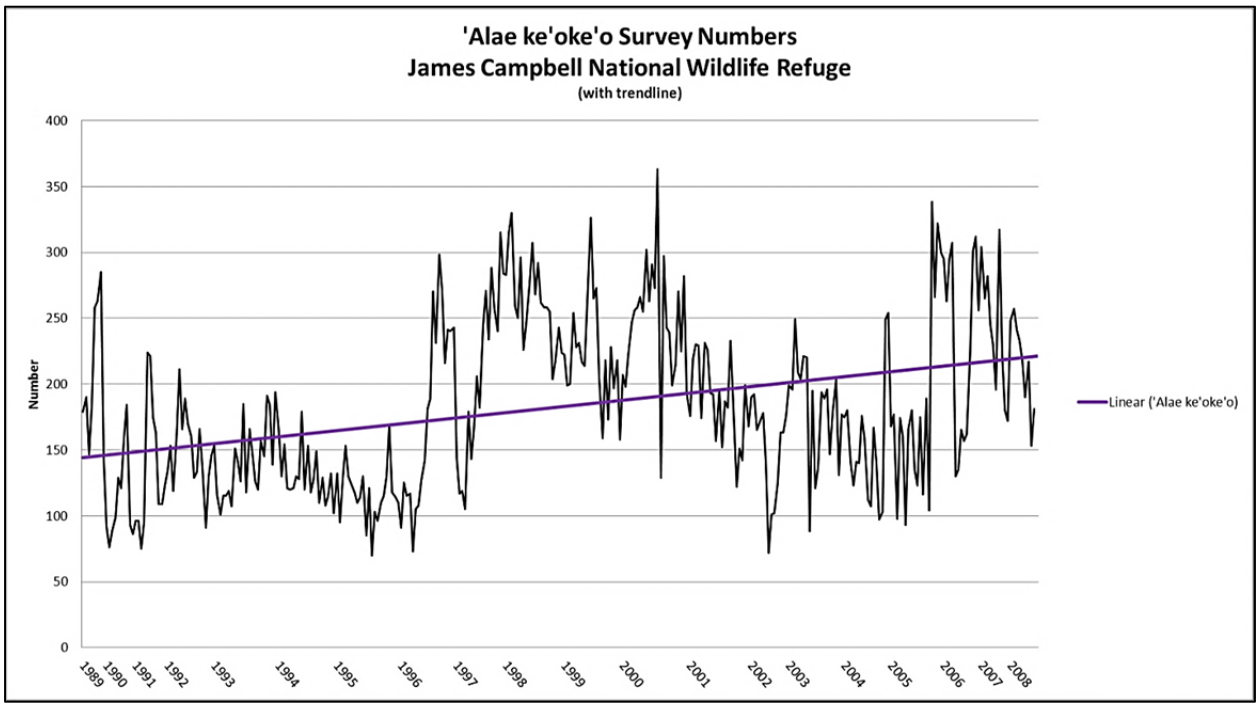
4.3.2 ‘Alae ke‘oke‘o (*Fulica alai*) or Hawaiian Coot

The ‘alae ke‘oke‘o is an endangered species endemic to the main Hawaiian Islands, except Kaho‘olawe, and has occurred sporadically as a vagrant to the NWHI, as far west as Kure Atoll. The Draft Revised Recovery Plan for Hawaiian Waterbirds lists the ‘alae ke‘oke‘o as having high potential for recovery and a low degree of threats. The North American Waterbird Conservation Plan considers the ‘alae ke‘oke‘o as a species of high concern. The State population has fluctuated between 2,000-4,000 birds with the O‘ahu population fluctuating between 500-1,000 birds. Inter-island dispersal is most likely influenced by seasonal rainfall patterns, wetland condition and food abundance (Brisbin et al 2002).

‘Alae ke‘oke‘o Laura Beauregard/USFWS

‘Alae ke‘oke‘o numbers on the Refuge fluctuate seasonally with the overall population trend on the Refuge showing a moderate increase over the past 30 years. Improved predator controls as well as habitat and water level management that provides more suitable habitat for this species throughout most of the year on the Refuge have contributed to the increase. The high count for ‘alae ke‘oke‘o on the Refuge was 358 birds, survey numbers are shown below in Figure 4.2. With the addition of new Refuge acreage, increased year-round habitat for ‘alae ke‘oke‘o will become available and will have a positive effect on their numbers.

Figure 4.2



‘Alae ke‘oke‘o are usually found on island coastal plains and prefer freshwater ponds or wetlands, brackish wetlands, and manmade impoundments. They prefer open water that is less than 12 inches deep for foraging and nesting habitat that has openwater with emergent aquatic vegetation or heavy stands of grass. Nesting occurs mostly March-September, with opportunistic nesting occurring year-round depending on rainfall. ‘Alae ke‘oke‘o will construct floating nests of aquatic vegetation, semi-floating nests attached to emergent vegetation, or in clumps of wetland vegetation. False nests are also sometimes constructed and used for loafing or brooding platforms. ‘Alae ke‘oke‘o feed on seeds and leaves of aquatic and terrestrial plants, freshwater snails, crustaceans, tadpoles of marine toads, small fish, and aquatic and terrestrial insects (Schwartz and Schwartz 1949, Brisbin et al. 2002).

Cats, dogs, and mongooses are the main predators of adult and young ‘alae ke‘oke‘o. Other predators include the ‘auku‘u, cattle egret, and large fish. ‘Alae ke‘oke‘o are susceptible to avian botulism outbreaks in the Hawaiian Islands (Brisbin et al. 2002).

