Pu‘u Maka‘ala Natural Area Reserve (NAR)
Management Plan

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Department of Land and Natural Resources
Division of Forestry and Wildlife
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EXECUTIVE SUMMARY

Pu‘u Maka‘ala Natural Area Reserve (NAR or Reserve) is situated on lands within the upper portions of Waiākea ahupua‘a of the South Hilo District and the kalana (sub-district) of ‘Ōla‘a within the District of Puna. It was formally established in 1981 by Governor’s Executive Order 3102 from lands withdrawn from the ‘Ōla‘a and Waiākea Forest Reserves (FR). The original 12,106 acre (ac) (4,899 hectare (ha)) Reserve was created to protect native wet forest. In November 2010, an additional 6,600 acres (2,671 ha) of the former Kūlani Correctional Facility property was added to the NAR, bringing the total acreage of the NAR to 18,706 acres (7,570 ha). This addition protects additional forest and native species as well as links important conservation areas including the ‘Ōla‘a Tract of Hawai‘i Volcanoes National Park (HAVO) and the upper elevation native forests of Kīlauea, Keauhou, and Upper Waiākea. These forests comprise an important water resource for the lower Puna and Hilo regions of Hawai‘i island, and provide exceptional habitat for a wide diversity of native plant and animal species.

The primary threats to biodiversity and watershed integrity at Pu‘u Maka‘ala NAR are feral ungulates (wild, hoofed animals such as pigs, sheep, goats and cattle), especially feral pigs (*Sus scrofa*) and non-native, invasive weeds. This management plan updates the 1989 Management Plan for Pu‘u Maka‘ala NAR to reflect management accomplishments and current management needs of this reserve, including proposed management for the Kūlani addition.

Governor Abercrombie’s *A New Day in Hawai‘i* plan calls for the stewardship of the natural resources that our survival, economy, and quality of life depend on. Priority actions of this Department of Land and Natural Resources (DLNR) initiative include managing invasive species, increasing Hawaii’s ability to withstand impacts from climate change, and restoring capabilities of the DLNR by finding additional sources of funding. The New Day Status Report also tasks the DLNR to ensure mauka watersheds are fully functioning so fresh water resources can be utilized and enjoyed by the people of Hawai`i in perpetuity. *The Rain Follows the Forest* is the Department’s plan to implement these central goals of the Abercrombie administration. *The Rain Follows the Forest* identifies priority watersheds, including Pu‘u Maka‘ala NAR, and outlines on-the-ground actions and projects required to protect and sustain Hawaii’s critical water sources.

The Pu‘u Maka‘ala Management Plan is aligned with the priorities and actions identified in *The Rain follows the Forest*. The overall management goal is to protect, maintain, and enhance Pu‘u Maka‘ala’s unique natural, cultural, and geological resources. Management programs have been developed to support this overall goal and include the following:

1. Ungulate Management
2. Weed Management
3. Habitat Protection and Rare Species Restoration
4. Monitoring
5. Public Access, Outreach and Education
6. Fire Prevention and Response
7. Enforcement
8. Partnership Collaboration

9. Infrastructure and Other Actions

The 2013 Management Plan for Puʻu Makaʻala outlines the planned management activities in Puʻu Makaʻala over the next fifteen years, along with an estimated budget for full implementation.

INTRODUCTION

The Natural Area Reserves System (NARS) was created in 1971 by the Hawaiʻi State Legislature to "preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaiʻi (HRS § 195-1)." The legislature further found that these unique natural assets should be protected and preserved, both for the enjoyment of future generations and to provide baselines against which changes to Hawaii's environment can be measured. The NARS is administered by the Hawaiʻi Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW). NARS Commission members act in an advisory capacity for the Board of Land and Natural Resources, which sets policies for the Department. Hawaiʻi Administrative Rules 13-209 relate to the management of the Natural Area Reserves System.

The NARS is based on the concept of protecting ecosystems – not merely single species. Because the natural resources of Hawaiʻi are under constant threat from invasive species, human encroachment, feral ungulates, climate change, and other threats, the NARS seeks to protect the best remaining examples of the State's unique ecosystems. In addition to setting aside these areas as reserves, the NARS program strives to actively manage these reserves in order to preserve the unique characteristics that make these areas an integral part of the natural heritage of Hawaiʻi. Reflecting this, the mission of the NARS program is: "The NARS exists to ensure the highest level of stewardship for Hawaii's natural resources through acquisition, active management, and other strategies."

The NARS presently consists of 20 reserves on five islands, encompassing more than 123,000 ac (49,776 ha) of the State's most unique ecosystems. The diverse areas found in the NARS range from marine and coastal environments to alpine desert, and from fresh lava flows to wet forests. These areas often serve as habitat for rare native plants and animals, many of which are on the verge of extinction. The NARS also include important watersheds, contributing to Hawaiʻi's sources of drinking water. Finally, the NARS forms an important part of the scenic landscape and contributes to the natural beauty of Hawaiʻi, contributing to the islands' overall appeal to visitors. Some of the most recognizable and visited NARS include Mauna Kea Ice Age NAR (Hawaiʻi), Kaʻena Point NAR (Oʻahu), and ʻĀhihi-Kīnaʻu NAR (Maui).

Puʻu Makaʻala NAR was established in 1981 with the issuance of Executive Order 3102, and it was created to protect unique wet native forest that provides habitat for native plants, invertebrates, and birds. The addition of 6,600 acres (2,671 ha) of the Kūlani property was completed in November 2010 with the issuance of a Governor's Executive Order 4338. This portion of the Reserve contains additional native habitats and species, including mesic forest ecosystems and high elevation habitat that contains existing populations of three critically endangered forest birds. Long-term management of the forested watershed of Puʻu Makaʻala

NAR provides multiple benefits to the state including protection of the island's water resources and undeveloped open space. The natural communities within the Reserve provide habitat for a diverse range of native plants and animals, from rare birds to endemic invertebrates, preserving Hawai‘i's biodiversity.

The NARS website provides general information on NARS programs and policies as well as information on NARS management across the state.

PU‘U MAKA‘ALA NAR: BIOPHYSICAL RESOURCES

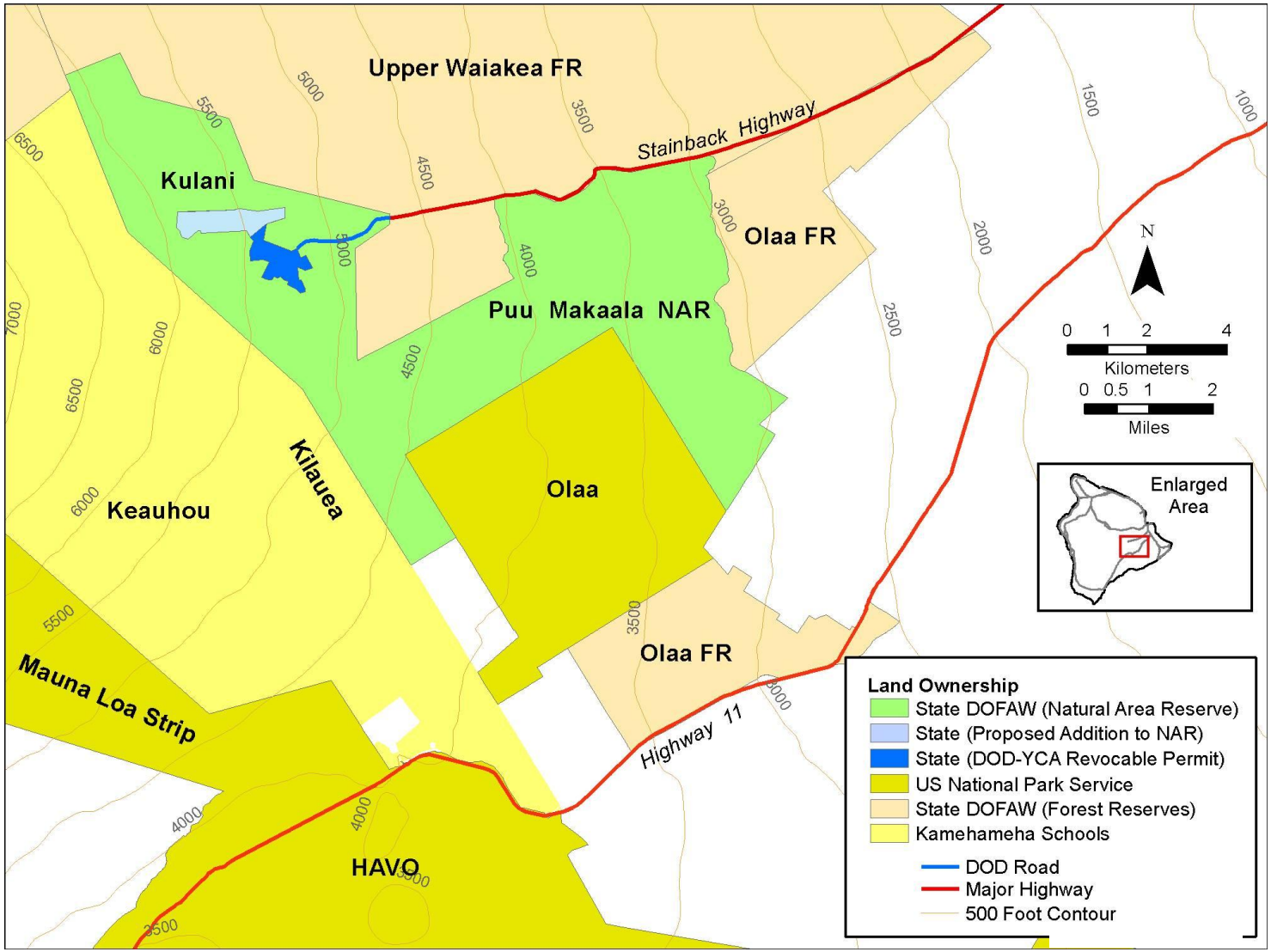
Location

Pu‘u Maka‘ala NAR occupies 18,706 acres (7,570 ha) in the Puna and South Hilo districts on the island of Hawai‘i (Figure 1). The NAR includes the following TMKs: 1-8-12:03, 1-9-01:1, 2-4-8:19, 2-4-8:21, 2-4-8:25 (portion), and 2-4-008:09 (portion).

Landmarks include Kūlani Cone, Pu‘u Kipu and Pu‘u Maka‘ala. The Reserve is bordered by the Upper Waiākea FR on the north and east, the ‘Ōla‘a FR on the east, the ‘Ōla‘a Tract of HAVO to the south, and private property to the west (Kamehameha Schools), southwest and southeast (numerous agricultural parcels). The former Kūlani Correctional Facility is being used by the state Department of Defense Youth Challenge Academy (DOD-YCA) under a revocable permit from DLNR. DOD-YCA controls access into the developed portions of the facility from the end of Stainback Highway. The state Department of Public Safety plans to reopen Kūlani Correctional Facility in 2014.

Access to the NAR is from Volcano (via Wright Road and Amaumau Rd) and along Stainback Highway (Figure 11).

Figure 1. Pu‘u Maka‘ala NAR



Topography, Climate, Geology, and Soils

Puʻu Makaʻala NAR is located on the eastern, windward slopes of Mauna Loa. Elevations within the NAR range from 2,800 - 6,229 feet (ft) (853 – 1,899 meters (m)).

The average annual rainfall is approximately 79 - 157 inches (2,000 – 4,000 milimeters) and the Reserve receives the prevailing northeast trade winds for much of the year. Condensation from ground-level clouds (fog drip) contributes additional moisture at higher elevations. The moist side of an ecotone (a transition to drier conditions) runs along the western edge of the NAR. Only the uppermost areas are subject to some seasonal nighttime freezing.

The NAR contains a variety of different ages and types of lava flows from Mauna Loa's northeast rift zone, which contributes to the diversity of soils and vegetation within the Reserve. U.S. Geological Survey (USGS) has mapped seven different age lava substrates in the Reserve (Figure 2). Flow substrate ages range from recent flows (1942) in the northwest corner of Kūlani to flows older than 10,000 years. There are several prominent cinder cones in the Reserve, including Kūlani Cone and Na Lua Mahoe. This area is classified by USGS as within Volcanic Hazard Zones 2 and 3. The Kūlani portion of the NAR is within Zone 2, which includes areas on the northeast rift zone. Since Mauna Loa's rift zones form prominent ridges, all the areas in Zone 2 are downslope of potential eruption sites. About 20 percent of this area has been covered by lava in historical time, 5 percent since 1950. Other portions of the NAR are within Zone 3, a designation for areas gradationally less hazardous than those in Zone 2 due to greater distance from recently active vents or because the topography makes it less likely that lava flows will cover the area.

Soils in the Reserve were formed in and on various aged volcanic substrates including cinder, ash, pāhoehoe and ʻaʻā, and the age and type of lava substrate greatly influences soil type (Figure 3). Natural Resources Conservation Services (NRCS) draft soils classification for the area includes twenty-five different soil types. Soils that cover the greatest extent of the NAR include the Ekeuiki-Pekailio complex (3-10% slopes), which consists of deep soils that formed in volcanic ash deposited over ʻaʻā. Lower elevations of the NAR contain Hao medial loam (3-10 % slopes), which consists of deep and very deep, moderately well drained soils that formed in volcanic ash. The Reserve also contains large areas of Kiloa extremely cobbly highly decomposed plant material (3 – 10% slopes) which consists of thin, well drained soils that formed in organic material and ash overlying ʻaʻā lava and Keei very cobbly slightly decomposed plant material (3 - 10% slopes) which is similar to Kiloa but formed over pāhoehoe. Other major soil types in the Reserve include deep, well drained soils formed in volcanic ash deposited over cinders (Kūlani hydrous mucky loam) and in material weathered from or formed in volcanic ash (Piihonua hydrous silty clay loam and Puaulu hydrous silt loam).

Figure 2. Pu‘u Maka‘ala NAR Geology (Substrate Age)