4.3.3 ‘Alae ‘ula (*Gallinula chloropus sandvicensis*) or Hawaiian Moorhen

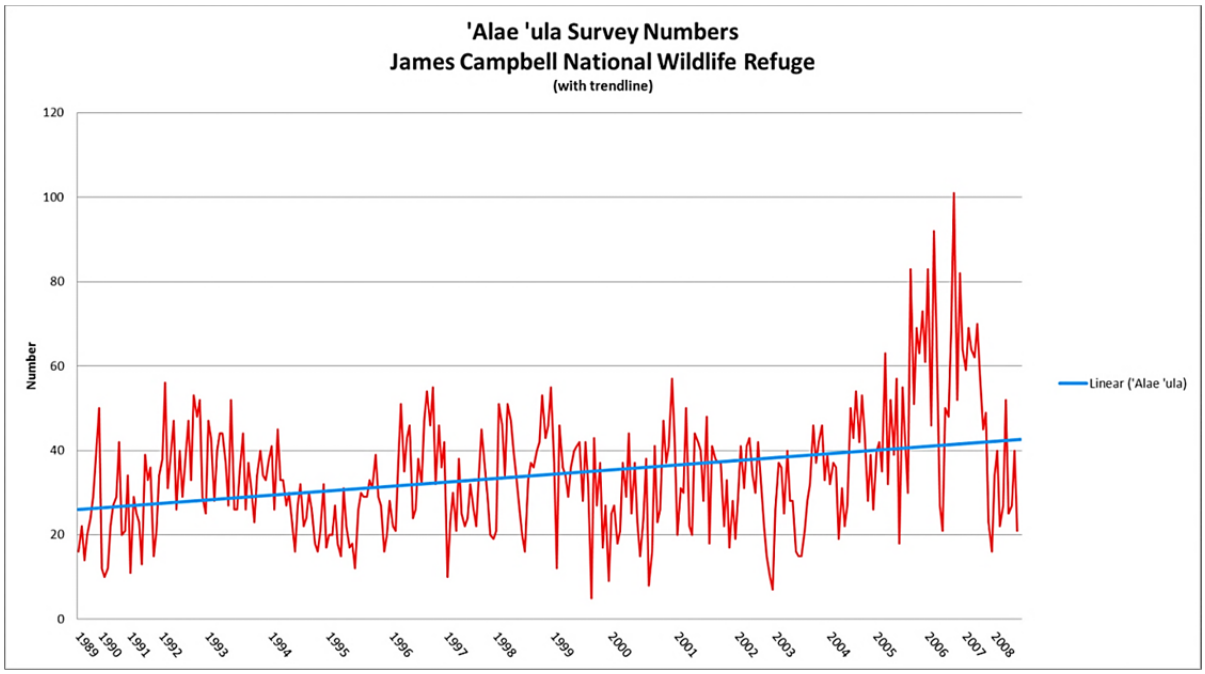
‘Alae ‘ula Mike Silbernagle/USFWS

The ‘alae ‘ula is an endemic, non-migratory subspecies of the common moorhen (*Gallinula chloropus*). It is believed the subspecies originated from stray migrants from North America that colonized Hawai‘i. Although it previously occurred on all the main Hawaiian Islands except Lana‘i and Kaho‘olawe, this species is currently only found on the islands of Kaua‘i and O‘ahu. The ‘alae ‘ula is considered to have a high potential for recovery with a moderate degree of threats (Hawai‘i Audubon Society 2005, Kushlan et al. 2002).

Cats, dogs, mongooses, and bullfrogs are known predators with ‘auku‘u and rats as possible predators. The ‘alae ‘ula is highly susceptible to human and predator disturbance. ‘Alae ‘ula are very secretive; thus, population estimates and long-term population trends are difficult to approximate. The Statewide population appears to be stable, with an average annual total of 314 birds between 1977-2002. Approximately half of this population occurs on O‘ahu (Engilis and Pratt 1993, Bannor and Kiviat 2002, Hawai‘i Audubon Society 2005).

‘Alae ‘ula numbers on the Refuge fluctuate seasonally with the overall population trend on the Refuge showing a general increase over the past 30 years. Annual numbers vary with habitat availability for this species, with a high count of 98 birds, as shown below in Figure 4.3. With the addition of new Refuge acreage, increased year-round habitat for ‘alae ‘ula will become available and will have a positive effect on their numbers.

Figure 4.3



4.3.4 Koloa maoli (*Anas wyvilliana*) or Hawaiian Duck

Koloa-mallard hybrids Mike Silbernagle/USFWS

The koloa maoli is an endangered waterfowl endemic to the Hawaiian Islands. The former range of the koloa includes all the main Hawaiian Islands except Lanaʻi and Kahoʻolawe. Currently, the only naturally occurring population of koloa maoli exists on Kauaʻi with repatriated populations on Oʻahu, Hawaiʻi, and Maui. The Draft Revised Recovery Plan for Hawaiian Waterbirds lists the koloa maoli as having a high potential for recovery and a high degree of threat due to hybridization with mallard ducks, the greatest threat to this species' continued existence. The current Statewide population of pure koloa is estimated at 2,200 birds; approximately 2,000 individuals occur on Kauaʻi and the remainder reside on the Island of Hawaiʻi. Birds on Oʻahu and Maui are thought to be primarily koloa-mallard hybrids, with estimated counts of 300 and 50 birds, respectively. Although hybridization is still a threat on the islands of Kauaʻi and Hawaiʻi, the koloa maoli population on these two islands appear to be stable. Three pure koloa maoli were found at James Campbell NWR during a genetic testing survey in 2008 (USFWS 2005, Engilis et al. 2002, Hawaii Audubon Society 2005, Uyehara et al. 2007).

The koloa maoli uses natural and manmade lowland wetlands, flooded grasslands, river valleys, mountain streams, montane pools, forest swamplands, aquaculture ponds, and agricultural areas. The Refuge provides suitable habitat for foraging, loafing, pair formation, and breeding. The majority of nesting occurs from March-June with broods observed year-round. Nests are placed in dense shoreline vegetation of small ponds, streams, ditches, and reservoirs. Types of vegetation associated with the nesting sites of koloa maoli include fetched and bunch-type grasses, rhizominous ferns, and shrubs. The diet consists of aquatic invertebrates, aquatic plants, seeds, grains, green algae, aquatic mollusks, crustaceans, and tadpoles (Engilis et al. 2002, USFWS 2005a).

In addition to hybridization concerns, other hazards exist for koloa maoli. Known predators of eggs and ducklings include mongooses, cattle egrets, cats, dogs; and possibly rats and Samoan crabs. ʻAukuʻu and bullfrogs have been observed to take ducklings. Avian diseases are another threat to koloa maoli with outbreaks of avian botulism occurring annually throughout the State. In 1983, cases of adult and duckling mortality on Oʻahu were attributed to aspergillosis and salmonella. In order for pure koloa maoli to successfully breed on Oʻahu, the removal of all hybrids and mallard ducks will need to occur (Engilis et al. 2002).

4.4 Other Hawaiian Waterbirds

4.4.1 ‘Auku‘u (*Nycticorax nycticorax hoactli*) or Black-crowned Night-heron

‘Auku‘u looks for prey Laura Beauregard/USFWS

The indigenous ‘auku‘u is a cosmopolitan species resident to the main Hawaiian Islands. The black-crowned night-heron is a species of moderate concern in North America; however, ‘auku‘u in Hawai‘i are not given this designation. In the past, this species has used the Refuge only for foraging. The high count for ‘auku‘u was 109 birds in the Ki‘i and Punamanō Units. There are breeding colonies within the new acquisition lands and we expect to maintain the current population size, which will result in higher numbers for the Refuge.