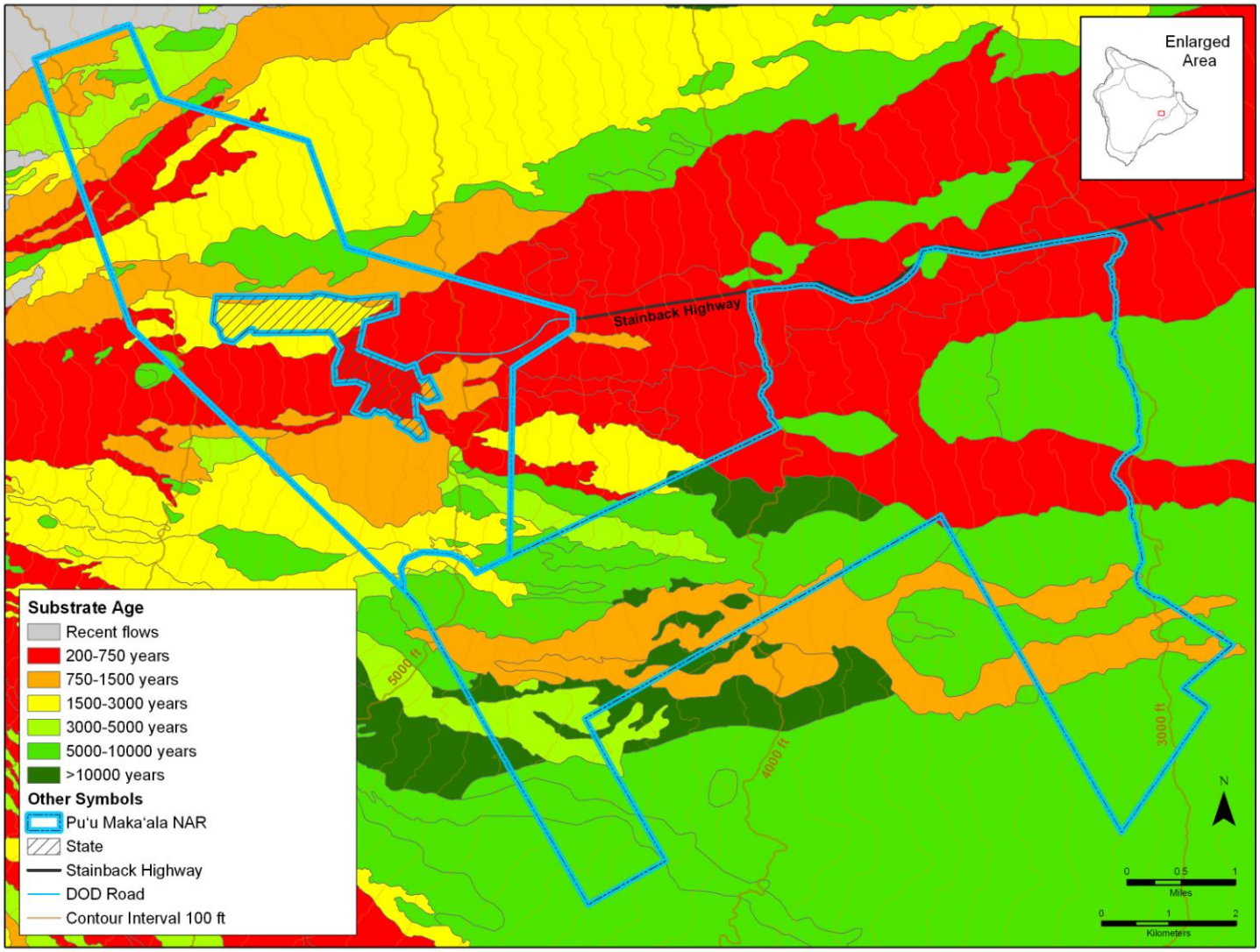
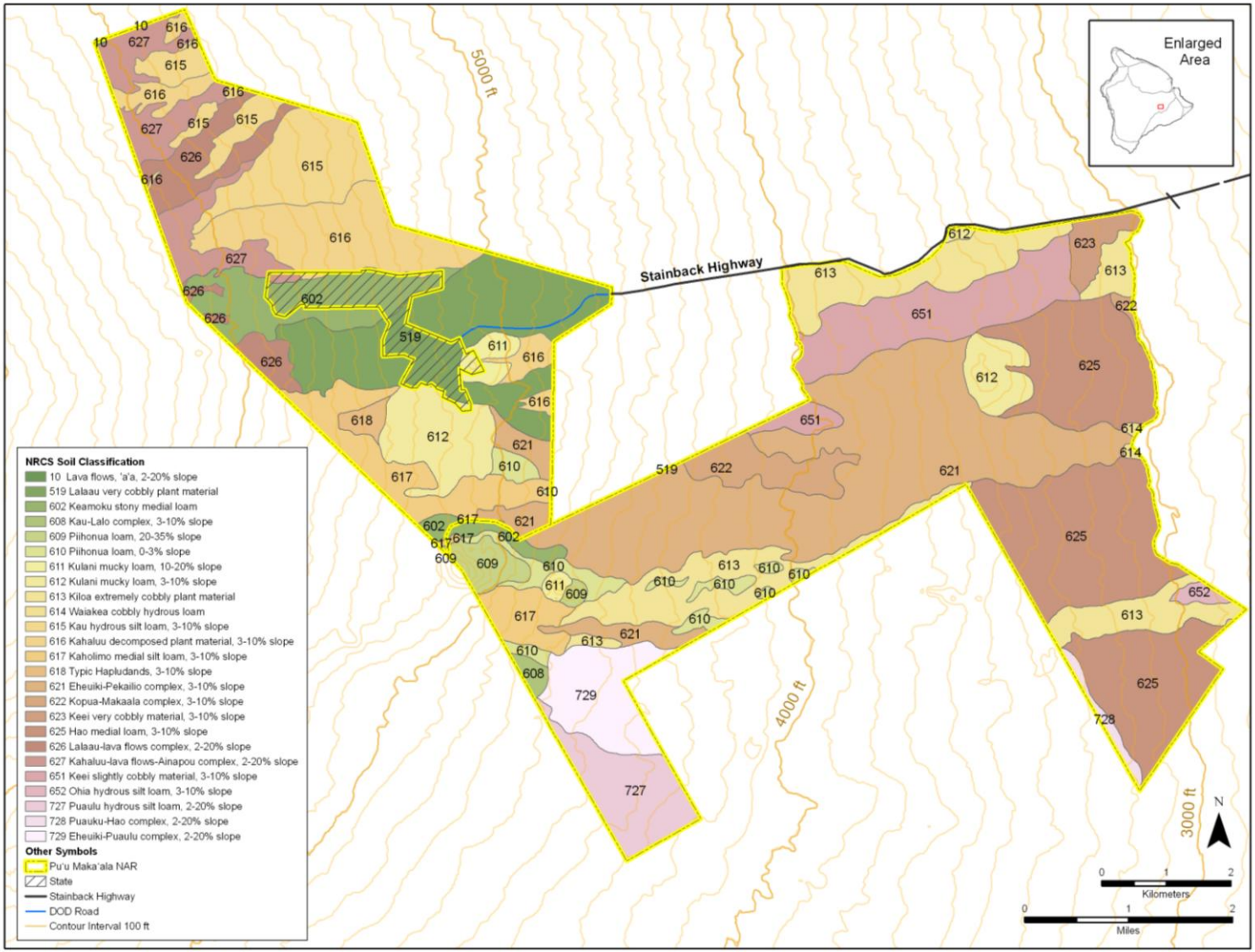


Figure 3. Pu‘u Maka‘ala Soils



Ecosystems and Species

Vegetation

Regionally, Puʻu Makaʻala NAR is an important conservation parcel and includes some of the best wet and mesic native forest on the island of Hawaiʻi. It provides a link between the lower elevation ʻŌlaʻa Tract of Hawaiʻi Volcanoes National Park and the higher elevation forests of Kīlauea, Keauhou and Upper Waiākea, thus protecting the transition between ʻōhiʻa (*Metrosideros polymorpha*) and koa (*Acacia koa*) forest types. These forests contain a full mosaic of different-aged ʻōhiʻa stands. While much of the forest is predominately ʻōhiʻa canopy, characteristics of the forest (e.g. density of ʻōhiʻa, composition of subcanopy and understory) change due to lava substrate type (ash, pāhoehoe, ʻaʻā and cinder), lava flow age and elevation/rainfall.

Puʻu Makaʻala NAR contains three general vegetation zones: lowland wet, montane wet and montane mesic. The lowland wet vegetation zone includes areas in the NAR below 3,281 ft (1,000 m). This zone transitions into the montane wet forest zone at higher elevations and contains similar species. In the Kūlani portions of the NAR, the general trend is from montane wet forest in the east to mesic habitats at the upper elevation, western portions (Figure 4). There is also a diversity of different wetlands present throughout the NAR, including bogs, seeps and emphermeral pools. Appendix A contains a list of plant species currently known from the NAR.

ʻŌhiʻa Lowland Wet Forest is present in the lower elevation, eastern side of the NAR (Figure 4). This forest type contains ʻōhiʻa canopy with hāpuʻu *(Cibotium spp.)* and other native trees and shrubs similar to those in the ʻŌhiʻa/Hāpuʻu Montane Wet Forest described below. Non-native weeds, particularly strawberry guava (*Psidium cattleianum*) are a major component of the lowland wet forests in the NAR. Along the NAR's boundary, approximately 360 ac (146 ha) of tropical ash (*Fraxinus udei*) plantations constitute the Reserve's only non-native dominated community. Within the scattered ash trees are elements of the surrounding ʻōhiʻa/hāpuʻu forest, as well as a variety of non-native species. The tropical ash is spreading into the surrounding native-dominated forest and control of this species is addressed in the weed management program section of this plan.

The montane wet zone contains three native plant communities: ʻŌhiʻa/Hāpuʻu Montane Wet Forest; Koa/ʻŌhʻia Montane Wet Forest; and *Carex alligata* Montane Wet Grassland (Figure 4).

ʻŌhiʻa/Hāpuʻu Montane Wet Forest occupies the majority of the Reserve. A variety of substrate types result in a mosaic of different-age stands of ʻōhiʻa/hāpuʻu forest. The closed ʻōhiʻa canopies can exceed 75 ft (23 m) in height. Other sections of the ʻōhiʻa/hāpuʻu forest are in various stages of dieback. These range from a few senescent trees to sections where all trees are dead and fallen, with a few snags standing over a 15 to 30 ft (4.5 to 9 m) canopy dominated by hāpuʻu and native trees. The hāpuʻu layer is dominated by *Cibotium glaucum* (hāpuʻu pulu), but hāpuʻu ʻiʻi (*C. menziesii)* and meu (*C. chamissoi)* can be locally abundant. Native trees include ʻōlapa (*Cheirodendron trigynum*), kāwaʻu (*Ilex anomala*), pilo (*Coprosma* spp.), kōlea (*Myrsine lessertiana*), smaller stature ʻōhiʻa, and occasionally naio (*Myoporum sandwicense*), manono

(*Hedyotis spp.)*, and loulu (*Pritchardia beccariana*). Vegetation under the hāpuʻu layer includes a mix of native ferns such as *Pneumatopteris sandwichensis*, hōʻiʻo (*Diplazium sandwichianum*), ʻamaʻu (*Sadleria* spp.), *Dryopteris* spp., and uluhe (*Dicranopteris linearis*), native shrubs like kanawao (*Broussaisia arguta*), ʻōhā wai (*Clermontia* spp.), haʻiwale (*Cyrtandra* spp.), hāhā (*Cyanea* spp.), maile (*Alyxia oliviformis*), ālani (*Melicope* spp.), and ʻōhelo (*Vaccinium* spp.), and herbs such as paʻiniu (*Astelia menziesiana*) and ʻalaʻala wai nui (*Peperomia* spp.). Sedges such as *Carex alligata* and *Uncinia uncinata* are also present.

Koa/ʻŌhiʻa Montane Wet Forest occupies a small portion of the northwestern edge of the Reserve on cinder and ash substrate in the Kūlani Cone area. Scattered individual koa trees, from 60 to 120 ft (18 to 36.5 m) in height, emerge from a layer of 30 to 90 ft (9 to 27 m) tall ʻōhiʻa. Under the canopy is an association of native trees that include kōlea, kāwaʻu, ʻōlapa, pilo, and young ʻōhia. While the ʻōhiʻa/hāpuʻu and koa/ʻōhiʻa wet forests share many of the same species, the ʻōhiʻa/hāpuʻu wet forest contains a higher overall diversity due its larger area and expanded elevational range.

Carex alligata Montane Wet Grassland is scattered in small distinct patches throughout the Reserve, occupying low lying water-saturated areas such as cinder cone pits or depressions in the forest. These grasslands may consist entirely of *Carex* but may also include scattered shrubs of ʻōhiʻa and patches of wawae'iole (*Lycopodium*). The largest examples in the NAR occupy cinder cone craters on Kūlani Cone and Na Lua Mahoe.

Montane mesic plant communities are found in the Kūlani portion of the NAR.

Koa/ʻŌhiʻa Montane Mesic Forest - Portions of Kūlani contain tall stature koa/ʻōhiʻa forest with other native trees and a hāpuʻu, native shrubs and ground fern understory. This forest type differs from the wet koa/ʻōhiʻa in that wet forest tends to have higher densities of hāpuʻu than mesic areas, which have more native trees and shrubs in the understory. Unless disturbed, both forest types have a diverse ground cover dominated by ferns.

ʻŌhiʻa Montane Mesic Forest - Portions of Kūlani contain plant communities composed primarily of open to closed canopy /ʻōhiʻa and an understory of native trees, shrubs, ferns and grasses without the prominent hāpuʻu component. This community can be found on intermediate aged lava flows as well as on young lava flows in association with other pioneer vegetation.

ʻŌhiʻa Woodland - This plant community consists of open canopy ʻōhiʻa with mixed native trees and a native shrub and native grass (*Deschampsia nubigena*) understory. This community is found on young to intermediate aged lava flows in the higher elevation, drier parts of Kūlani. Some areas within this community have depressions in the lava flow surface that collect water and have formed perennial wetlands containing native grasses and sedges.

A diversity of native plants is found within the natural communities of Puʻu Makaʻala, including over 160 plant and fern species endemic to Hawaiʻi (Appendix A contains a list of native and introduced plant species currently known from the NAR, including endemic species). Fifteen species of federally listed endangered plants occur in or near Puʻu Makaʻala NAR, and Puʻu Makaʻala contains federally designated critical habitat for seven endangered plants:

Argyroxiphum kauense, *Clermontia lindseyana*, *Cyanea shipmanii*, *Sicyos alba*, *Cyrtandra giffardii*, *Cyanea stictophylla*, and *Phyllostegia velutina*. Puʻu Makaʻala provides habitat for another twenty plant species that are Candidates for listing or considered Species of Concern (SOC) (Table 1).

Numerous other plant species historically and/or currently found in or near the NAR have no official status but are considered rare by NAR staff, other land managers and/or scientists. These species include: *Dubautia* sp. (unknown species), *Embilia pacifica* (kilioe), *Nothocestrum longifolium* (ʻaiea), *Phyllostegia vestita*, *Phytolacca sandwicensis*, *Plantago pachypylla*, *Platydesma spathulata*, *Stenogyne scrophularioides* (māʻohiʻohi), *Tetraplasandra kavaiensis* (ʻohe ʻohe), *Tetraplasandra oahuensis* (ʻohe mauka) and *Urera glabra* (ōpuhe).

Figure 4. Pu‘u Maka‘ala NAR Vegetation

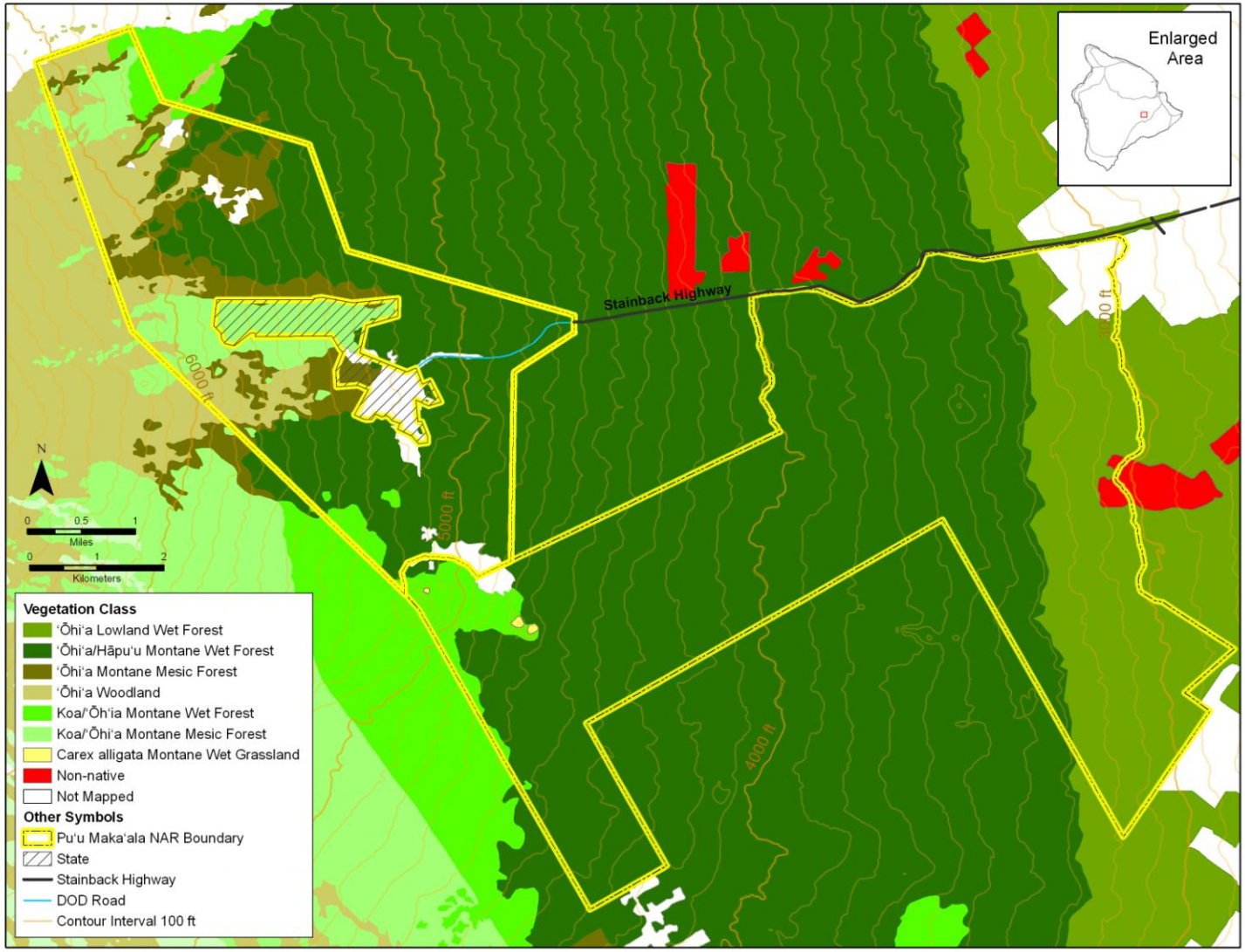


Table 1. Endangered and rare plant species historically and/or currently found in or near Puʻu Makaʻala NAR.