‘Auku‘u use a wide range of aquatic habitat types including mountain streams, lowland ponds and estuaries, aquaculture farms, and suburban/urban waterways. The ‘auku‘u is diurnal in Hawai‘i and is known to forage on crustaceans, insects, fish, frogs, and mice. They have been observed eating the eggs and young of the endangered ae‘o, koloa maoli, and ‘alae ke‘oke‘o. This species may also be a predator of ‘alae ‘ula eggs and young. Nesting occurs in colonies in December-February in Hawai‘i. ‘Auku‘u are susceptible to human disturbance during nesting (Davis 1993, Mitchell et al. 2005, USFWS 2005a).

4.5 Migratory Waterfowl

Koloa mohā © Michael Walther

For centuries, migratory ducks, geese, and other waterfowl have wintered on the Hawaiian Islands from September-May. Of the nearly 30 species of migratory ducks and geese using the islands, the most common winter migrants observed at James Campbell NWR include koloa mohā (northern shoveler), koloa māpu (northern pintail), mallard, lesser scaup, green-winged teal, and American wigeon. Migratory mallards do not pose the same hybridization threats to koloa maoli as the domestic, resident mallards because they rarely breed during their winter stop-overs (Staples & Cowie 2001).

4.6 Migratory Shorebirds

An ʻakekeke forages during visit © Michael Walther

The Pacific Island Region functions as essential migratory habitat for maintaining global shorebird populations. James Campbell NWR plays an important role in providing wintering grounds for shorebirds in the Hawaiian Islands. Thirty-five species of shorebirds have been recorded on the Refuge. The most common migratory shorebirds by order of abundance on Oʻahu wetland refuges are the kōlea (Pacific golden plovers), ʻakekeke, hunakai (sanderling), and ʻūlili (wandering tattler) (Table 4.3). The only resident shorebird is the aeʻo. The majority of the migratory shorebirds use the Refuge from August-April for loafing and foraging (Engilis and Naughton 2004).

Shorebirds primarily utilize wetlands and tidal flats; however, estuaries, grasslands, and uplands are also important habitats. Although large portions have been altered for urban development, Oʻahu offers the most diverse shorebird habitat of all the Hawaiian Islands. Grasslands and beaches are important habitats for the kōlea and the kioea (bristle-thighed curlew). Oʻahu golf courses support an estimated 1,900 kōlea during the winter, and this species has even been observed roosting on urban rooftops (Engilis and Naughton 2004).

Threats to shorebirds in the Pacific Region include habitat loss, pest plants and animals (predation, disease, and competition), human disturbance, and environmental contaminants. The kōlea is the most common shorebird in the Pacific Region, with Hawaiʻi 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 Region is considered to be a critical area for supporting hemispheric populations of both these species (Engilis and Naughton 2004).

Table 4.3. Shorebirds of Primary Conservation Importance in the Pacific Region

Species	Hawaiʻi Winter Population	Regional Trend	Conservation Category
Kōlea	15,000-20,000	Unknown	High Concern
Aeʻo	1,200-1,600	Unknown	Highly Imperiled
Kioea	800	Unknown	High Concern
ʻŪlili	1,000	Unknown	Moderate Concern
ʻAkekeke	5,000-7,000	Unknown	Low Concern

Source: Engilis and Naughton (2004)

4.7 Seabirds

Resting ʻuaʻu kani © Michael Walther

The ʻuaʻu kani is the only seabird currently known to nest on the Refuge. Reproductive success is unknown but predation appears to be a major limiting factor. Six seabird species have been selected for priority management because of their habitat preferences at other nesting sites in Hawaiʻi that resemble the conditions at the Refuge. In order of feasibility of attraction and colony establishment, the species are mōlī, ʻuaʻu kani, koaʻeʻula, ʻa, kaʻupu, and Christmas shearwater. These species are currently observed along the Refuge coastline and vicinity. Mōlī have attempted to nest near the Refuge but were killed by dogs.

4.8 Raptors

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

Pueo are hard to detect and we do not have accurate counts for their presence. No nests have been documented to date. The Refuge offers breeding and foraging habitat for the pueo. Unlike most owls, pueo are diurnal and are occasionally seen hovering or soaring over open areas. Like short-eared owls in continental environments, those in Hawaiʻi primarily consume small rodents, insects, and, rarely, birds. Males perform aerial displays known as a sky dancing display to prospective females.

Found on all the main Hawaiian Islands from 0-8,000 feet, pueo occupy a variety of habitats including wet and dry forests. Listed by the State as Endangered on Oʻahu, pueo are likely susceptible to the same factors that threaten other native Hawaiian birds, including loss and degradation of habitat, predation by introduced mammals, and disease.

Pueo © Tom Dove

4.9 Endangered Mammals

4.9.1 ‘Ōpe‘ape‘a (*Lasiurus cinereus semotus*) or Hawaiian Hoary Bat

‘Ōpe‘ape‘a Dan Clark/USFWS

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 a coat of 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 somewhat similar to the shape of the bat.

We suspect ‘ōpe‘ape‘a may use the Refuge for foraging areas, just before and after sunset, feeding on night-flying insects, including moths, beetles, crickets, mosquitoes, and termites. They have been documented near the Refuge. Wetlands appear to be important foraging areas; they are also is attracted to insects that congregate near lights. Breeding has only been documented on the islands of Hawai‘i and Kaua‘i. Bats are affected by habitat loss, pesticides, predation, and roost disturbance. A reduction in tree cover (e.g., roost sites) might be the primary reason for the species’ decline in Hawai‘i.

4.9.2 ‘Īlio-holo-i-ka-uaua (*Monachus schauinslandi*) or Hawaiian Monk Seal

‘Īlio-holo-i-ka-uaua are among the most critically endangered mammals in the world. Only about 1,200 seals are alive today. Most seals live in the NWHI, but there is a small and potentially growing population of seals in the main Hawaiian Islands where a 2005 survey observed 76 individuals.

Its Hawaiian name means “the dog that runs in the rough seas.” They frequently haul-out on shorelines to rest and molt. Females also 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. Pupping occurs in late winter and spring. ‘Īlio-holo-i-ka-uaua can live to 25 years of age.

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. Īlio-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 level rising above some islands. Terrestrial habitat is used about one-third of the time and requirements there 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.