Taxon	Common name	Status*	NAR Critical Habitat	Location**
Adenophorus periens	palai laʻaū	E		ʻŌlaʻa Tract
Anoectochilus sandvicensis	jewel orchid	SOC		ʻŌlaʻa Tract
Argyroxiphum kauense	Mauna Loa silversword	E	Yes	Puʻu Makaʻala (Kūlani)
Asplenium schizophyllum		SOC		Puʻu Makaʻala
Asplenium peruvianum var. insulare		E		Kīlauea, Puʻu Makaʻala
Clermontia lindseyana	ʻoha wai	E	Yes	Puʻu Makaʻala (Kūlani), Kīlauea
Clermontia peleana	ʻoha wai	E		ʻŌlaʻa FR, Puʻu Makaʻala
Cyanea coplandii	hāhā	E (X)		660-1,600 m wet forest
Cyanea giffardii	hāhā	SOC(X)		725-800 m wet forest
Cyanea platyphylla	ʻakūʻakū	E		Puʻu Makaʻala
Cyanea shipmanii	hāhā	E	Yes	Puʻu Makaʻala (Kūlani), Kīlauea
Cyanea stictophylla	hāhā	E	Yes	Puʻu Makaʻala (Kūlani), Kīlauea, Puʻu Makaʻala
Cyanea tritomantha	ʻakū	C		Puʻu Makaʻala
Cyrtandra giffardii	haʻiwale	E	Yes	Puʻu Makaʻala
Cyrtandra tintinnabula	haʻiwale	E		ʻŌlaʻa Tract
Eurya sandwicensis	ānini	SOC		Puʻu Makaʻala
Fragaria chiloensis ssp. sandwicensis	ʻōhelo papa	SOC		Keauhou
Gardenia remyi	nānū	C		Upper Waiakea FR
Joinvillea ascendens ssp. ascendens	ʻohe	C		Puʻu Makaʻala
Liparis hawaiensis	ʻawapuhiakanaloa	SOC		ʻŌlaʻa Tract
Pittosporum hawaiiense	hō ʻawa	SOC		Puʻu Makaʻala (Kūlani)
Phyllostegia ambigua		SOC		Puʻu Makaʻala
Phyllostegis floribunda		C		Puʻu Makaʻala, ʻŌlaʻa Tract Upper Waiakea FR

Taxon	Common name	Status*	NAR Critical Habitat	Location**
Phyllostegia macrophylla		SOC		Puʻu Makaʻala, Kīlauea
Phyllostegia racemosa	kīponapona	E		Keauhou
Phyllostegia velutina		E	Yes	Puʻu Makaʻala
Pritchardia beccariana	loulu	SOC		Puʻu Makaʻala
Rubus macraei	ʻākala	SOC		Puʻu Makaʻala (Kūlani), Keauhou
Schieda diffusa		SOC		ʻŌlaʻa Tract
Sicyos alba	ʻānunu	E	Yes	Puʻu Makaʻala
Sisyrinchium acre	mauʻu lāʻili	SOC		Puʻu Makaʻala (Kūlani)
Stenogyne macrantha	māʻohiʻohi	SOC		Puʻu Makaʻala
Trematolobelia grandifolia	koliʻi	SOC		Puʻu Makaʻala
Vicia menziesii	Hawaiian vetch	E		Kīlauea, Keauhou
Zanthoxylum kauaense	aʻe, mānele, heaʻe	SOC		Upper Waiakea and ʻŌlaʻa FR
* E = endangered; T = threatened; C = candidate for listing; SOC = species of concern; (X) = possibly extinct ** Species with populations historically/currently known from Puʻu Makaʻala NAR or nearby locations are noted.				

Wildlife

The project area provides habitat for seven honeycreepers (Subfamily Drepanidinae) endemic to the Hawaiian Islands. These include four endangered species: Hawai‘i creeper (*Oreomystis mana*), Hawai‘i ‘ākepa (*Loxops coccineus*), ‘akiapōlā‘au (*Hemignathus munroi*) and ‘ō‘ū (*Psittirostra psittacea),* a species which has not been sighted in the area since the mid-1980’s and may be extinct. The non-endangered honeycreepers found in the project area include: ‘apapane (*Himatione sanguinea*), Hawai‘i ‘amakihi (*Hemignathus virens*), and ‘i‘iwi (*Vestiaria coccinea)*. Other native forest birds reported from the project area include, ‘elepaio (*Chasiempis sandwichensis*), and ‘ōma‘o or Hawaiian thrush (*Myadestes obscurus*). Native forest birds are primarily found in the upper elevations of the NAR (above 4,000 ft (1,219 m)) elevation where lower numbers of mosquitoes reduce the incidence of diseases such as avian malaria and pox.

The Kūlani portion of the NAR is identified as a recovery area for Hawai‘i creeper, Hawai‘i ‘ākepa, and ‘akiapōlā‘au in the U.S. Fish and Wildlife Service (FWS) forest bird recovery plan and in the State Comprehensive Wildlife Strategy. Recovery areas are habitat that will allow for the long-term survival and recovery of endangered Hawaiian forest birds. The Kūlani area has some of the highest densities of native forest birds on the island. This relative abundance is due to large tracts of intact, upper elevation native forest. Kūlani may also be considered as a potential future release site for captively-raised Hawaiian crow, or ‘alalā (*Corvus hawaiiensis*). Although this species is not historically known from this area, ‘alalā are known historically from nearby (Hawaii Volcanoes National Park) and neighboring Keauhou is being considered as a possible release site. Other native birds known from the area include the endangered Hawaiian hawk or ‘io (*Buteo solitarius*), nēnē (*Branta sandvicensis),* Hawaiian owl or pueo (*Asio flammeus sandwichensis*) and Pacific golden-plover or kōlea (*Pluvialis fulva*). Additionally, the ‘ua‘u or Hawaiian petrel (*Pterodroma sandwichensis*) and the ‘akē‘akē or band-rumped storm petrel (*Oceanodroma castro*) may overfly the NAR going to nesting areas on the upper, eastern slopes of Mauna Loa.

Table 2. Native birds historically and/or currently found in or near Pu‘u Maka‘ala NAR.

Taxon	Common Name	Status
Corvus hawaiiensis	‘alalā, Hawaiian crow	endemic - endangered
Asio flammeus sandwichensis	pueo, Hawaiian owl	endemic
Branta sandvicensis	nēnē, Hawaiian goose	endemic - endangered
Buteo solitarius	‘io, Hawaiian hawk	endemic - endangered
Chasiempis sandwichensis	‘elepaio	endemic
Hemignathus munroi	‘akiapōlā‘au	endemic - endangered
Hemignathus virens	‘amakihi	endemic
Himatione sanguinea	‘apapane	endemic
Loxops coccineus	Hawai‘i ‘ākepa	endemic - endangered
Oceanodroma castro	‘akē‘akē, band-rumped storm petrel	indigenous - candidate
Oreomystis mana	Hawai‘i creeper	endemic - endangered
Myadestes obscurus	‘ōma‘o	endemic
Pluvialis fulva	kōlea, Pacific golden plover	indigenous
Psittirostra psittacea	‘ō‘ū	endemic – endangered

Pterodroma sandwichensis	ʻuaʻu or Hawaiian petrel	endemic - endangered
Vestiaria coccinea	ʻiʻiwi	endemic

Non-native birds including Japanese white-eye (*Zosterops japonicus*), red-billed leoithrix (*Leiothrix lutea*), northern cardinal (*Cardinalis cardinalis*) and kalij pheasant (*Lophura leucomelanos)* are common in the NAR.

Appendix B provides a list of native and non-native bird species currently and/or historically known from Puʻu Makaʻala.

Although native invertebrates were only incidentally noted during 1989 surveys, a high diversity of representative insects, spiders and snails, particularly *Succinia* spp. was observed. An arthropod survey conducted in 1995 collected and recorded 217 species of insects, related arthropods and land snails from the Wright Road unit of Puʻu Makaʻala. Of those identified, 58% were native species. Appendix C provides a list of invertebrates collected, including non-native invertebrates and land snails. Table 3 summarizes notable insects found during the 1995 survey including: three species of picture wing flies (*Drosophila* spp.), three endemic genera of leaf hoppers (*Leialoha*, *Nesodyne*, and *Nesothoe*), and one species of endemic damselfly (*Megalagrion hawaiiense*). Two other species of damselfly are also known from the area (*Megalagrion calliphya* and *Megalagrion koelense*). Different types of wetlands (e.g. bogs, seeps and ephemeral pools) support different damselfly species. *Megalagrion koelense* breeds in small pockets of water in the leaf axils of native lilies (*Astelia*).

Portions of the NAR were surveyed for an endemic lineage of spiders: the genus *Tetragnatha*. Although spiders are one of the most important groups of predators in the Hawaiian forests, they are virtually unknown; perhaps because of they are almost exclusively nocturnal (Gillespie 1992). The NAR is federally designated as critical habitat for *Drosophila mulli*, a listed endangered picture wing fly which is dependant on the native loulu (*Pritchardia beccariana*). In 2011, the NARS Invertebrate Program organized a four-day invertebrate Bioblitz in the Kūlani section of the Reserve. This effort will result in an updated invertebrate species list for the Reserve as well as provide information for future management actions targeting native invertebrates.

Although the lava tube caves in the area have not been investigated, research in adjacent areas has documented a well-preserved cave fauna. Lava tube caves harbor specialized invertebrate species dependent on native forests above the caves (Mueller-Dombois et al. 1981).

Hawaiʻi's only endemic land mammal, the ʻōpeʻapeʻa or endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), also uses the area but the Reserve has not been sampled for bat activity.

A variety of non-native animals such as feral pigs, rats (*Rattus* spp.), mice (*Mus musculus*), cats (*Felis catus*), and mongoose (*Herpestes auropunctatus*) are present in the Reserve. Coqui frogs (*Eleutherodactylus coqui*) have been found at Kūlani, at the facility complex, and in areas adjacent to the NAR such as along Stainback Highway.

Table 3. Notable Native Insects in Pu‘u Maka‘ala NAR (summarized from Preston 1995).

TAXA	DESCRIPTION
COLEOPTERA Aglycyderidae (Proterinid Weevils)	These tiny (less than 3 mm long) primitive weevils are remarkably diverse in Hawai‘i. About 175 species are known only from Hawai‘i; these constitute more than 90% of the world's fauna in the family. The larvae are wood borers, mostly in twigs and stems of native plants, and most species are host specific. Unidentified species were collected in the NAR
DIPTERA Drosophilidae (Pomace Flies) *Drosophila* spp. (picture wing group)	Hawaiian Drosophilidae are one of the best studied examples of adaptive radiation. Over 600 species have been described, and another 200 species are known but not yet named. The existence of such a diverse fauna in Hawai‘i provides an ideal natural laboratory for comparative studies in evolutionary biology. At least 3 species belonging to the large "picture wing" group were collected. The NAR is critical habitat for the listed endangered species *Drosophila mulli* (not detected in the 1995 surveys by Preston).
Muscidae (House Flies and relatives) *Lispocephala confluens* (Malloch, 1928) *Lispocephala dexioides* (Grimshaw, 1901) *Lispocephala ingens* (Grimshaw, 1901)	The endemic genus *Lispocephala* contains over 100 known species, which are all predatory on other insects. Thirty species are known from the Big Island, and of these only 3 species were collected: *Lispocephala confluens* previously only known from Moloka‘i and Maui, *L. dexioides*, known only from Maui and the Big Island, and *L. ingens*, known from Oahu, Moloka‘i, Maui and the Big Island.
HETEROPTERA Miridae (Plant Bugs) *Hyalopeplus pellucidus* (Stål, 1859) *Orthothotylus spp.* *Sarona* sp.	Hawaiian plant bugs remain poorly known (about 50 species have been named, but at least another 100 species are in collections). Most species are plant feeders, but many are predaceous or omnivorous. Many species are found only in a small geographical area and feed on a single species of plant. Three native species were identified: *Hyalopeplus pellucidus* is a common species with a wide host range, including guava and other alien plant species; *Orthotylus*, a widespread genus; and the endemic genus *Sarona*.
Nabidae (Damsel Bugs) *Nabis oscillans* Blackburn, 1888	The damsel bugs are all predatory on other insects. There are 30 Hawaiian species, but new species continue to be discovered. *Nabis oscillans* Blackburn, 1888 was collected.
Pentatomidae (Stink Bugs and Shield Bugs)	*Coleotichus blackburniae*, the koa bug, is the largest and most conspicuous native true bug (nearly an inch long and iridescent blue, green, maroon, and yellow). Once common on koa and a‘alii throughout Hawai‘i, it is now rare due to the introduction of several parasites for biological control of the pestiferous southern green stink bug in the 1960’s. Historically known from the NAR, but none were seen during this survey.
HOMOPTERA Cicadellidae *Nesophrosyne* spp.	Seven endemic genera of leaf hoppers, plant hoppers, and psyllids were collected. Several species in the native genus *Nesophrosyne* (Cicadellidae) were abundant.
Cixiidae *Iolania perkinsi* Kirkaldy, 1902 *Oliarus* (2 species)	*Iolania perkinsi* Kirkaldy, 1902 a native cixiid restricted to Hawai‘i island and associated with native ferns, was common. Specimens of two species in the other native genus *Oliarus* were also collected.
Delphacidae *Leialoha* sp. *Nesosydne* (2 species) *Nesothoe* sp.	Three endemic genera of leaf hoppers were common in Pu‘u Maka‘ala: *Leialoha*, *Nesosydne*, and *Nesothoe*.
HYMENOPTERA Ichneumonidae (Ichneumon wasps)	These wasps are parasites of other insects; the adult female searches for, and lays eggs in, suitable hosts. Individuals of several species were collected sporadically as expected. In addition, on one occasion, dozens

Enicospilus nigrolineatus Ashmead, 1901 *Enicospilus* (2 species) *Spolas* nr. *hawaiiensis* (Ashmead, 1901) *Spolas* (2 species)	of individuals of the native genus, *Enicospilus*, were collected. *Enicospilus nigrolineatus* (Ashmead, 1901), a very large and showy species was collected in every Malaise trap sample. Two undetermined *Enicospilus* spp.were also present in the trap in larger numbers. Three species in the native genus *Spolas* were also found as well as the ever abundant and purposely introduced parasite, *Ichneumon purpuripennis* Cresson, 1877. Other native species of wasps were collected in and around the trap sites, but identification will have to wait for specialists.
LEPIDOPTERA Crambidae (Crambid Moths) *Eudonia* (5 species) *Mestolobes minuscula* (Butler, 1881) *Mestolobes* sp.	The crambids are a diverse group of mostly small moths, which are exceptionally well-represented in Hawai‘i (206 named species). The genus *Mestolobes* with 33 species is endemic to Hawai‘i. *Mestolobes minuscula* (Butler, 1881) is a common moth in the lowlands yet nothing is known of its biology. Adults of many *Eudonia* species resemble the lichens upon which they rest, and the larvae are probably associated with lichens. There are over 100 species in the genus, but many remain undescribed.
Geometridae (Inchworms) *Eupithecia monticolens* Butler, 1881 *Scotorythra artemidora* Meyrick, 1899 *Scotorythra brunnea* (Warren, 1896) *Scotorythra euryphaea* Meyrick, 1899 *Scotorythra pachyspila* Meyrick, 1899	The genus *Scotorythra* contains 38 species, all endemic to the Hawaiian Islands. Two species, *S. diceraunia* Meyrick, 1928 and *S. euryphaea* Meyrick, 1899 are new records for the island of Hawai'i. Specimens of the predatory inchworm *Eupithecia monticolans* Butler, 1881 were also trapped.
Lycaenidae and Nymphalidae (Blue and Brush-footed Butterflies) *Vanessa tameamea* Eschscholtz, 1821	Only two species of butterflies are native to Hawai‘i, a blue (Blackburn's butterfly, or *Udara blackburni* (Tuely, 1878), which feeds on koa, a'alii and other legumes) and an admiral or brush-footed butterfly (Kamehameha butterfly or *Vanessa tameamea* Eschscholtz, 1821, which feeds on mamaki and other Urticaceae). Both species are locally common where their hosts are found. Only the Kamehameha butterfly was observed flying near both trapping sites.
ODONATA Coenagrionidae (Damselflies) *Megalagrion hawaiiense* (McLachlan, 1883)	There are 29 species in the endemic genus *Megalagrion*. *M. hawaiiense* (McLachlan, 1883) was frequently encountered in rain puddles throughout the Reserve. The historic record yielded 5 other species of damselflies known to inhabit the Reserve. *M. calliphya microdemas* (Perkins, 1899), *M. peles* (Perkins, 1899) and two alien species: *Enallagma civile* (Hagen, 1862) and *Ischnura ramburii* (Selys-Longchamps).
ORTHOPTERA Gryllidae (Crickets) *Laupala* spp. *Paratrigonidium* sp.	There are 243 native species of crickets known from Hawaii (Otte 1994), which is more than twice as many as the total number known from the rest of the United States. Most native species have restricted ranges; some are known from only small areas within single islands. Their great diversity makes them ideal for evolutionary studies (Otte, 1994). Hawaiian crickets live mostly in trees and shrubs, but some forage in the leaflitter. Most are omnivores, feeding on both plant and animal material. Two native genera of swordtail crickets (*Trigonidium* and *Laupala*) were collected in Pu‘u Maka‘ala.