‘Īlio-holo-i-ka-uaua rests on beach
© Jim Collin/ AP

Conflicts and interactions with a variety of ocean and beach users are becoming more frequent and significant in the main Hawaiian Islands. Dogs have attacked ʻīlio-holo-i-ka-uaua, and they carry diseases that are potentially lethal to ʻīlio-holo-i-ka-uaua. Human disturbance, especially of mothers with pups, may be a threat at the Refuge. Prior to recent acquisition, Refuge lands did not include the shoreline habitat suitable for this species, therefore monitoring did not occur. Incidental observations over the past year have documented at least two individuals hauling-out on the shore on several occasions. Increased monitoring will provide a better understanding of the use; and management is expected to increase the likelihood of pupping along the Refuge shoreline. In recent years, pupping has been documented nearby on the shore between the Turtle Bay Resort and the Refuge.

4.10 Invertebrates

4.10.1 ʻŌpaeʻula (*Halocaridina rubra)* or Hawaiian Red Shrimp

The ʻōpaeʻula is a tiny (less than half an inch long) reddish shrimp of the family Atyidae found only in Hawaiʻi's brackish water anchialine pools. It is the most common species of anchialine shrimp in Hawaiʻi and can reach 15 years of age, an unusually long time for a tiny crustacean. This species is known to occur on the islands of Hawaiʻi, Maui, and Oʻahu. They graze on the film of algae and diatoms growing on rocks and other hard surfaces. This endemic species is threatened by loss of habitat due to coastal development, the introduction of predatory pest fishes, and perhaps by collection for the pet trade. Its Hawaiian name means "red shrimp." Eight different genetic lineages of ʻōpae ʻula exist in Hawaiʻi. Data show that a lineage was confined to a particular region of a single Hawaiian Island, with each island harboring at least two lineages.

ʻŌpaeʻula are known to occur in two locations on the Refuge. Due to some of the geologic features found in the expansion area, additional anchialine pools containing this species are anticipated. If degraded sites are found, habitat restoration will be pursued.

4.11 Marine Reptiles

4.11.1 Honu (*Chelonia mydas*) or Hawaiian Green Turtle

Honu use the Refuge beach for resting and nesting. Mature males are distinguished from females by their longer, thicker tails. 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

Honu basking on the shore Laura Beauregard/USFWS

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 of age (Gardner 1996).

Females may lay up to 6 clutches per season, often returning to the same site for each clutch every 12-15 days. Each clutch contains approximately 100 eggs and sex determination is temperature-dependent. Incubation takes about 60 days. Evidence shows that Hawaiian honu only migrate throughout the 1,500-mile expanse of the Hawaiian Archipelago, and so make up a discrete population. Hatchlings and juveniles live in pelagic waters, but little is known of their specific distribution.

Litter and other marine debris can prove deadly when they entangle honu or are mistaken for food and ingested. Plastics are particularly harmful as they may remain in the honu's stomach for long periods of time, releasing toxic substances. Ingested plastics also can clog the digestive system. Noise, lights, and beach obstructions are disruptive to nesting areas and rats, mongooses, and dogs prey on the eggs. The Hawaiian honu is listed as threatened under the ESA (Perrine 2003).

Human disturbance to adults coming to shore to lay eggs may be a threat at the Refuge. A first attempt at annual monitoring occurred in 2010, resulting in at least one successful nest with 57 hatchlings. Increased monitoring will provide a better understanding of the use; and management is expected to increase the likelihood of additional nests in suitable habitat.

4.12 Native Plants

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 comprised 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, populations of Hawai‘i’s native vegetation have greatly declined. 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. With expansion of the Refuge, protection and outplanting will improve the native plant diversity and distribution (Cuddihy and Stone 1994).

4.12.1 Naupaka Kahakai (*Scaevola taccada*) or Beach Naupaka

Naupaka are indigenous shrubs that grow from 3-10 feet tall along coasts throughout the tropical Pacific and Indian Oceans. They have bright green succulent leaves with fragrant white flowers that appear to have split in half with five petals remaining on one side.

Flowers and fruit of naupaka kahakai
Laura Beauregard/USFWS

Part of the coastal dunes and scrub/shrub communities, naupaka kahakai provide cover and nesting substrate for seabirds and shorebirds. It is abundant and naturally occurring on the Refuge.

This species is the only non-endemic 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. Mixed with salt, the fruit or root bark of naupaka kahakai was used for cuts, skin diseases, and wounds (Ka‘aiakamanu 2003).

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

One of the most common native species found in Hawaiian coastal areas, ‘ilima have yellow-orange flowers with five petals. The ground-hugging plant has heart-shaped 1-inch-long slivery-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.

‘Ilima Laura Beauregard/USFWS

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 to a child. The root bark mixed with the plant’s blooms was used as an asthma remedy (Walther 2004).

4.12.3 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, and has been identified as a potential roosting site for ‘ōpe‘ape‘a. The Refuge anticipates restoring hala as a component of native habitat restoration projects within the expansion lands (Walther 2004, DOFAW 2005).

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 1997, Wagner 1990).

Hala grove Laura Beauregard/USFWS

Historical accounts and legend emphasize the hala groves that covered the coastal plain. A Hawaiian chant describes the native hala of Kahuku (Elbert 1965:280-281):

A kukui au a Kahewahewa	As I reported to Kahewahewa
Ku au nana i laila,	I stood and gazed, then
Haloiloi kuu waimaka e uwe.	Tears filled my eyes causing me to weep.
Nani na hala ka oiwi o Kahuku,	How beautiful are the hala, native trees of Kahuku,
I ka lawe a ka makani he mikioi.	As they are fanned by the Mikioi wind.

4.13 Invasive Species

For the purpose of this CCP, 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. Native species as well as nonnative species can become invasive when their natural ecosystem is out of balance.

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 these species. Most native species lost their natural defense mechanisms and are more vulnerable to introduced species. As stated earlier in this CCP, we refer in invasive species as “pest species” in the management strategies (Pattison et al. 1998, Ikuma et al. 2002, Middleton 2006).

4.13.1 Mammals

Black rat © Jack Jeffrey

Rat (*Rattus* spp.)
Three pest rat species are found throughout the Hawaiian Islands. Polynesian rats arrived from the central Pacific 1,500 years ago with the Polynesians; Norway rats reached the Hawaiian Islands after the arrival of Captain Cook in the 1770s; and black rats most likely arrived in the 1870s. It is estimated that these three species have populated nearly 82 percent of the major islands.

Black and Polynesian rats can be found from 0-10,000 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 (Tobin and Sugihara 1992, Hays and Conant 2007).

All three species 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, Harrison et al. 1984, Brisbin et al. 2002, Engilis et al. 2002, 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. Rat control is conducted year-round at the James Campbell NWR with various methods including the use of rodenticide placed in bait stations, live traps, and snap traps.

Small Indian Mongoose (*Herpestes javanicus*)

Mongoose on the prowl © Chuck Babbitt

The small 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 0-10,000 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 home range of a female in Hawai‘i is about 3.5 acres, and the main reproductive period occurs February-August. The high density of mongooses in the Hawaiian Islands is due to abundant food and the lack of natural predators. They are voracious omnivores, consuming insects, reptiles,

mammals, amphibians, crabs, plants, and birds. In Hawai‘i, mongooses are diurnal predators that primarily eat invertebrates and secondly small mammals. 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 waterbirds, various seabirds, and migratory shorebirds. In addition, mongooses are known to consume young honu (Tomich 1986, Staples and Cowie 2001, Mitchell et al. 2005, Hays and Conant 2007).

Mongoose populations are managed using traps and diphacinone rodenticide. Since mongooses are a constant threat to waterbirds, year-round control has been conducted on the Refuge since 2004.

Cat (*Felis catus*)

Cats arrived in Hawai‘i in the early 1800s on European ships and are now found on all the main Hawaiian Islands from 0-10,000 feet. They are frequently observed on the Refuge and are occasionally caught in our trapping program.

Neutered and released cat with ‘alae ‘ula
© Michael Walther

Cats are natural hunters with their sharp teeth; the upper teeth overlap the lower, giving them a firm grasp to shake or tear prey to death. Food habits of cats in Hawai‘i include insects, centipedes, crustaceans, lizards, mice, rats, bird eggs, birds, and ‘ōpe‘ape‘a (Scott and Thomas 2000, Brisbin et al. 2002, Engilis et al. 2002, Mitchell et al. 2005).

Pig (*Sus scrofa*)

In the wetlands at James Campbell NWR, pigs have trampled across mudflats and other habitats used by endangered and migratory waterbirds. Their mere presence creates a disturbance to all habitats of the Refuge. Uncontrolled, they have the potential to degrade wetlands, reduce nesting and fledgling success of endangered waterbirds, and perpetuate spread of invasive plants, mitigating our efforts to enhance a variety of habitats on the Refuge.

Pigs at Punamanō Mike Sibernagle/USFWS

Impacts to ecosystems can take the form of decreased water quality, increased propagation of pest plant species, increased soil erosion, modification of nutrient cycles, and damage to native plant species. Rooting, trampling, and compaction influence plant regeneration, community structure, soil properties, nutrient cycling, and water infiltration. Pigs may induce the spread of pest plant species because these plants typically favor disturbed areas and colonize more quickly than many native plants. Habitat damage is particularly important in wet areas where plant communities and soils tend to be more sensitive to disturbance. Wild pigs can be predators of ground-nesting birds, although the impact of this predation on the populations of ground-nesting birds is yet unclear (Seward et al. 2004, Kaller and Kelso 2006)

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 wedge-tailed ‘ua‘u kani birds were killed by a pack of dogs at the nearby Kahuku Golf Course and in 2006, dogs killed nearly 180 ‘ua‘u kani chicks at Ka‘ena Point. 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. The Refuge has documented cases of ‘alae ke‘oke‘o and koloa maoli killed by dogs. Fencing is our primary means to keep dogs off the Refuge.

Dogs running through Ki‘i Unit
Mike Silbernagle/USFWS

4.13.2 Birds

Cattle Egret (*Bubulcus ibis*)
The cattle egret was introduced to Hawai‘i in 1959 from Florida for insect control on cattle and has become widespread. Rookeries were documented on Ni‘ihau, Kaua‘i, O‘ahu, Hawai‘i Island, Moloka‘i, Lana‘i, and Maui by the mid-1980s. One of the largest and oldest known rookeries is on O‘ahu near Kahuku. The actual roost site has moved to different sites over the years, and in 1982 this roost contained over 3,000 birds. A roost located on a parcel of land being acquired and added to the Refuge has been surveyed for several years and numbers have ranged from 100-1,800 birds. A survey conducted in 2010 yielded no birds at the roost/rookery.

Cattle egret © Michael Walther

Its diet primarily consists of grasshoppers, crickets, spiders, flies, frogs, and nocturnal moths, but the bird will also consume prawns, mice, crayfish, and the young of native waterbirds. Cattle egrets have been documented taking chicks of all endangered waterbirds species occurring on the Refuge. If numbers increase and predation on endangered waterbirds exceeds our target limit, population control measures as identified in the IPM and/or CCP strategies would be implemented (Brisbin et al. 2002, Engilis et al. 2002, Hawaii Audubon Society 2005).

4.13.3 Amphibians

Nonnative amphibians also have a negative effect on native Hawaiian species. Recent radio transmitter studies at James Campbell NWR provide conclusive evidence that certain nonnative amphibians are key predators of juvenile Hawaiian waterbirds.

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. Both wetland units are infested with cane toads. The adults only require water for breeding, an event 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 endangered waterbird eggs and young (Yamamoto and Tagawa 2000, Staples and Cowie 2001).

Cane toad Laura Beauregard/USFWS

North American Bullfrog (*Rana catesbeiana*)
North American bullfrogs were brought to Hawai‘i in the late 1800s. They have been identified as a major predator of ae‘o chicks and chicks of other endangered waterbirds on the Refuge. Nocturnal predators, they will ambush and eat insects, mice, fish, and birds. They sit quietly and wait for prey to pass by, then lunge with their powerful hind legs, mouths open wide. Bullfrogs compete with waterbirds for food. Crayfish are an important food item for ‘alae ke‘oke‘o and examination of bullfrog stomach contents indicates crayfish are also taken regularly. Control measures on the Refuge include water level management, live trapping, and shooting.

Bullfrogs can reach 8 inches in length, with males weighing up to 1 pound. Typically green or gray-brown with brown spots; they have easily identifiable circular eardrums, or tympanum, on either side of their heads. The bullfrog’s call is a deep bellow, made day and night, and can be heard up to ¼-mile away. In breeding season, the throat of the male is yellow, whereas the female’s is white. Unlike other frogs, it spends most of its time in water from where it also does most of its hunting (National Aquarium 2010).

North American bullfrog Mike Silbernagle/USFWS

4.13.4 Invertebrates

Although the Hawaiian Islands support a large number of native invertebrates, wide arrays of pest invertebrates have invaded marine and freshwater habitats. Between 20-30 species of introduced snails are believed to have established themselves on the Hawaiian Islands (Staples and Cowie 2001).