PU‘U MAKA‘ALA NAR: SOCIOCULTURAL RESOURCES

Land Use

All of Pu‘u Maka‘ala NAR is located within the State Conservation District. The Reserve includes both the Protective and Resource Subzones. Conservation District Use Permit no. SH-3/9/81-1340 approves the creation and management of the NAR as a permitted use of the Conservation District. Under the 2005 Hawai‘i County General Plan, all of Pu‘u Maka‘ala is designated as Conservation by the Land Use Pattern Allocation Guide. The area is not within the County’s Special Management Area. The Pu‘u Maka‘ala Management Plan is consistent with or implements portions of numerous existing plans and cooperative efforts (Table 4).

In July 2009, the Division of Public Safety announced the closure of the 7,244 acre (2,932 ha) Kūlani Correctional Facility. In May 2010, The NARS Commission recommended the addition of portions of Kūlani to Pu‘u Maka‘ala NAR, which was approved by the Board of Land and Natural Resources (BLNR) in September 2010. In November 2010, the Governor signed Executive Order 4338 adding 6,600 ac (2,671 ha) of Kūlani to Pu‘u Maka‘ala NAR.

The Kūlani portion of the NAR surrounds approximately 600 ac (243 ha) of state lands formerly used by Kūlani Correctional Facility. The main campus of the former Kūlani Correctional Facility (approximately 280 ac (113 ha)) is being used by DOD-YCA under a revocable permit from DLNR (Figure 15). DOFAW has access, utility and conservation easements over this area, and DOD-YCA and DOFAW have a memorandum of agreement regarding access by DOFAW over the internal roads, conservation management, road maintenance, and conditions under which public access will be permitted, etc. DOD-YCA is planning to use these lands until the State Division of Public Safety reopens Kūlani Correctional Facility. DOFAW will be requesting approximately 342 ac (138 ha) of former pasture as an addition to Pu‘u Maka‘ala NAR (Figure 15). DOFAW currently has a right of entry permit for this area for data collection, survey and conservation management while this request is processed. This area is a high priority for addition to the NAR due to the recovery of ‘ōhi‘a - koa forests following the removal of cattle in 2005 and the presence of rare and endangered plants and animals.

Public access is allowed in the NAR for recreational and cultural uses. Current public use of Pu‘u Maka‘ala primarily includes hiking, bird watching, and hunting. Hunting in portions of the NAR is regulated by Chapter 13-123, Hawaii Administrative Rules (Rules Regulating Game Mammal Hunting), and areas where hunting is allowed are designated as part of Hunting Unit K. Some uses, including hiking or nature study with groups larger than ten, research, scientific collecting, gathering (including Native Hawaiian religious and customary gathering rights) and commercial uses require a Special Use Permit from the Executive Secretary of the NARS Program in Honolulu (808-587-0063) (Hawai‘i Administrative Rules 13-209).

Table 4. Consistency with other plans and cooperative efforts.

Plan/Cooperative Effort	Comment
The Rain Follows the Forest - A Plan to Replenish Hawaii's Source of Water (DLNR, November 2011)	The Reserve is identified as a priority watershed area on the island of Hawai‘i
DOFAW Statewide Assessment and Resource Strategy (SWARS) 2010	Identifies areas of greatest need and opportunity for forests in Hawaii and develops a long-term strategy for management. Objectives include: 1.1. Identify and conserve high-priority forest ecosystems and landscapes; 2.2. Identify, manage and reduce threats to forest and ecosystem health; 3. 3. Enhance public benefits from trees and forests; 3.1. Protect and enhance water quality and quantity; 3.5. Protect, conserve and enhance wildlife and fish habitat; 3.7. Manage and restore trees/forests to mitigate and adapt to global climate change.
U.S. Fish and Wildlife Designation of Critical Habitat for 12 Species of Picture-Wing Flies From the Hawaiian Islands (2009)	Supports recommendations for habitat management for *Drosophila mulli*
Three Mountain Alliance (TMA) Management Plan (2008) and TMA Weed Management Plan (2009)	Supports mission and goals of the TMA watershed partnership and TMA weed management
Puna Community Development Plan (2008)	Mentions Pu‘u Maka‘ala NAR and discusses the importance of preserving native forests and species.
U.S. Fish and Wildlife Revised Recovery Plan for Hawaiian Forest Birds (2006)	Supports recovery actions 1 and 2: protect and manage ecosystems for the benefit and recovery of forest birds.
Hawai‘i Comprehensive Wildlife Conservation Strategy (2005)	Implements objectives 1, 2, 3, 4, and 5
County of Hawai‘i General Plan (2005)	8.2(c) Protect and promote the prudent use of Hawaii's unique, fragile, and significant environmental and natural resources. 8.2 (d) Protect rare or endangered species and habitats native to Hawai‘i. 8.3 (b) Encourage a program of collection and dissemination of basic data concenrning natural resources. 8.3 (e) Encourage an overall conservation ethic in the use of Hawai‘i resources by protecting, preserving, and conserving the critical and significant natural resources of the County. 8.3 (o) Encourage the continued identification and inclusion of unique wildlife habitat areas of native Hawaiian flora and fauna with the NARS.
U.S. Fish and Wildlife Final Designation and Nondesignation of Critical Habitat for 46 Plant Species From the Island of Hawaii, HI (2003)	Supports recommendations for habitat management for *Sicyos alba*, *Cyrtandra giffardii*, *Cyanea stictophylla*, and *Phyllostegia velutina*
U.S. Fish and Wildlife Service Recovery Plan for the Multi-Island Plants (1999)	Supports objective 1: protect habitat and control threats for *Adenopherus periens*
U.S. Fish and Wildlife Service. Big Island II: Addendum to the Recovery Plan for the Big Island Plant Cluster (1998a)	Supports objective 1: protect current populations and manage threats for *Phyllostegia racemosa*, *Phyllostegia velutina* and *Sicyos alba*.
U.S. Fish and Wildlife Service Final Recovery Plan for Four Species of Hawaiian Ferns (1998b)	Supports objective 1: protect current populations and manage threats for *Asplenium peruvianum* var. *insulare*
U.S. Fish and Wildlife Recovery Plan for the Hawaiian Hoary Bat (1998c)	Supports objective 2: protect and manage current populations and identify and manage threats
U.S. Fish and Wildlife Recovery Plan for the Big Island Plant Cluster (1996)	Supports objective 1: protect current populations and manage threats for *Clermontia lindseyana*, *Clermontia peleana*, *Cyanea copelandii*, *Cyanea stictophylla*, *Cyrtandra giffardii*,and *Cyrtandra tintinnabula*.

Cultural Resources

In 2004, Kumu Pono Associates prepared *He Moʻolelo ʻĀina: A Cultural Study of the Puʻu Makaʻala Natural Area Reserve, District of Hilo and Puna, Island of Hawaiʻi*, a detailed study of historical and archival literature and limited oral history interviews and consultation with kamaʻaina and others with knowledge of the land. This document is an important reference for cultural resources management in the NAR. Excerpts from the study are included below.

> "The Natural Area Reserve takes its name from Puʻu Makaʻala, literally, Stay-alert Hill—named by State Forester, Ralph Daelher in the early 1960s—the summit of which is situated a little more than 3,600 feet above sea level. While the name of the *puʻu* is of recent origin, no older name identifiable with the hill was located. Many *puʻu* on the uplands slopes of the Hilo and Puna Districts are named, and it is likely that in traditional times this hill too had a name or names, depending on the area it was viewed from.
>
> The native traditions and historical accounts associated with the neighboring lands of the upper Hilo-Puna forests span many centuries, from Hawaiian antiquity to the later period following western contact. The narratives describe customs and practices of the native people who resided on these lands, walked the trails, and who were sustained by the wealth of the forest lands.
>
> Among the most detailed descriptions of the Hilo-Puna forest lands, including documentation of traditional and customary rights, are those found in the Kingdom collections, documenting the history of land tenure, and defining the boundaries of *ahupuaʻa* of Waiākea and ʻŌlaʻa. Detailed oral testimonies from elder native tenants were taken in court proceedings of the mid to late 1800s, document the occurrence of traditional and customary practices, and nature of the resources within given *ahupuaʻa*. In those records, we learn of the traditional knowledge and occurrence of native practices in the lands which today are a part of, and adjoin the Puʻu Makaʻala NAR.
>
> Because the lands of the upper ʻŌlaʻa and Waiākea region were remote, it appears that access was most frequently made by specialists in the collection of bird feathers, the makers of canoes, and collectors of other unique items for which the region may have been known. Except for the detailed narratives of the tradition of Pikoi-a-ka-ʻalalā, most other traditions, and early historical accounts by native Hawaiians, seem to place the routes of travel beyond the limits of the lands within the Puʻu Makaʻala NAR. The main routes being out of Hilo through ʻŌlaʻa, *mauka*, near its boundary with Keaʻau, or mauka between Kīlauea, across Keauhou (of Kapāpala in Kaʻū), within view of the boundary between ʻŌlaʻa (Puʻu Kūlani), and out across the Waiākea and Humuʻula lands of the Hilo District. Thus, there appears to be little specific reference in the historical record to the immediate study area lands.
>
> From the journals, letters, and articles of historic visitors traveling the routes mentioned above, we are given a glimpse into the nature of the landscape, and a record of changes thereon, with the passing of time. As outlying lands were changed—resulting from the impacts of introduced grazing animals, and in some instances from lava flows of Mauna Loa—we develop a sense of why the Puʻu Makaʻala NAR is important to the future well-

being of the Hawaiian natural environment. The NAR is a remnant of the unique cultural and natural landscape as described in the traditional accounts.

In Hawai‘i prior to western contact, all land, ocean and natural resources were held in trust by the high chiefs (*ali‘i ‘ai ahupua‘a* or *ali‘i ‘ai moku*). The use of land, fisheries and other resources was given to the *hoa‘āina* (native tenants) at the prerogative of the *ali‘i* and their representatives or land agents (*konohiki*), who were generally lesser chiefs as well. By 1845, the Hawaiian system of land tenure was being radically altered, and the foundation for implementing the *Māhele ‘Āina* (a fee simple right of ownership) was set in place by Kauikeaouli (Kamehameha III). Following implementation of the *Māhele*, the King also initiated a land grant program, issuing fee simple "Royal Patents" on granted land. In addition to the sale of fee-simple interests in land, the Crown and Government lands were also made available for leases and, in some cases, for sale. Together, these three land programs opened the door for the development of the large ranching interests in the lowlands below ‘Ōla‘a and Waiākea, and on the Keauhou-Kapāpala forest lands. Because of the remote nature of the lands and dense forests of the ‘Ōla‘a-Waiākea lands that make up the Pu‘u Maka‘ala NAR, no leases or conveyances were recorded for those lands. This said, it is likely that Hawaiian visitation collection of resources associated with traditional and customary practices continued in the Pu‘u Maka‘ala NAR lands for some time through the middle to late 1800s.

In 1862, a Commission of Boundaries (the Boundary Commission) was established in the Kingdom of Hawai‘i to legally set the boundaries of *ahupua‘a* that had been awarded to *Ali‘i, Konohiki*, and foreigners during the *Māhele*. In 1874, the Commissioners of Boundaries were authorized to certify the boundaries for lands brought before them (W.D. Alexander in Thrum 1891:117-118). The primary informants for the boundary descriptions were old native residents of the areas being discussed (generally born between the 1780s to 1820s).

Native testimonies describe a wide range of traditional practices in the uplands of Waiākea, ‘Ōla‘a, and in adjoining lands. The types of usage includes: travel on native trails, land use in a wide range of elevational zones; collection of resources; the collection of, or "hunting" of birds; canoe making; and the subsequent practices associated with hunting introduced ungulates—all under the control of *Konohiki*. In regards to hunting, it will be noted that descriptions of traditional hunting practices are limited to native species of birds, including the *ua‘u, nēnē, mamo* and *‘ō‘ō*; while description of historical hunting practices are limited to goats, which were hunted under contract of *Konohiki*, the Crown, or the Government. The testimonies also record that changes had occurred on the landscape during the lifetime of the witnesses. It is of importance to note that the boundaries were known by the native tenants, and the rights to take or hunt resources in traditional times were fiercely protected—individuals without chiefly, genealogical claims, or residency ties to given lands were not allowed to trespass and take resources from the *ahupua‘a*.

Our review of more than 60,000 native Hawaiian land documents dating from 1846 to 1910 revealed many references to *pua‘a* (pigs), but nearly every reference was in the context of them being near-home and as being cared for (raised), not hunted. In the same review of the native Hawaiian land documents and a large collection of writings from native authors (e.g.,

D. Malo, 1951; J.P. Ii, 1959, S.M. Kamakau 1961, 1964 & 1976), every reference to traditional collection or "hunting" (a word seldom used in the historical records), was in the context of native birds—those used either for food or from which feathers were collected for royal ornaments and symbolic dress.

After ca. 1815, we find that when native Hawaiians went hunting in the uplands—as described in testimonies and historical texts of the time—they were hunting bullocks, goats and other introduced grazers, and this was generally done on the demand of their landlords, and later for the growing ranches being established in the islands. The first full-scale efforts of western-style hunting in the Humuʻula-Waiākea and Keauhou (Kaʻū) region does not appear in reference until around 1840 (cf. Kamakau, 1961; Government Communications in this study). Those early outings were focused on collection of hides and tallow; and controlling wild herds of animals that were a threat to travelers, agricultural fields, residences, and forest resources.

Because of the remote nature of the ʻŌlaʻa and Waiākea forest lands which comprise the present-day Puʻu Makaʻala NAR, no government communications pertaining to historic trails or government road projects exist for the region. Boundary Commission testimonies describe trails through the forest lands, rising from the lowlands of Waiākea, ʻŌlaʻa, Keauhou and Humuʻula. Based on the native traditions and *kamaʻāina* testimonies, it is likely that "practitioner" trails existed throughout the forest region. Features such as "*kauhale manu*" (bird-catcher's shelters), "*kahua kalaiwaa*" (canoe-makers clearings), "*oioina*" (trailside resting places and shelters), the "*ala hele*" (trails), and other features associated with traditional and customary accesses, would leave little evidence in the present-day, as the traditional features and uses generally had minimal impact on the natural landscape. Those things left behind, not cared for or maintained, were simply reabsorbed into the landscape.

In the early 1900s, the Hilo and ʻŌlaʻa forest lands were determined to be of significance, and worthy of protection. In between 1905 to 1928, the lands of the ʻŌlaʻa and Waiākea Forest Reserves, and the neighboring Kīlauea Forest Reserve were dedicated to the public interest as unique natural resources.

It appears that it was not until the late 1940s, that a road was cut up through the Waiākea-ʻŌlaʻa forest lands, and this in conjunction with the opening of the Kūlani Prison Farm.