Apple Snail (*Pomacea* spp.)
Five species of nonnative apple snails occur in the continental U.S. In Hawai‘i, only four species have established, including *Pomacea canaliculata, P. bridgesii, P. paludosa*, and *Pila conica*. They were intentionally released into taro fields as a potential human food resource. All four species have a similar appearance making the species difficult to distinguish. The *Pomacea* species in Hawai‘i are

primarily herbivores that consume aquatic and semi-aquatic vegetation. The presence of *P. canaliculata* can be detected by the snail's large pink egg masses laid above water on vegetation, rocks, or any rigid surface (Yamamoto and Tagawa 2000, Staples and Cowie 2001).

Laying eggs www.applesnail.net

Of the four species, *P. canaliculata* is the most serious threat to wetland ecosystems and agriculture (taro and watercress) throughout the State. This apple snail is the most voracious plant eater. During feeding, *P. canaliculata* may consume most of the plant or make cuts, causing damaged plants to be highly susceptible to disease. Although *P. canaliculata* is a freshwater snail, it can tolerate low levels of salinity. It is sufficiently tolerant to sea water to survive long enough to be carried by currents from one stream mouth to another (Levin and ʻOnipaʻa Nā Hui Kalo 2006, Yamamoto and Tagawa 2000, Rawlings et al. 2007).

Apple snails prefer slow moving, shallow water areas. They cannot tolerate cold waters, but can survive significant amounts of time out of water and are able to undergo dormancy periods by burying in mud. Field tests have shown that fields submerged for longer than 48 hours with brackish water will kill apple snails; however, this management technique will also change soil productivity toward brackish water adapted vegetation. Field flushing with salt has successfully killed snails in some ponds at James Campbell NWR, but snails are still present in ditches and drainages (Cowie 2002, Levin and ʻOnipaʻa Nā Hui Kalo 2006).

Ants

Hawaiʻi is one of the few places on Earth believed to harbor no 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 known to attack, injure, or kill young birds. Ants are also implicated in having negative effects on native and endangered plants. Control of ants has potential on the Refuge to protect trust resources. The Service is currently studying the efficacy of various baits and approved toxins on pest ants on Oʻahu. It is anticipated that over the course of this CCP, the Refuge will adopt IPM methods to control ants based on the results of these studies

4.13.5 Plants

At the ecosystem level, pest plants have been shown to be capable of changing fire regimes, altering nutrient cycling patterns, and modifying the surface runoff of water. Pest plants can physically displace native species, and/or supersede them in 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 (Jui Min et al. 2007).

Almost half the flora of the Hawaiian Islands is comprised of naturalized nonnative plants, approximately 1,100 species. According to Staples et al. (2000), invasive plants in Hawaiʻi 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; and
- 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. Pest species outcompete more desirable plant species here, as well as invade open water and mudflat habitats. In addition, the high biomass characteristic of invasive grasses produces a high amount of fuel for fire. At James Campbell NWR, a combination of control techniques are employed for pest plant removal including chemical, mechanical (hand and tractor), prescribed burns, and water level manipulations. The following five introduced plant species are of major concern on the O‘ahu wetland refuges.

California Grass (*Brachiaria mutica*)

California grass (Family-Poacaeae) is a sprawling perennial with culms up to 19 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 reported to be well adapted to a wide range of soil conditions (sandy to clay) and tolerates moderate shade but prefers full sun (Tropical Forages 2005).

California grass Mike Silbernagle/USFWS

It grows prolifically in wet swampy habitats, but it can also withstand severe drought. In addition to displacing native plants, California grass alters and destroys aquatic environments, causing a reduction in bird habitat. The grass also interferes with stream flow and poses a nuisance to marine navigation when rafts of the grass float out to sea. The Hawai‘i-Pacific Weed Risk Assessment is a research project conducted by the University of Hawai‘i and the USDA Forest Service to identify plants that pose a high risk in Hawai‘i and other Pacific Islands. The assessment of California grass reflects the species is “documented to cause significant ecological or economic harm in Hawai‘i” (Stone et al. 1999, Motooka et al. 2003).

An on-site study determined that this species can grow 6 feet a month at James Campbell NWR. Intensive control measures for California grass on the Refuge include mechanical, chemical, and prescribed fire as described in detail in the IPM program (Appendix E).

Khaki weed (*Alternanthera pungens*)
Khaki weed (Family-Amaranthaceae) is a perennial prostrate herb, sometimes rooting at the nodes. Flowers are sessile; bracts are approximately 0.16 inch long, tipped with a 0.08-0.12 inch-long spine. Khaki weed is native to Venezuela, Brazil, Peru, and Ecuador, and is widely naturalized elsewhere in the world (Wagner et al 1999, USDA-GRIN Online Database).

Khaki weed Mike Silbernagle/USFWS

In Hawai‘i it was first recorded on O‘ahu in 1959 and has become naturalized on O‘ahu, Moloka‘i, and Hawai‘i. It is common in beach parks and other low elevation, dry, disturbed areas. Khaki weed is easily dispersed by numerous spiky, straw-colored burrs that are transported by animals, machinery, or water. The large and deep woody taproot allows the plant to tolerate drought and makes control difficult. These traits contribute to the plant’s invasive ability. To control khaki weed, the Refuge conducts spot spraying and maintains a dense groundcover of lowgrowing grasses or other desireable species which prevent germination and spread (Wagner et al. 1999, Smith 2002).

***Pluchea* spp.**
Pluchea spp. (Asteraceae) is comprised of two shrub species in Hawai‘i – Indian marsh fleabane (*P. indica*) and sourbush (*P. carolinensis*) – and a hybrid of the two species. Indian fleabane is an erect shrub up to 6.6 feet tall. It is native to temperate and tropical Asia and northern Australia and is naturalized elsewhere. In Hawai‘i, it occurs in lowland, coastal habitats such as wetlands and fishponds. Initially recorded on O‘ahu in 1915, Indian fleabane has been identified on Maui, O‘ahu, Kaua‘i, and Ni‘ihau. It prefers marshes and saline soils (Motooka et al. 2003, USDA, GRIN Online Database).

Pluchea indica Mike Silbernagle/USFWS

Sourbush 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, sourbush has spread to all the main Hawaiian 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 outcompete native sedges on the Refuge, reducing forage and nesting habitats for birds. They tend to harbor huge nests of paper wasps, which are a hazard to Refuge staff and the public. The Refuge uses mechanical, chemical, and prescribed burning techniques to control this pest species.

California Bulrush (*Schoenoplectus californicus*)
California bulrush is a perennial sedge in the Cyperaceae family. This rhizomed water plant is found in marshy areas from southern and western North America to South America. It has tall, thin, dark green stems which are usually triangular in cross-section and woolly, bristly tan or brown flowers in panicle inflorescences. It has characteristics common in the sedge family, such as creeping. It is intolerant of shade, but can spread rapidly by vegetative means (Wagner et al. 1999, NRCS 2008).

California bulrush at Punamanō Mike Silbernagle/USFWS

California bulrush has almost covered the wetland habitat at the Punamanō Unit, significantly decreasing the value to waterbirds. This weed is highly successful in Hawai‘i compared to the continental mainland due to the lack of a winter dry cycle. The most common tactics used in the Refuge to control it are burning, tilling, and use of herbicides. Flooding has also been employed as a removal tactic during the early stages of growth, however, this method decreases bird habitat by changing pond salinities. Other proposed methods of removal include helicopter-applied herbicide and use of an amphibious excavator.

Silverhead *(Blutaparon vermiculare)*
Silverhead is a perennial herb in the Amaranthaceae family. It is native to Africa, the southern states of North America, and South America. This species forms dense groundcover with prostrate stems and ascending branches that flower year-round , outcompeting native plants and degrading wetland features important to endangered species recovery. Silverhead was added as a new State record to naturalized flora in 1994 after being found in an aquaculture facility at the end of the old runway in 1991. At James Campbell NWR, this species occurs primarily along pond edges (Wagner and Herbst 1994).

Silverhead pest plant Mike Silbernagle/USFWS

The primary control method used on the Refuge is chemical spraying, as detailed in the IPM program (Appendix E).

4.13.6 Diseases

Avian botulism
Avian botulism is a paralytic disease caused by ingestion of a toxin produced by the bacteria, *Clostridium botulinum*. This bacteria is widespread in soil and requires warm temperatures, a protein source and an anaerobic (no oxygen) environment in order to become active and produce toxin. Decomposing vegetation and invertebrates combined with warm temperatures can provide ideal conditions for the botulism bacteria to activate and produce toxin.

Birds either ingest the toxin directly or may eat invertebrates (e.g., chironomids, fly larvae) containing the toxin. Invertebrates are not affected by the toxin and store it in their body. A cycle develops in a botulism outbreak when fly larvae (maggots), feed on animal carcasses and ingest toxin. Ducks that consume toxin-laden maggots can develop botulism after eating as few as three or four maggots.

Outbreaks can occur most anytime on the Refuge, but typically occur during the summer months during warm to hot weather. Thousands of birds have been know to die during a single outbreak in areas of high waterfowl concentrations. In Hawai‘i there is no seasonal pattern to this disease.

Botulism is one of the few wildlife diseases we can actually manage effectively. Although we do not know all the environmental triggers that cause *Clostridium botulinum* to start producing toxin, we do know that if mortalities are detected early enough, certain management techniques, if implemented quickly, can rapidly stop and mitigate the magnitude of waterfowl mortality. The Refuge uses carcass pick up and removal as well as water level management in its efforts to minimize impacts of this disease. Because animal carcasses are an excellent source of protein, removing them reduces the resources the bacterium needs to produce toxin and can help reduce or eliminate toxin production. Draining or flooding the wetland can change the environmental conditions sufficiently so as to stop the production of toxin.

Fibropapilloma tumor disease
Fibropapillomatosis (FP) of marine turtles is a debilitating neoplastic disease with a global distribution that was originally described in honu in Hawai‘i in 1958. The prevalence in certain coastal habitats has increased or remained high since systematic surveys were started in the early 1980s. These tumors can result in debilitation and even death to individual animals. The Refuge will monitor the frequency and severity of FP occurring on honu observed along the shoreline. Research continues as to the cause and potential future remedies for this disease (Herbst 1994, Balazs 1991).

4.14 Habitats

The units of James Campbell NWR are located on lowland coastal areas. On the island of O‘ahu, these habitats have been severely altered by a variety of factors including pest species and land use changes. Continued threats to these habitats remain and conservation efforts are needed to improve habitat conditions.

4.14.1 Coastal Dune/Beach Strand

Coastal habitats are lands between 0-985 feet in elevation that are typically vegetated with strand species. The area paralleling the shoreline, also referred to as the beach strand, includes beaches, coastal dunes, and the zone immediately inland of the dunes. Beaches are the most seaward portion of the coastal region and are composed of sand or other loose materials that are constantly exposed to waves and tides. Coastal dunes are ridges or mounds of

Beach strand Laura Beauregard/USFWS

sand located immediately landward of the beach. These mounds are formed by an accumulation of windblown sand that is trapped via obstacles such as vegetation. Dunes are dynamic features that erode during periods of high waves (a process termed scarping) and rebuild when heavy wave action subsides. The coastal dune ecosystem is an integral part of the beach system in Hawaiʻi; it functions as a natural, elevated buffer against erosion, flooding, high waves, storms, tsunamis, and other coastal hazards (Wagner et al. 1999, Char and Balakrishna 1979, University of Hawaiʻi 2005).

The natural dune and coastal beach strand habitat along the Kahuku coastal plain, including the seaward portion of James Campbell NWR, is one of last remaining undeveloped coastal dune areas on Oʻahu. Coastal communities on the windward sides of the Hawaiian Islands are exposed to a variety of harsh conditions including strong trade winds and high surf. As a result, vegetation tends to be low and wind-sheared. Strand vegetation on sandy or dune areas typically includes ʻakiʻaki, pōhuehue, hinahina, naupaka, pōhinahina, Bermuda grass, nanea, alena, *Reichardia picroides*, ʻohai, nama, and Australian saltbush (Mueller-Dombois and Fosberg 1998).

In addition to providing habitat for native flora, the coastal dune areas at James Campbell NWR provide resting habitat for the endangered ʻīlio-holo-i-ka-uaua, and nesting habitat for threatened honu. Dunes in Kahuku provide habitat for seabirds and shorebirds including the kōlea and kioea, two shorebird species designated as a high conservation concern. These coastal dune areas formerly provided nesting areas for the endemic pueo. Pueo are common on Maui, Kauaʻi, and Hawaiʻi; however, the State of Hawaiʻi has listed it as an endangered species on Oʻahu (Hawaii Audubon Society 2005).

Recreational and coastal development pressures have severely impacted coastal dunes throughout the State of Hawaiʻi and the Island of Oʻahu. Commercial and residential developments along the coastline level the dune environment. Grading and landscaping alter the naturally occurring topography and ecology of dunes. Soil filling, in order to support nonstrand vegetation, compacts and traps dune sands and sand that is removed by waves cannot be replaced. This trapping causes a continual decrease in sand and loss of the beach environment. In addition, the continuous trampling by vehicles and pedestrians on the dunes causes erosion and sand movement. Vogt (1979) found that fewer than 10,000 pedestrians walking over sand dunes during a single season can eliminate dune vegetation and result in erosion. Because the beach area in Hawaiʻi is attractive to both visitors and residents, pedestrian traffic has a significant impact on these areas. Offroad recreational vehicles also flatten dunes and impact strand species (Tabata 1980, University of Hawaiʻi and Maui Planning Department 1997, DLNR 1999).