Hawaiian traditions and beliefs, shared spiritual and familial relationships with the natural resources around them. Each aspect of nature from the stars in the heavens, to the winds, clouds, rains, growth of the forests and life therein, and everything in the land and in the ocean, was believed to be alive. Indeed, every form of nature was a body-from of some god or lesser deity. As an example, in this context, and in association with lands which are now included in a part of the landscape of the Puʻu Makaʻala NAR, we find the Kū-ka-ʻōhiʻa-Laka, is a defied guardian of the *ʻōhiʻa* growth of ʻŌlaʻa; *Ua-kuahine*, is the body form of a goddess of the rains in ʻŌlaʻa; and *Kū-lili-ka-ua* is the god of the thick mists that envelop the forests of the upper Puna, Waiākea, and Keauhou lands. Indeed, tradition also tells us that the gods and goddesses of these forest lands were very protective of them. In olden times,

travel through them was accompanied by prayer, and care. Traditions tell us that many a careless traveler, or collector of resources, found themselves lost in a maze of overgrowth and dense mists, for disrespectful and careless actions.

In the Hawaiian mind, care for each aspect of nature, the *kino lau* (myriad body-forms) of the elder life forms, was a way of life. This concept is expressed by Hawaiian *kūpuna* (elders) through the present day, and is passed on many native families. When discussing the relationship of native families with the lands and resources around them, it is not uncommon to hear *kūpuna* express the thought — *"E mālama i ka ʻāina, a e mālama hoʻi ka ʻāina iā ʻoe! E mālama i ke kai, a e mālama hoʻi ke kai iā ʻoe!"* (Care for the land, and the land will care for you! Care for the sea, and the sea will care for you!). This concept is one that is centuries old and is rooted the spirituality of the Hawaiian people. Importantly, the converse is that when one fails to care for, or damages nature—the *kino lau*—around them, they are in-turn punished. This is expressed in many traditional sayings, one being, *"Hana ʻino ka lima, ʻai ʻino ka waha!"* (When the hands do dirty-defiling work, the mouth eats dirty-defiled food!). In this cultural context, anything which damages the native nature of the land, forests, ocean, and *kino lau* therein, damages the integrity of the whole.

Writing in the late 1860s and early 1870s, native historian, S.M. Kamakau, related to readers some aspects of the Hawaiian association and understanding of the mountain lands and forests. While describing traditional knowledge of the divisions of land, Kamakau wrote:

> Here are some other divisions of the islands, together with their descriptive names.
>
> Heights in the center or toward the side of a land, or island, are called *mauna*, mountains, or *kuahiwi*, "ridge backs." The highest places, which cover over with fog and have great "flanks" behind and in front (*kaha kua, kaha alo*)—like Mauna Kea—are called *mauna*; the place below the summit, above where the forests grow is the *kuahiwi*. The peak of the mountain is called *pane poʻo* or *piko*; if there is a sharp point on the peak it is called *puʻu pane poʻo*; if there is no hill, *puʻu*, and the peak of the mountain spreads out like the roof of a house, the mountain is described as a *kauhuhu mauna* (house ridgepole mountain); and if there is a precipitous descent, *kaolo* [from the peak] to the *kauhuhu mauna* below this is called a *kualo* ("block"). If there are deep ravines (*ʻalu haʻahaʻa*) in the sides of the mountain it is called a *kihi poʻohiwi mauna* ("shoulder edge" mountain). A place that slopes down gradually (*hamo iho ana*) is called a *hoʻokuʻu* (a "letting down"); a sheer place is called a *pali lele koaʻe* (cliff where *koaʻe* birds soar), or a *holo* ("slide"), or a *waihi* (a "flowing down"). Rounded ridges that extend from the mountains or "ridge backs" or hills are called *lapa* or *kualapa* or *moʻo*—and, if they are large, *ʻolapalapa* or *ʻomoʻomoʻo*. Depressions between *lapa* or *moʻo* are *awawa*, valleys.
>
> Here are some names for [the zones of] the mountains—the *mauna* or *kuahiwi*. A mountain is called a *kuahiwi*, but *mauna* is the overall term for the whole mountain, and there are many names applied to one, according to its delineations

(*ʻano*). The part directly in back and in front of the summit [Kamakau 1976:8]
proper is called the *kuamauna*, mountaintop; below the *kuamauna* is the *kuahea*, and *makai* of the *kuahea* is the *kuahiwi* proper. This is where small trees begin to grow; it is the *wao nahele*. *Makai* of this region the trees are tall, and this is the *wao lipo*. *Makai* of the *wao lipo* is the *wao ʻeiwa*, and *makai* of that the *wao maʻukele*. *Makai* of the *wao maʻukele* is the *wao akua*, and *makai* of there the *wao kanaka*, the area that people cultivate. *Makai* of the *wao kanaka* is the *ʻamaʻu*, fern belt, and *makai* of the *ʻamaʻu* the *ʻapaʻa*, grasslands.

A solitary group of trees is a *moku laʻau* (a "stand" of trees) or an *ulu laʻau*, grove. Thickets that extend to the *kuahiwi* are *ulunahele*, wild growth. An area where *koa* trees suitable for canoes (*koa waʻa*) grow is a *wao koa* and *mauka* of there is a *wao laʻau*, timber land. These are dry forest growths from the *ʻapaʻa* up to the *kuahiwi*. The places that are "spongy" (*naele*) are found in the *wao maʻukele*, the wet forest.

Makai of the *ʻapaʻa* are the *paheʻe* [*pili* grass] and *ʻilima* growths and *makai* of them the *kula*, open country, and the *ʻapoho* hollows near to the habitations of men. Then comes the *kahakai*, coast, the *kahaone*, sandy beach, and the *kalawa*, the curve of the seashore—right down to the *ʻae kai*, the water's edge.

That is the way *ka poʻe kahiko* named the land from mountain peak to sea. [Kamakau 1976:9]

Among the native terms listed by Kamakau above, is one which stands out in reference to the Waiākea-ʻŌlaʻa forest lands of the Puʻu Makaʻala NAR—this zone is the wao *akua* (zone or region of the gods and deities). The *wao akua* is so named because of the pattern of cloud cover and precipitation which settles upon the mountain slope—this covering was interpreted as concealing from view the activities of the gods and deities therein (cf. David Malo 1959:16-18; and M.K. Pukui, pers. comm. 1975).

In the traditional context above, we find that the mountain landscape, its' native species, and the intangible components therein, are a part of a sacred Hawaiian landscape. Thus, the landscape itself is a highly valued cultural property. Its protection, and the continued exercise of traditional and customary practices, in a traditional and customary manner, are mandated by native custom, and State and Federal Laws (as those establishing the ʻŌlaʻa and Waiākea Forest Reserves, the Puʻu Makaʻala NAR, and the Endangered Species Act).

In this discussion, protection does not mean the exclusion, or extinguishing of traditional and customary practices, it simply means that such practices are done in a manner consistent with cultural subsistence, where each form of native life is treasured and protected. *Kūpuna* express this thought in the words, *"Hoʻohana aku, a hoʻōla aku!"* (Use it, and let it live!)."

Additional information on the cultural resources of the Reserve is contained in cultural study for Keauhou, an adjacent area (Maly 2005). This study contains boundary commission testimonies for Keauhou and includes descriptions of adjacent areas, including Kūlani (Kūlani Cone and

Puʻu Kipu); the history of the establishment of the ʻŌlaʻa, Waiākea and Kīlauea Forest Reserves; and a description of Kūlani Cone by Joseph Rock in 1919.

Archaeological and Historic Sites

The State Historic Preservation Division has no records of historic properties or archeological sites from Puʻu Makaʻala NAR. Most of this dense forest area has not been surveyed for sites. Previous archeological surveys for fence construction projects did not identify any archeological sites. Trails, small forest shrines, burial caves and lava tube shelters are the types of features that may be present, as the greater area was used historically by Hawaiians for activities such as bird hunting, harvesting timber for canoe-making and gathering forest plants for medicinal uses.

In a study for a sewage treatment plant for Kūlani Correctional Facility, Rechman (2001) reported that project site falls within the rainforest zone as defined by McEldowney (1979). The archeological expectations for the general area are very limited. Pre-contact period bird catchers may have ventured into the forest seasonally and established temporary residences. Such sites would have been constructed of perishable materials.

Rechman's report (2001) noted that the summit of Puʻu Kūlani or Kūlani Cone marks the traditional land divisions of South Hilo, Puna and Kāʻu and this Puʻu should be considered a cultural property due to references in chant and legend.

The Puu ʻŌʻō trail, a historic cattle crossing route from Keauhou to Humuʻula, is just above the Kūlani portion of the Reserve.

The Kūlani portion of the Reserve was used since 1946 as a prison camp, and certain areas were used for logging, ranching and other activities. Hawaiʻi Tribune Herald newspaper printed a series of articles on the history of Kūlani Correctional Facility and Kūlani Rd by Kent Warshauer in 2001. The Kūlani road was completed in 1945 by prison work crews from Waiākea prison camp, which was moved to Kūlani in 1946. The road from the main facility complex to an area that would become Mauna Loa Boys School, a home for delinquent boys, was was completed in 1946. Construction of the Boy's School was completed in 1952 and the facility opened as Mauna Loa Forestry Camp - modeled after the Civilian Conservation Corps camps. One proposed activity for the boys would be to plant koa and naio to replace timber cut by Kūlani inmates. The Camp had numerous issues with boys escaping, including the fatality of one boy. When Territorial House members toured the camp in 1953 they called the project "one of the most expensive and impractical projects ever constructed in the Territory of Hawaiʻi," and they closed the facility later that year. Since closure the facility was used intermittently by Kūlani Correctional Facility and by the military for training.

Warshauer (2002) also wrote about the history of the Army Rd area of the Reserve, which was used by the military from 1964 - 1970 for the testing of chemical and biological weapons.

Infrastructure

Infrastructure within Puʻu Makaʻala NAR primarily consists of roads, unimproved trails, and fencing. No recreational facilities (e.g., bathrooms, freshwater sources, improved campsites) exist within Puʻu Makaʻala NAR.

Public access into the NAR is primarily via Wright Road or Stainback Highway (Figure 11).

DOFAW has an access, utility and conservation easement for staff management purposes through the internal roads of the Kūlani Facility (area under revocable permit to DOD-YCA).

The Reserve contains the Mauna Loa Boy's School facility which has not been maintained and is in currently in severe disrepair. Other former correctional facility infrastructure is also present in the Reserve (e.g. old ranch fencing, water tanks, water catchments, and roads).

Regional Partnerships

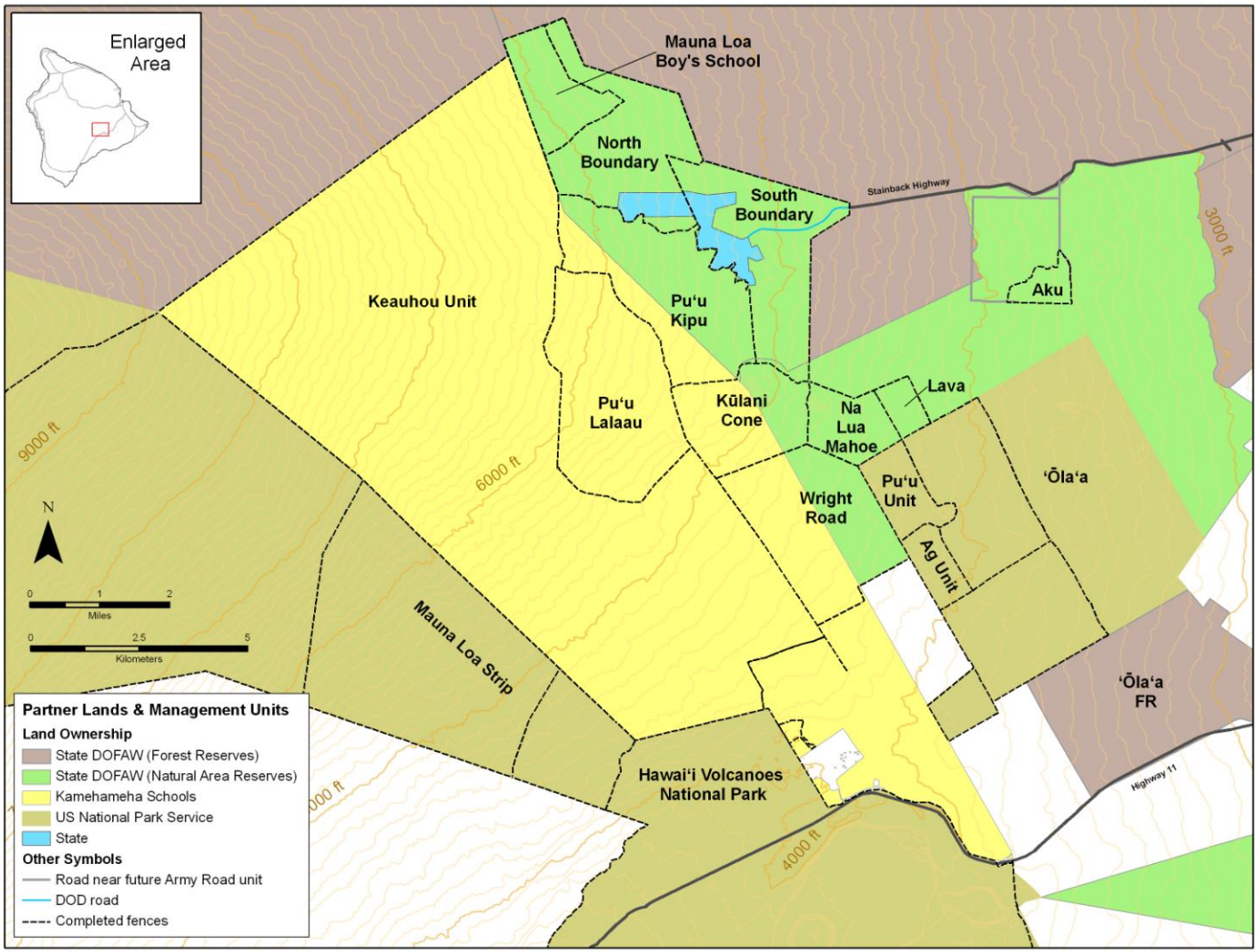
Existing management of Puʻu Makaʻala NAR has significantly benefited from cooperation with adjacent landowners, particularly the ʻŌlaʻa -Kīlauea Partnership (now called the Three Mountain Alliance (TMA)) (Figure 5). The TMA is a voluntary public-private partnership of landowners and agencies with a management interest in the landscape and a goal to coordinate conservation management on a landscape level. The overall management goal of TMA is to sustain the multiple ecosystem benefits, provided by the three mountains of Kīlauea, Mauna Loa, and Hualālai, by responsibly managing its watershed areas, native habitat and species, historical, cultural, and socio-economic resources for all who benefit from the continued health of the three mountains.

The intact montane native forest area including Puʻu Makaʻala was the initial focus of the TMA and forms the core of conservation management in the region. The TMA assisted with the construction and maintenance of existing fencing, including fencing at Kūlani, and collaboration with the TMA has increased the effectiveness of monitoring, weed and ungulate control efforts in the NAR. Fencing at Puʻu Makaʻala is linked to fencing in adjacent areas (Kamehameha Schools lands and Hawaiʻi Volcanoes National Park) to make a much larger protected area, enhancing joint management for conservation across the larger landscape. Three fenced units in the NAR cross ownership boundaries and include both NAR and Kamehameha Schools lands (Puʻu Kipu, Kūlani Cone and Wright Rd. units) (Figure 5). These units were constructed to take advantage of existing roads and cleared areas and protect native forest on an ecosystem level rather than by land ownership.

TMA partners including NAR staff have fenced and removed ungulates from over 14,000 ac (5,666 ha), and ungulate control work is underway in an additional 20,000 ac (8,094 ha) that has already been fenced. These units on Puʻu Makaʻala NAR and Kamehameha Schools lands (Keauhou and Kīlauea) are adjacent to an additional 15,000 ac (6,070 ha) of existing fenced management units in Hawaiʻi Volcanoes National Park (ʻŌlaʻa Tract and Mauna Loa Strip Road) (Figure 5). The fenced units include some of the best quality native forest in Hawaiʻi, and they are now being used as recovery areas for native ecosystems and rare and endangered species.

TMA members are collaborating on numerous management initiatives in addition to fencing and ungulate control including weed control, rare plant reintroduction, forest bird monitoring, reforestation and educational programs.

Figure 5. Three Mountain Alliance Land Ownership and Management Units.