With the purchase of the expansion area, the Service plans to restore the coastal dune ecosystem at the James Campbell NWR. Other dune restoration projects in Hawaiʻi, such as Kamaʻole and Memorial Beach Park, significantly enhanced the recreational value of the beach and upland areas. The State of Hawaiʻi Coastal Erosion Management Plan (1999) lists the restoration of dune systems as a major component to improve Hawaiʻi's coastal region. Dune management tools include planting native coastal vegetation; controlling pest plants; prohibiting vehicles (including all-terrain vehicles); and regulating public access.

4.14.2 Wetlands

Punamanō wetland George Fisher/USFWS

Wetlands typically have three distinguishing characteristics: (1) hydrological conditions that exhibit inundation or saturation; (2) unique hydric soil conditions; and (3) hydrophyte vegetation that is adapted to wet conditions. Although wetlands typically share these common characteristics, the precise definition of a wetland varies among managers, landowners, and agencies. The Service defines wetlands as "lands transitional between terrestrial and aquatic system where the water table is usually at or near the surface or the land is covered by shallow water." According to this definition, unvegetated areas including beaches, mudflats, and ponds can be considered wetlands. The USACE and EPA define wetlands as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstance do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Because of these varied definitions, three indicators are used to assess whether an area is considered a wetland: hydrology, vegetation, and soils (Mitsch and Gosselink 1993, Erickson and Puttock 2006).

In the Koʻolauloa District, we find the following wetlands: Turtle Bay Golf Course Ponds, Kuilima Mitigation Pond, Punahoʻolapa Marsh, James Campbell NWR, Kahuku Aquafarms, the Airstrips Ponds, Kahuku Prawn Farm, Lāʻie Aquaculture Farm/Poʻohaili Wetlands, Hauʻula, Punaluʻu Prawn Farm, Kahana State Park/Huilua Pond, and Kaʻaʻawa Wetlands. Wetland areas at the Refuge are especially important (in regard to waterbird and seabird habitat) due to the significant management activities that occur. Small remnants of the Punahoʻolapa wetland, located between the Punamanō Unit and the Turtle Bay Resort, have also been noted as providing habitat for Hawaiian waterbirds (DPP 1999, Levin and ʻOnipaʻa Nā Hui Kalo 2006).

In addition to providing habitat, wetlands are critical components of an area's hydrology by serving as retention areas for flood waters. These areas help reduce the velocity of water and decrease erosion through sediment attenuation. Reduced siltation results in decreased turbidity of ports, harbors, and rivers. Another value that wetlands provide is trapping pesticides and fertilizers, such as phosphate and nitrates. By filtering these pollutants, wetlands improve water quality in streams and marine areas. Wetlands also function as a groundwater recharge area for potential human use. Finally, the aesthetic qualities of wetlands offer recreation and leisure areas for tourists and local residents (USFWS 1984, Erickson and Puttock 2006).

Wetland management at James Campell NWR will expand to more functional acreage for endangered, migratory, and resident bird species with the acquisition lands.

4.14.3 Exposed Coral Shelf and Anchialine Pools

Exposed coral shelf Mike Silbernagle/USFWS

The exposed coral shelf consists of coral outcropping or cemented calcareous sand on the island of O‘ahu. The coral reefs formed in shallow ocean water during the time the ocean was at a higher level. Small areas of coral outcrop are exposed on the ocean shore, on the coastal plains, and at the foot of the uplands.

Sinkholes in the coral shelf often contain anchialine pools in Hawai‘i. Anchialine pools are exposed portions of the groundwater table that have a subsurface connection to the sea. The Hawai‘i Department of Health defines anchialine pools as: "…coastal bodies of standing waters that have no surface connections to the ocean but display both tidal fluctuations and salinity ranges characteristic of fresh and brackish waters, indicating the presence of subsurface connections to the water table and ocean." Anchialine pools are known occur in two locations on the Refuge. Additional pools may be discovered as habitat restoration projects are implemented in the expansion area (Maciolek 1983, Char and Balakrishna 1979, Craft et al. 2008).

These habitats represent a unique coastal ecosystem dominated by bacterial mats, algae, emergent aquatic plants, mollusks, and crustaceans under natural, undisturbed conditions. Anchialine ponds are considered to be windows into a far more extensive subterranean brackish water ecosystem that is home to a unique assemblage of native species. They have the potential to harbor four species of endemic anchialine shrimp that are listed as candidate endangered species: *Metabetaeus lohena, Vetericaris chaceorum, Palaemonella burnsi,* and *Procaris hawaiiana* (Maciolek and Brock 1974).

4.14.4 Coastal Shrubland (Scrub/Shrub)

Scrub/shrub habitat Mike Silbernagle/USFWS

Scrub/shrub areas are dominated by woody vegetation less than 20 feet tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. Approximately 22 percent of native Hawaiian plant species are found in this ecoregion. Coastal and lowland dry shrublands occur on the lowest leeward slopes of the higher Hawaiian Islands.

Clearing and burning of lowland dry shubs began with the arrival of Polynesians and the last remnants are being destroyed today through continued development, expansion of agriculture and pasture, and burning. This habitat in the new expansion lands of the Refuge is currently dominated by pest species such as kiawe, ironwood, and koa haole (WWF 2010, Walther 2004).
Prior to human settlement, this scrub/shrub area was dominated by a dry forest with habitat for several forest birds, such as honeycreepers, fly catchers, flightless rails, and other flightless birds (all now extinct). Hawaiian dry forests have been reduced by 90 percent. Land utilization by the early

Polynesians damaged portions of the Hawaiian landscape, but this was nothing compared to the devastation that followed with the introduction of herbivores. Cattle, sheep, goats, deer and the European pig were introduced by early European explorers in exchange for supplies. Because there were no natural predators, these herbivores devastated the natural ecosystems, pushing the rate of extinction (flora and fauna) to alarmingly high numbers (Kimura and Nagata 1980).

One of the most significant influences leading to the degradation and loss of native Hawaiian habitats has been the influx of pest plants. The Refuge plans to work with partners to restore a more natural scrub/shrub community through removal of invasive plants and outplanting of native plants that were part of the historic vegetative community. Where there is suitable substrate, we will determine the feasibility of establishing populations of the endangered ‘Ewa hinahina and ‘akoko.