SUMMARY OF MAJOR THREATS

Invasive Species - Ungulates

The primary ungulates of concern in Puʻu Makaʻala are feral pigs, although feral goats (*Capra hircus*), feral sheep (*Ovis aries*) and mouflon sheep (*Ovis musimon*) are known from adjacent lands and could potentially become a threat to the NAR in the future. Feral pigs destroy native vegetation and prevent its regeneration by eating, trampling, and digging up plants, and may accelerate the invasion of weed species by dispersing seeds on their coats and in their droppings. Pig disturbance of native ground cover through rooting and wallowing facilitates the invasion and establishment of weeds. In addition, pig wallows and pig- hollowed out hāpuʻu trunks provide mosquito-breeding sites that can promote the spread of avian diseases such as avian malaria and pox – the two most deadly diseases for native forest birds. The continued presence of feral pigs contributes to loss of native plants and loss of ground cover that adversely affects groundwater retention.

Portions of Puʻu Makaʻala NAR are designated as part of Hunting Unit K under Chapter 13-123, Hawaii Administrative Rules (Rules Regulating Game Mammal Hunting). Hunters should check with the DOFAW office (19 East Kawili Ave., Hilo, HI 96720) to get current information on hunting rules and any changes in special conditions, bag limits, seasons and open areas.

Invasive Species - Plants

Invasive non-native plants, or weeds, constitute a severe threat to the native ecosystems in the NAR. Certain priority weeds are problematic because they can establish and survive in undisturbed native forest; disperse long distances via wind or birds; affect large portions of land; displace native vegetation; grow and reproduce rapidly; convert diverse assemblages of native plants to monocultures of alien species; and encourage fire by increasing fuels on formerly natural fire breaks (i.e. lava flows). These weeds can displace distinctive native flora, resulting in a loss of species diversity and eventually in more pronounced and permanent changes to ecosystem function such as alteration of primary productivity and nutrient cycling. Many invasive weed species completely replace native vegetation resulting in total loss of native habitats thereby negatively affecting native bird, arthropod and snail communities.

Invasive weeds with great potential for spreading and causing habitat modification are identified in this plan as high priority for control or eradication. Weed species were prioritized based on observed invasiveness and other criteria including growth form, dispersal mechanisms, ability to displace native vegetation and ability to alter ecosystem cycles (water, nutrients and succession). High priority invasive weeds currently present in Puʻu Makaʻala include:

- Strawberry guava (*Psidium cattleianum*)
- Banana poka (*Passiflora tarminiana*)
- Himalayan raspberry (*Rubus ellipticus*)
- Cane tibouchina (*Tibouchina herbacea*)
- Kāhili ginger (*Hedychium gardnerianum*)
- Palm grass *(Setaria palmifolia)*

- Australian tree fern *(Sphaeropteris cooperi)*
- Clidemia or Koster's curse *(Clidemia hirta)*
- Tropical ash (*Fraxinus uhdei*)
- Silver-leaf cotoneaster *(Cotoneaster pannosus)*

Other weed species are not considered as highly threatening in the NAR as those listed above but are still a problem in localized areas. These weeds will be controlled during weed control work (e.g. Japanese anenome (*Anemone hupehensis*), *Selaginella kraussiana*, blackberry (*Rubus argutus*) and thimbleberry (*Rubus rosifolius*)) but are not generally a target of management.

Additional weed species that are a serious concern to land managers are present in adjoining areas and have not yet been detected in the NAR. It is a high priority to prevent the establishment of these species in the NAR. Species of concern include but are not limited to miconia (*Miconia calvescens)* and night-blooming jasmine *(Cestrum nocturnum).* Other weed species may be added to the NAR priority weed list if monitoring shows their range and abundance increasing in native ecosystems targeted for management.

ʻŌhiʻa dieback has been observed in Puʻu Makaʻala, particularly at lower elevations. Dieback is a natural successional phenomenon in which old stands of trees die synchronously, leaving gaps in the forest canopy. The gaps created in the forest canopy by dieback provide an opportunity for the invasion of non-native weeds which prevents regeneration by ʻōhiʻa and other native plants.

Invasive Species - Other Animals

A variety of non-native small animals have the potential to become serious pests to the biodiversity found in Puʻu Makaʻala. Feral cats, rats, mice, mongoose, dogs, birds, amphibians and reptiles are known to consume or compete with native species and may contribute the spread of invasive weeds. Feral cats kill birds, which nest, feed, and roost in trees, as well as native sea birds and other species that nest on the ground or in burrows. Rats prey on native birds (particularly females on the nest), eggs, nestlings, native land snails and endemic invertebrates and are also known to eat the seeds, fruits and/or strip the bark of native plants. The NAR has been invaded by non-native forest birds (e.g. Japanese white-eye, northern cardinal, Japanese bush warbler (*Cettia diphone*) and other species). Non-native birds may compete with native forest birds for food and other resources and act as reservoirs for avian diseases. Non-native birds also contribute to the spread of weeds by eating the fruits of weedy species (e.g. yellow Himalayan raspberry, banana poka and kāhili ginger) and spreading seeds. Both Jackson's chameleon (*Chamelaeleo jacksonii*) and coqui frogs (*Eleutherodactylus coqui*) have growing populations in areas adjacent to the NAR, and these species can consume native invertebrates, such as insects, spiders, and small snails.

Non-native invertebrates are present, but largely undocumented, and can consume native plants, interfere with plant reproduction, predate or act as parasites on native species, transmit disease, affect food availability for native birds, and disrupt ecosystem processes. The invasion of the yellowjacket wasp (*Vespula pennsylvanica*), voracious predators of numerous species of native invertebrates, is of concern, and these wasps have been implicated in the local extinction of two

species of endemic *Drosophila* in the adjacent ʻŌlaʻa Tract. Slugs (*Milax gagates*, *Limax maximus*, *Veronicella* spp.) consume fruit from native plants and prey on seedlings and mature plants. The two-spotted leafhopper (*Sophonia rufofascia*) is a major concern for the *uluhe* fern, which is particularly sensitive to leafhopper feeding. Mosquitoes (*Aedes albopictus* and *Culex quinquefasciatus*) transmit deadly diseases to native birds.

Fire

Due to the high rainfall in most portions of Puʻu Makaʻala, fire is not normally a concern in the NAR. However, fire does pose a threat to the NAR, particularly in the drier portions of Kūlani during times of drought and in roadside areas accessible to human activity. Continued feral ungulate damage to native ecosystems can covert native forest to non-native grasses and shrubs, which are more vulnerable to fires causes by lightning strikes or humans. Wildfires leave the landscape bare and vulnerable to erosion and non-native weed invasions. Hawaii's flora evolved with infrequent, naturally-occurring episodes of fire, so most native species are not fire-adapted and are unable to recover well after wildfires. Alien plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire. The principal human-caused ignition threats are catalytic converters and other hot surfaces of vehicles or heavy equipment. Careless disposal of cigarettes also presents a very real threat. The principal natural ignition sources are lava flows and lightning.

Additional Threats - Disease, Climate Change, Volcanic Activity, Illegal Human Activity

Introduced diseases and pathogens can threaten both native animals and plants. The introduction of new diseases and pathogens, in addition to those currently known, is possible. Avian pox and avian malaria are mosquito-transmitted diseases that currently affect native Hawaiian birds. In the extreme isolation of the Hawaiian Islands, birds evolved in the absence of these diseases and lost their natural immunity. Avian pox is caused by a virus (*Avipoxvirus*) and avian malaria by a single-celled parasite (*Plasmodium relictum*). For some bird species infection with these diseases is almost always fatal.

Other diseases also pose threats to the watershed, humans and wildlife. Cats are host of a potentially fatal disease called toxoplasmosis. In Hawaiʻi, toxoplasmosis has killed native Hawaiian birds and also poses a threat to marine mammals. In addition to threatening wildlife, toxoplasmosis poses a significant health risk to pregnant women. Feral pigs can serve as reservoirs and vectors of diseases such as brucellosis and pseudorabies which are transmissible to humans, wildlife, pets and livestock. Pigs also spread fatal diseases such as fecal bacteria (*enterococcus*) and *Escherichia coli* (*E. coli*) and pigs and other small mammals spread leptospirosis.

Introduced plant diseases such as ʻōhiʻa rust (*Puccinia psidii*) and koa wilt have the potential to impact the major components of the forest throughout the NAR. ʻŌhiʻa rust affects other Myrtaceae taxa. In severe infections, growing tips wither and die back. Koa wilt is a serious, often fatal disease of the native tree koa. Trees affected with the disease rapidly lose their canopies and may die within a few months.

Climate change may affect the NAR through altering rainfall patterns and amounts. Changing climate may affect the abundance and seasonality of precipitation, thereby altering forest composition, growth and structure. Rare ecosystems and species may be affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Detrimental invasive species may change their distribution and abundance due to changes in the climate (e.g. mosquitoes may be more frequently found at higher elevations due to warming temperatures). Increases in mosquito populations in the upper elevations would increase the incidence of avian disease, negatively affecting remaining native forest bird populations.

Volcanic activity has the potential to impact the NAR as the Reserve is situated on Mauna Loa, an active volcano. The Reserve is on the northwest rift zone and is vulnerable to eruptions originating at vents on that flank. The Reserve is classified by USGS as being within lava hazard Zones 2 and 3. About 20 percent of the Zone 2 area has been covered by lava in historical time, 5 percent since 1950. The 1984 Mauna Loa flow came within a mile of Kūlani. Volcanic gases from nearby vents can cause high concentrations of gases that affect native plants, animals and people.

Illegal human activity occurs on a small scale, primarily in the form of illegal harvesting (maile, hāpuʻu, and other native trees and plants), vandalizing signs and fences and occasional illegal motorized vehicle use. Marijuana cultivation may also occur. These activities destroy infrastructure and native species. Some illegal activities create openings in the forest that can be invaded by weeds.

OVERVIEW OF EXISTING MANAGEMENT

In general, management at Puʻu Makaʻala has primarily included ungulate management (construction and maintenance of fencing and ungulate control), weed control and habitat protection, and rare species restoration. Major accomplishments from these management programs are summarized below. NAR staff also work on monitoring, education and outreach, and review special use permits for certain activities proposed in the NAR. A cultural study for the Reserve was completed in 2004.

Ungulate Management

Between 1991 and 2003, NAR staff and partners constructed nine fenced ungulate-proof management units totaling approximately 9,600 ac (3,885 ha) in the Kūlani and Puʻu Makaʻala sections of the Reserve, to protect the NAR from feral ungulates (Figure 5).

The Kūlani units (Mauna Loa Boys School, Puʻu Kipu, South Boundary and North Boundary) as well as Wright Road unit and the Kūlani Cone unit were constructed as projects of the ʻŌlaʻa - Kīlauea Partnership (now known as the TMA). The Wright Road unit, Puʻu Kipu unit and the Kūlani Cone unit each encloses a portion of the western edge of the NAR as well as a portion of adjacent Kamehameha Schools property in Kīlauea forest. These fenced areas are jointly managed by NARS staff and the TMA. Two additional fenced units (Na Lua Mahoe and Lava

Flow units) are adjoining the Wright Road and Kūlani Cone units to the east. Finally, the ʻAkū unit, in the Army Road area, protects the endangered ʻānunu (*Sicyos alba*).

NAR and TMA staff completed feral pig control in these nine units (Lava Flow, Na Lua Mahoe, Kūlani Cone, Puʻu Kipu, Wright Road,ʻAkū, Mauna Loa Boys School, South Boundary and North Boundary). These units have had all feral pigs removed and are currently pig-free.

Fence inspection and maintenance is a critical ongoing management activity. All fences are inspected and maintained on a monthly basis to monitor for and prevent pig ingress.

Weed Management

NAR staff and partners have monitored all species of non-native plants along four different sets of transects since 1988. Initially, 7.7 miles (12.4 kilometers (km)) of transect were monitored for weeds by the Hawaiʻi Heritage Program to gather information to support the development of a comprehensive management plan. In 1995, 17 miles (27 km) of new transects were installed across the higher elevation portions of the Reserve above 3,281 ft (1,000 m). As fenced units were built, additional finer scale transects were installed and monitored within specific units to document vegetation changes following ungulate removal including 2.5 miles (4.1 km) in ʻAkū Unit (2000, 2008) and 6.6 miles (10.6 km) in the NAR portion of the Wright Rd Unit (2003, 2006 and 2008). Na Lua Mahoe and Lava units were monitored for weeds in 2000. Figures 6 - 8 show weed presence for certain priority weed species along monitoring transects.

In the Kūlani portion of the Reserve, USGS monitored weeds along transects in Puʻu Kipu and Kūlani Cone and Mauna Loa Boy's School units for three years (1999-2001). These data provide a valuable baseline for weed distribution and abundance. USGS monitored each transect for presence or absence of 80 different weed species divided into three different priority groups and did cover estimates of weeds encountered. USGS staff also took incidental data on the presence of priority weeds during other survey and research work. Maps of priority weed distribution along the Kūlani transects are included in the TMA weed management plan http://hawp.org/_library/documents/three-mountain-alliance/tmaweedplanjune2009.pdf . The North and South Boundary units of the Kūlani portion of the NAR have never been systematically monitored for weeds.

NARS and USGS monitoring results indicate target weed densities are generally low (<5%) in the higher elevation (>4,199 ft (1,280 m)) fenced units (Puʻu Kipu, Mauna Loa Boys School, Kūlani Cone, Wright Rd, Na Lua Mahoe, and Lava Units) except localized populations of Himalayan yellow raspberry and banana poka, and weeds in open wetland sites and previously disturbed areas. Isolated individuals of kāhili ginger, strawberry guava, palm grass and Australian tree fern have been identified and controlled within these fenced units. Weed densities increase in lower elevations, particularly for banana poka, Himalayan yellow raspberry, strawberry guava, palm grass and cane tibouchina. Within the ʻAkū unit weed cover values are typically low, but many target weeds including strawberry guava are widely distributed throughout the unit.

Weed surveys and management are a critical second step following the removal of pigs. Weed management within Puʻu Makaʻala NAR is focused on the ungulate-free fenced units. The lowest

elevation portion of the Reserve, where fencing has not been proposed is highly weedy and is not currently managed for weeds unless high priority incipient weeds are detected (e.g. miconia). Early detection and rapid response weed monitoring/control is conducted quarterly along invasion corridors (e.g., roads, trails, and fence lines) in and adjacent to fenced management units. NAR staff also does weed control sweeps in the ʻAkū and Wright Road units. With weed sweeps, all target non-native species are mechanically and/or chemically controlled within fenced units by ground crews. Units are divided into management blocks, which are systematically swept on 3 – 5 year intervals with the exception of high infestation sites, which are revisited annually. Blocks are prioritized for control based on weed density, proximity to managed sites, logistical feasibility and staff resources.

NARS and TMA staff has controlled priority weeds within Kūlani with a focus of areas along roads to prevent weed invasion into forested areas. High quality native forest in the Kūlani portion of the Reserve is adjacent to highly disturbed areas with former prison infrastructure (e.g. buildings, pastures, reservoir, cinder pit, sewage treatment facility and roads) that contain larger populations of high priority weeds.

Figure 6. Pu‘u Maka‘ala NAR Priority Weed Distribution (Kāhili Ginger, Palm Grass and Cane Tibouchina).

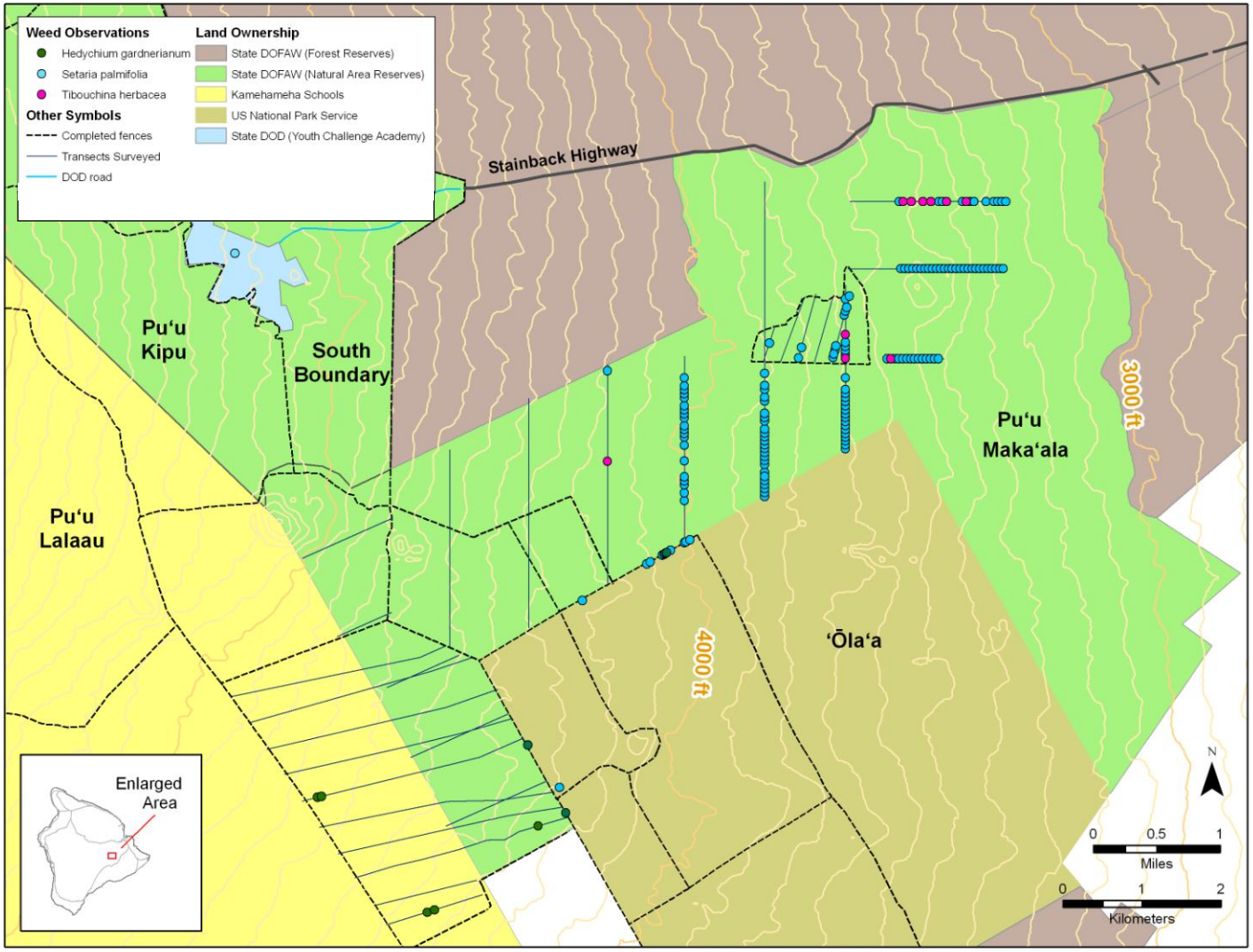


Figure 7. Pu‘u Maka‘ala NAR Priority Weed Distribution (Banana Poka and Strawberry Guava).

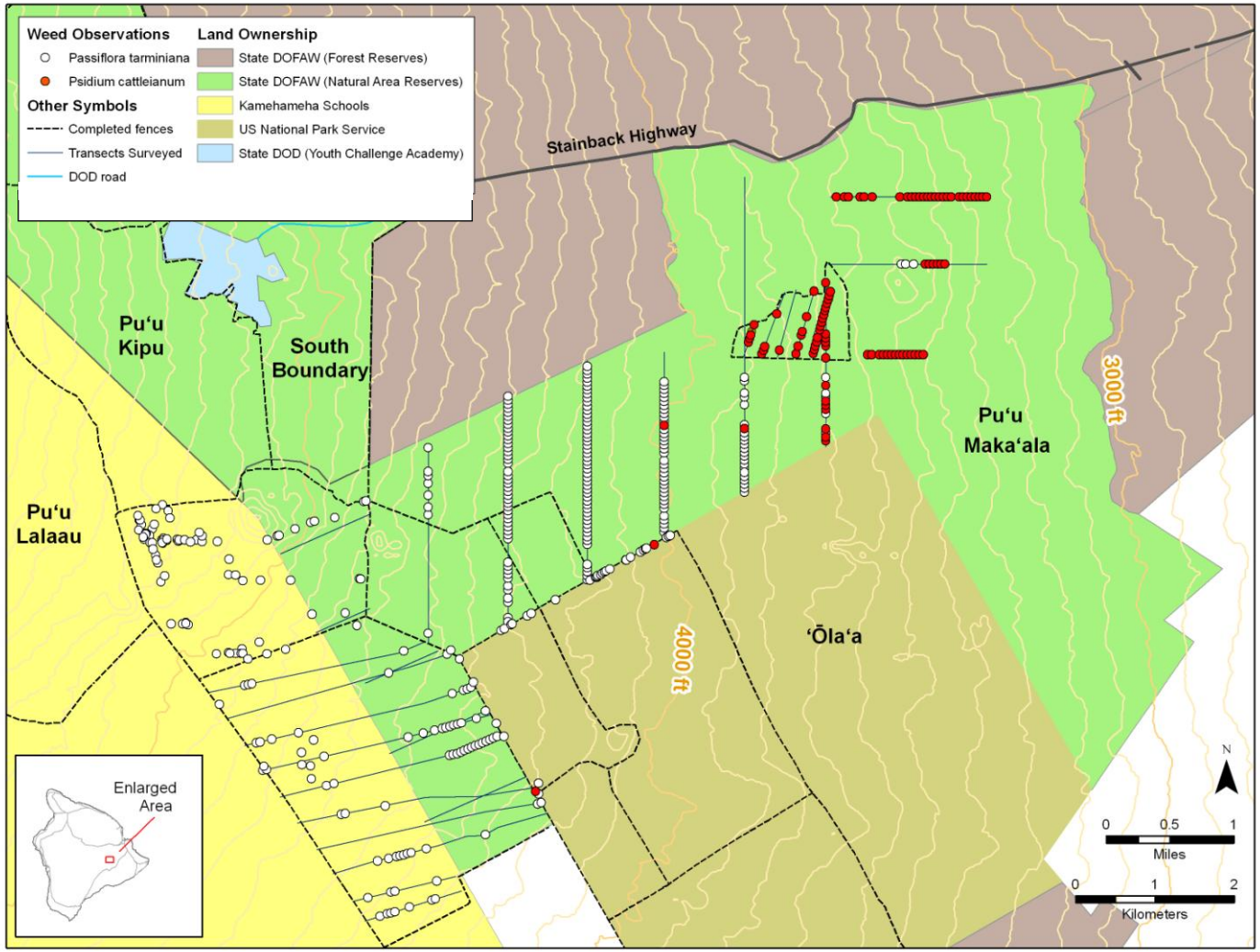
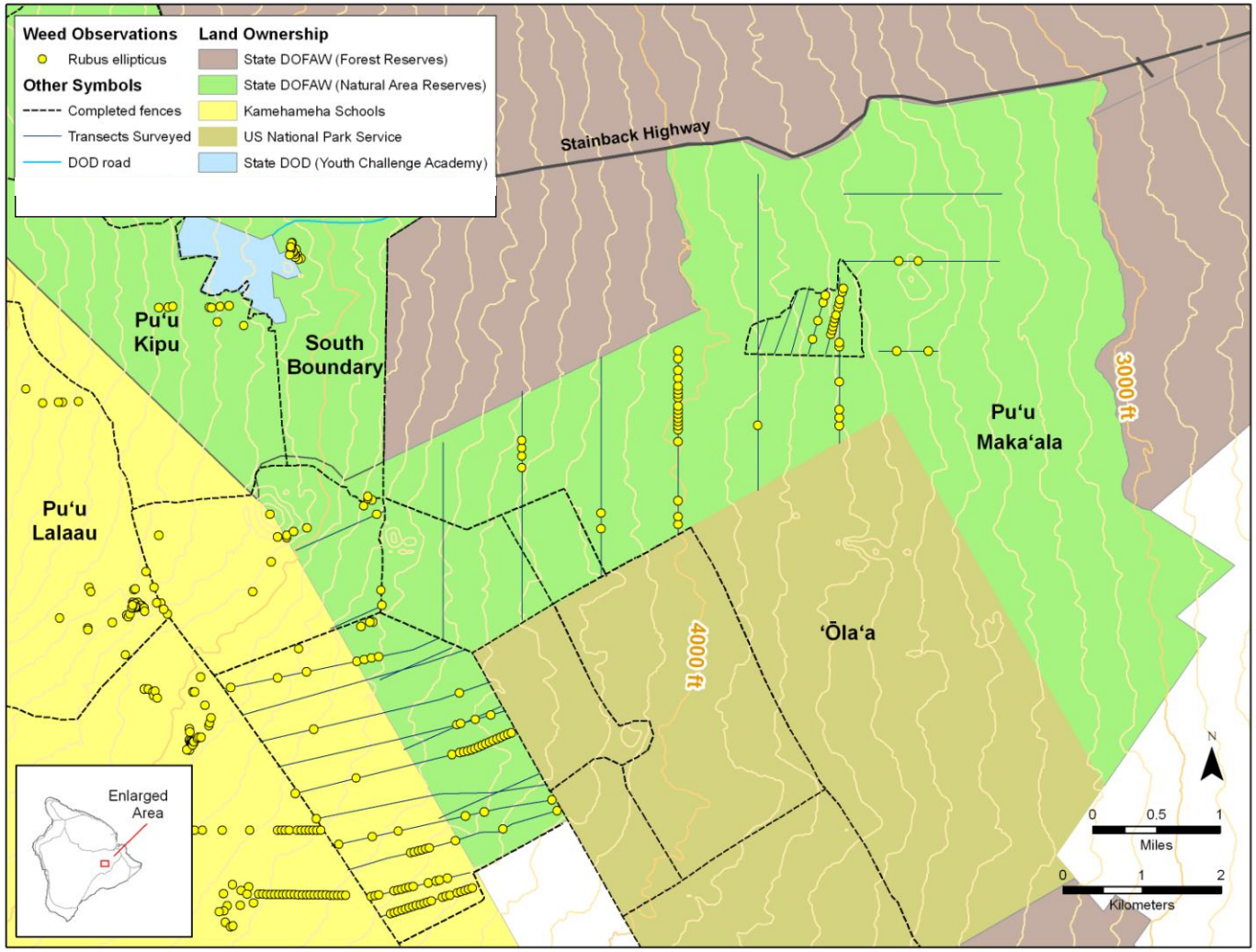


Figure 8. Pu‘u Maka‘ala NAR Priority Weed Distribution (Yellow Himalayan Raspberry).



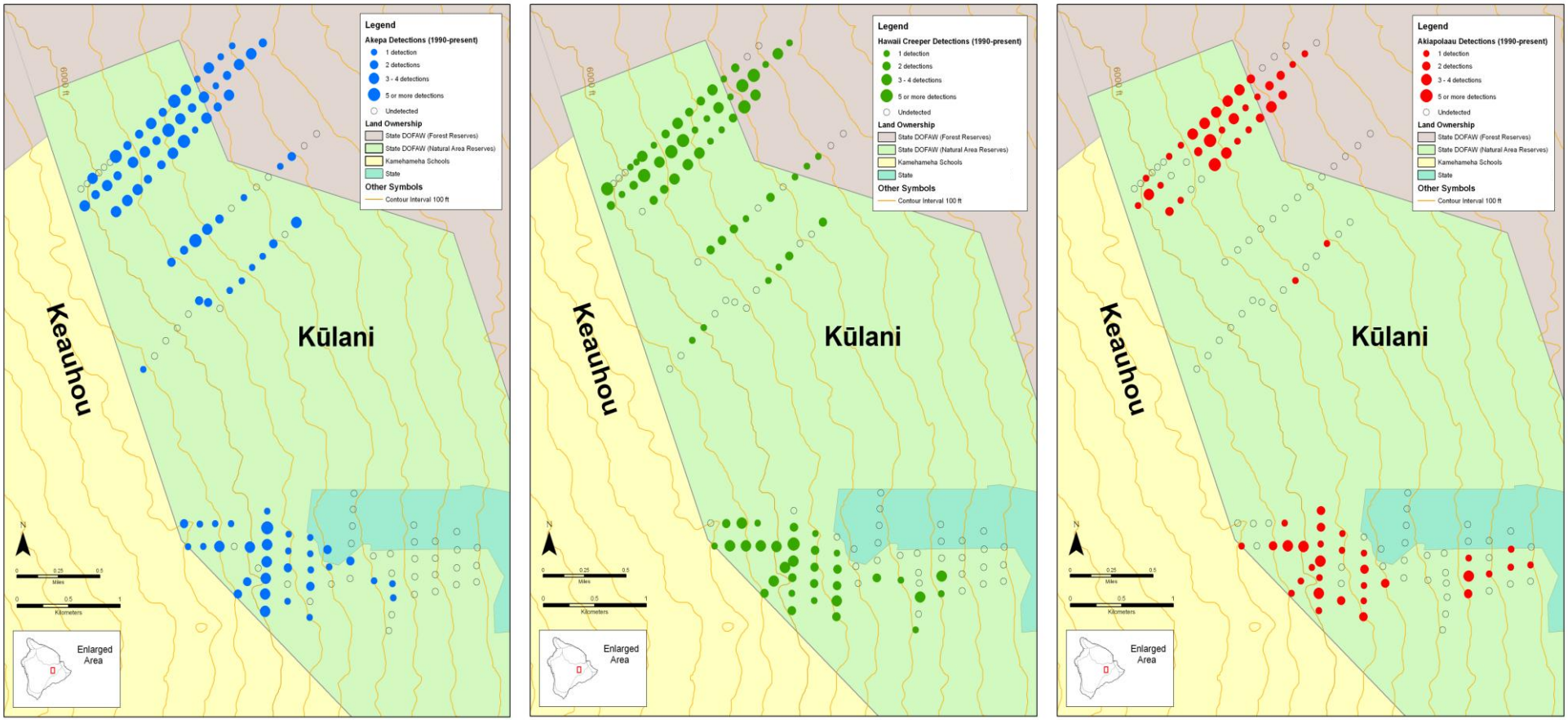
Habitat Protection and Rare Species Restoration

In 2001 and 2008 NAR staff quantified ground cover, select target native species frequency and density, and nonnative species frequency and cover along transects in the ʻAkū unit to monitor changes in the forest as a result of ungulate control. Plant cover in the understory changed dramatically following eight years of feral pig exclusion. The frequency of exposed soil decreased from >50 percent in 2000 to only 11 percent in 2008, largely due to increases in herb and grass/sedge cover. In addition, the density and/or frequency of five native target understory species increased significantly following pig exclusion. Data from this study indicates that past pig activity in the NAR limited the establishment and spread of native understory species, and that pig removal results in native understory species recovery.

Numerous species of rare and endangered plants have been outplanted in Puʻu Makaʻala NAR to assist with recovery efforts for these species. Rare plants reintroduced into the NAR through outplanting include *Argyroxiphum kauense, Anoectochilus sandvicensis, Clermontia lindseyana, Clermontia peleana, Cyanea shipmanii, Cyanea stictophylla, Joinvillea ascendens ssp. ascendens, Phyllostegia velutina, Phyllostegia floribunda, Platydesma spathulata, Pritchardia beccariana, Sicyos alba, Schieda diffusa,* and *Stenogne scrophularioides.* NAR staff tag and map all rare outplanted plants as well as regularly monitor their survival and growth.

TMA has conducted surveys of endangered, native, and alien bird species once per year in the Kūlani portion of the Reserve as well as the adjacent Kīlauea Forest. Detections of endangered birds along transects in this area is shown in Figure 9. Bird population trend information allows for an evaluation of changes in distribution and abundance over time which can be evaluated relative to active or inactive management programs. A sharp decline in native species or an increase in alien bird species can be detected by this method, and may be an important indicator of need for additional management response to a new threat (e.g., increase in avian disease or predation) in an area. The Hawaiʻi Forest Bird Interagency Database Project analyzes the monitoring data every five years and produces reports on forest bird densities and population trends. The most recent analysis was completed in 2005, and is available at: http://pubs.usgs.gov/of/2005/1441/report.pdf .

Figure 9. Endangered Forest Bird Occurrence along monitoring transects in the Kūlani portion of the Reserve



MANAGEMENT PROGRAM

The overall management goal is to manage threats to the integrity, diversity and functioning of Pu‘u Maka‘ala NAR ecosystems so that the unique natural and cultural resources are protected, maintained, and enhanced.

Management programs that support this overall goal include the following:

1. Ungulate Management
2. Weed Management
3. Habitat Protection and Rare Species Restoration
4. Fire Prevention and Response
5. Monitoring
6. Public Access, Outreach and Education
7. Enforcement
8. Partnership Collaboration
9. Infrastructure and Other Actions

Cultural resources are addressed through the protection of the natural resources through the programs above. According to Maly (2004), "…the mountain landscape, its' native species, and the intangible components therein, are a part of a sacred Hawaiian landscape. Thus, the landscape itself is a highly valued cultural property."

Ungulate Management

Objective: Preserve and protect native forest and watershed from feral ungulate damage by maintaining existing fenced units, increasing the total acreage of ungulate-free areas through the construction of four new fenced management units, and completely removing ungulates from all fenced management areas.

Actions:

1. Maintain integrity of nine existing fenced units (Kūlani Cone, Wright Rd, ‘Akū, Na Lua Mahoe, Lava, Pu‘u Kipu, Mauna Loa Boys School, North Boundary and South Boundary) and new fenced units through regular inspection, maintenance and replacement of existing fencing.
2. Monitor existing nine fenced ungulate-free units for ungulate ingress, and control ungulates, if necessary.
3. Construct approximately 17 miles (27 km) of new fencing within the NAR to delineate the boundary of the NAR, subdivide an existing management unit in the Kūlani section of the NAR and create four new fenced management units between the existing fenced units of the Kūlani and Pu‘u Maka‘ala sections of the NAR, and Hawai‘i Volcanoes National Park.
4. Install pedestrian walkovers and gates for pedestrian access into fenced units.
5. Implement feral ungulate control using a variety of methods that may include special public hunts, trapping, staff control, and snaring to completely remove animals from fenced units after fence construction.

6. Monitor new units for ungulate presence following complete removal and control ingress ungulates, if necessary.

Ungulate management, primarily for feral pigs, is the highest priority management program in the NAR. Although public hunting currently accounts for some pigs taken from the Reserve, more animals need to be removed in order to protect the biological and water resources of the Reserve and limit damage to native Hawaiian ecosystems. To reduce feral pig numbers sufficiently to protect the resources of the NAR, a combination of fencing and animal removal from fenced units is needed. Without fencing, ungulate control requires ongoing effort, due to reproduction of existing populations and continued ingress from adjacent properties.

Maintenance of existing fences and monitoring for ungulate presence is necessary to prevent reinvasion of currently ungulate-free areas. Construction of new fencing, when completed, will protect an additional approximately 5,000 ac (2,023 ha) of the NAR from damage by ungulates (Figure 10). Fencing will be completed based upon the availability of funding for labor and materials. NAR and/or TMA staff and/or contractors will implement fence construction in phases. Proposed new fenced management units have been prioritized based on quality of native ecosystems and presence of existing fencing from adjacent units. Other considerations in the design of the fenced units include logistics, accessibility, delineation of NAR boundary, and feasibility for effective feral ungulate control. Initial field surveys have been conducted to identify approximate locations for the planned fence alignments, and final fence alignments will be sited to avoid any impacts to botanical, faunal, and archaeological resources. Approximately 17 miles (27 km) of new fencing is needed to construct the four planned management units, at an estimated average cost of approximately $100,000 per mile (labor, materials and helicopter).

As fence construction is completed, various methods will be used to remove ungulates from the fenced units. Public hunting will be encouraged during the first phase of ungulate removal, but additional control methods including drives, trapping, staff control with dogs, and snaring, may be needed to remove all the ungulates. Upon completion of proposed new fencing and ungulate control, approximately 14,600 ac (5,908 ha) or 78% of Puʻu Makaʻala will be ungulate free.

The lower, eastern portion of the NAR (including the Ihope road region adjacent to the National Park ʻŌlaʻa tract up to the 3,400 feet (1,036 meters) elevation) is not currently a priority for fencing. While still native-dominated, high densities of weeds make this section a lower priority for fencing and animal removal.

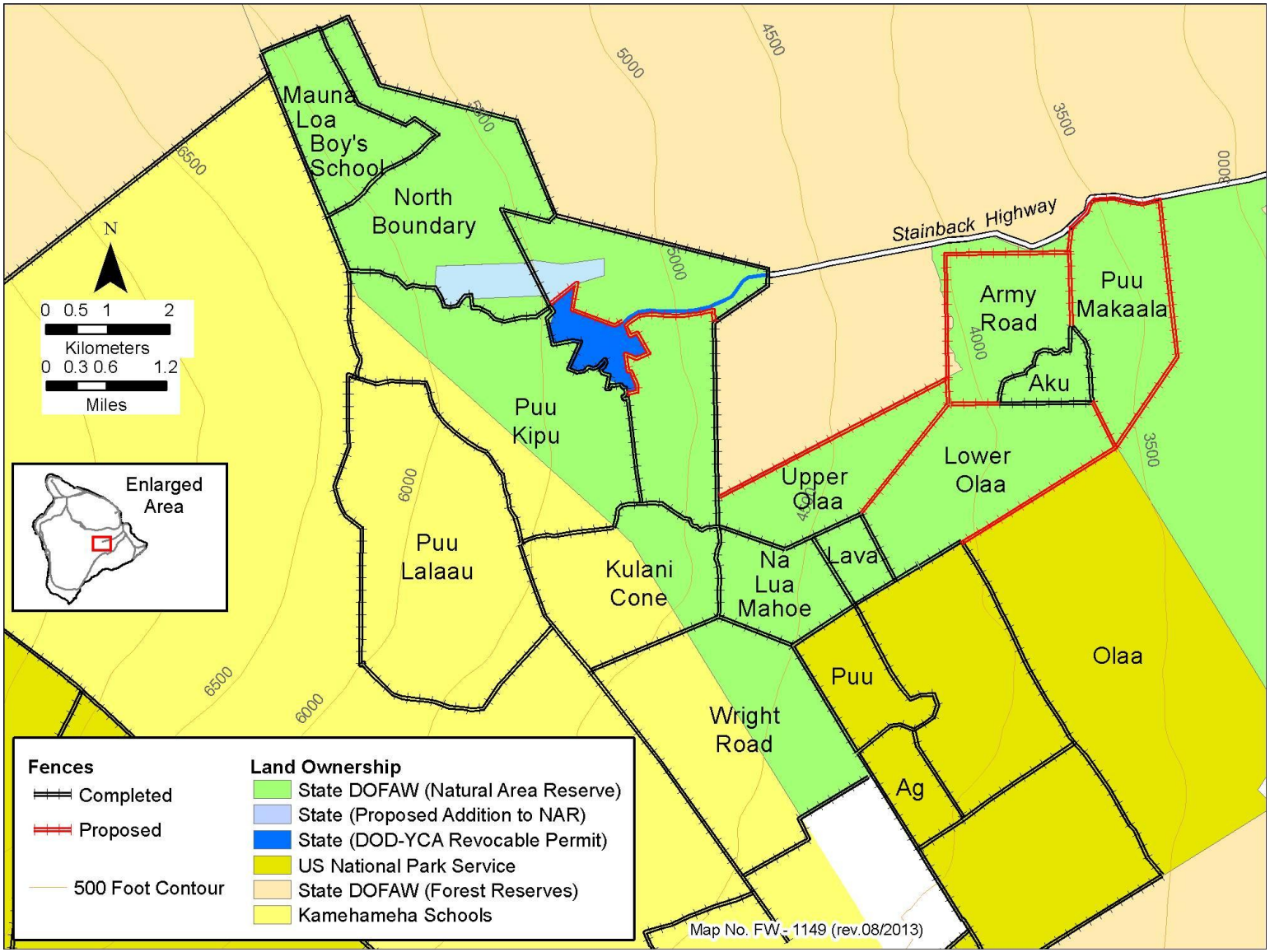
<u>Proposed New Fencing</u> (in order of priority) (Figure 10):

- Kūlani South Boundary Unit - Subdivide the existing unit by fencing 2 miles (3,219 m) around the perimeter of the Facility and along Stainback Highway. Subdividing this large unit will help with management, should ingress of ungulates occur and will delineate the boundary of the NAR.
- Upper ʻŌlaʻa Unit - 1,000 ac (405 ha) will require 4.3 miles (6,900 m) of new fencing. This unit will tie into existing fenced units (Kūlani Cone, South Boundary, Na Lua Mahoe and Lava).
- Army Road Unit - 1,000 ac (405 ha) will require 4 miles (6,400 m) of new fencing. This unit will tie into existing fencing of Upper ʻŌlaʻa unit and the ʻAkū unit. Fencing will follow the

existing road corridor. When fencing of this unit is completed Army Road will be converted to a public, pedestrian trail.

- Lower ʻŌlaʻa Unit - 1,570 Ac (635 ha) will require 2.5 miles (4,100 m) of new fencing. This unit will tie into existing fencing (Lava unit as well as a portion of Hawaiʻi Volcanoes National Park ʻŌlaʻa tract fencing).
- Puʻu Makaʻala Unit - 1,215 ac (492 ha) will require 4 miles (6,400 m) of new fencing. This unit will be the lowest elevation unit currently proposed for the NAR, and will include the puʻu known as Puʻu Makaʻala.

Figure 10. Pu‘u Maka‘ala NAR Existing Management Units and Proposed Fencing



Weed Management

Objective: Protect intact native areas within the NAR by eradicating incipient weeds along common invasion corridors (e.g. roads, trails, fences), and if possible, eradicate or contain select high priority weeds in fenced units within the NAR.

Actions:

1. Identify highest priority intact native areas for intensive weed control. The highest priority areas are generally fenced, ungulate-free management units.
2. Monitor and map the distribution of high priority weeds and develop a control strategy.
3. Control weeds along invasion corridors (e.g., roads, trails, fences) and within management units using approved methods (chemical, manual and/or biocontrol).
4. Maintain procedures to prevent introduction of new weeds and invertebrates (i.e., sanitation protocols).
5. Support state-wide weed early detection and prevention programs and weed control research including new chemical, mechanical and biological control techniques, and participate, where appropriate, in experimental weed control management methods.
6. Monitor management efficacy in intact native areas to determine if weed control measures are effective and whether re-visitation intervals can be lengthened.
7. Monitor weeds to detect changes in long term distribution and abundance.

NAR priority areas for weed management are generally fenced, ungulate-free management units. Removal of ungulates from fenced units is a critical first step in weed control because it allows for the recovery of native vegetation by minimizing ground disturbance and reducing the spread of weeds by ungulates. Certain incipient weeds (high priority weeds that are just beginning to invade the area) may be targeted in unfenced areas to prevent their establishment and spread within the NAR.

The NAR has an ongoing weed monitoring and mapping program, and this data provides a valuable baseline for weed distribution and abundance. Weed mapping is essential to developing a comprehensive control strategy. Distribution mapping includes compiling transect monitoring data, incidental observations and reconnaissance surveys to map the distribution and abundance of weeds. Results from surveys will then be used to better delineate the weed populations core extent and outlying individuals, and permit the development of an effective control strategy. NAR staff monitor weed control areas to evaluate the effectiveness of control efforts.

Weed control goals for the existing Puʻu Makaʻala management units and proposed new fenced units include early detection and preventing the establishment of incipient, habitat modifying weeds that are not currently present in the NAR (e.g. miconia) or are still localized. For priority weeds already present in the NAR, the goal is to eliminate all known occurrences within targeted control areas and/or to contain the spread of priority species. Due to limited resources for monitoring and control throughout these dense rainforest areas, NAR staff will focus control efforts in disturbed areas such as roads, trails, and fence lines as these often serve as corridors for weed establishment and spread. Prevention is a critical component of the weed management

program, and it is important to avoid and/or reduce the inadvertent introduction and spread of weeds by researchers, managers and students working in and visiting the area. NARS staff and volunteers will follow protocols for cleaning of boots, equipment and vehicles prior to entry into the NAR. Staff will also implement sanitation to prevent the introduction of other harmful species such as invertebrates (ants, wasps etc) and coqui frogs.

NAR staff will also completely sweep fenced management units as funding and resources become available. Units are divided into management blocks, and these blocks are prioritized for control based on weed density, proximity to managed sites, and logistical feasibility. Blocks are systematically swept at 3 – 5 year intervals, although highly weed infested sites may be re-visited annually for follow-up control. Staff will focus on removing all priority species within fenced units but will also remove other non-native weeds encountered.

A combination of control techniques including manual, mechanical and herbicides are used to remove weeds. The technique used is based on the characteristics of the target species, the sensitivity of the area in which the species is found, and the effectiveness of the control technique. Weed control research into new monitoring, mapping (including remote sensing) and control methods will be integrated into the weed management program over the course of this plan as appropriate. Due to widespread and heavy infestations of certain weeds (e.g. banana poka and strawberry guava) and limited resources, NARS staff and partners intend to test the efficacy of approved biocontrol agents within the Reserve, when available. The banana poka fungal biological control agent (*Septoria passiflorae*) has been approved and shown to be successful in tests elsewhere on the island, and the effectiveness of this agent needs to be determined for the NAR.

<u>Proposed Weed Control Projects</u> (in priority order):

- Early detection and rapid response weed monitoring and control on a quarterly basis along invasion corridors in and adjacent to fenced management units.
- ʻAkū Unit – Complete sweeps for priority weeds including palm grass, strawberry guava, selaginella, banana poka, and yellow Himalayan raspberry.
- Wright Rd Unit – This unit is too large for complete control sweeps with currently available resources so staff will focus on sweeps in weed hot spots for priority species including banana poka, kāhili ginger, and yellow Himalayan raspberry. More complete sweeps of the unit will be made as additional resources are available.
- Puʻu Kipu, South Boundary, North Boundary, Mauna Loa Boys School, Kūlani Cone, Na Lua Mahoe, and Lava units - These higher elevation units have relatively low densities of weeds, and the focus of control in these areas will continue to be weed invasion corridors and known weed hotspots, until resources are available for more complete weed control sweeps. Priority weeds in these areas are primarily banana poka and yellow Himalayan raspberry.
- New fenced units – These lower elevation units have more weed problems than the existing units currently targeted for weed control. As new fenced units are completed and ungulates are removed, these areas will become a higher priority for weed management. NARS staff will follow a similar strategy for weed control in these areas (e.g. installation of weed monitoring transects, control in invasion corridors and more complete sweeps if resources are available).

- Weed monitoring and mapping will be conducted every five years along transects in fenced management units and every 10 years in the unfenced sections of the NAR to detect changes in weed distribution and abundance over time as well as detect incipient invaders.

Habitat Protection and Rare Species Restoration Program

Objective: Manage high quality forest habitats, rare, threatened and endangered plant and animal species at sustainable community and population levels.

Actions:

1. Maintain the integrity of high quality forest habitats to the extent possible through the maintenance and expansion of fencing, feral ungulate control and weed control programs.
2. Prevent the introduction of incipient habitat-modifying species and new threats (e.g. new weed species, invasive invertebrates, coqui frogs etc) and remove them before they become established.
3. Map, monitor and protect existing wild populations of rare and endangered species to contribute to their population stabilization and recovery.
4. Re-introduce certain species of rare and endangered plants in appropriate protected habitat through outplanting, and coordinate outplanting and other management actions with the PEPP and other agencies and organizations working on rare plant recovery.
5. Enhance habitats for forest birds, nēnē, and ʻuaʻu or Hawaiian petrel through small mammalian predator removal and other habitat management (reducing larval habitat for mosquitoes and controlling yellow-jacket wasps).
6. Release ʻalalā (Hawaiian crow) and other endangered birds in appropriate habitat.
7. Implement native habitat restoration projects (e.g. forest restoration in disturbed areas, wetland restoration) and monitor the results of management activities.

Fencing and ungulate removal is discussed in the section on the Ungulate Management program. Fencing and the creation of ungulate-free areas is critical to the long-term health and recovery of native ecosystems including rare plants, forest birds and other native species. These management actions, along with weed management and the prevention of new habitat-modifying weeds and harmful non-native species (e.g. invertebrates and other species such as coqui frogs) are the most critical actions needed to protect existing native habitat and rare species. NAR staff may need to implement other habitat restoration and species management, as necessary.

In some instances, large scale habitat protection and restoration through the implementation of priority management actions is not enough to recover certain rare and endangered plants. These species may have wild populations that are so low that the species cannot survive and recover without additional management. Over the past decade, numerous species of rare plants have been propagated and reintroduced into fenced, ungulate-free areas of the NAR to contribute to their overall recovery in the wild. These species (Table 1) will continue to be a focus for the NAR rare species program. The goal of NAR rare plant management is to remove threats to these species and ensure their long-term survival in secure and self-sustaining wild populations.

NAR staff work will work cooperatively with other organizations and agencies on rare plant recovery including FWS, TMA, The Hawaiʻi State Plant Extinction Prevention Program (PEPP)

and the Volcano Rare Plant Facility (VRPF) of the University of Hawai‘i. Management actions specific to rare plant recovery includes rare plant surveys to locate wild individuals, collection of propagation and genetic storage materials and reintroduction through outplanting. PEPP is focused on preventing the extinction of taxa with fewer than 50 individuals in the wild. The VRPF propagates all rare plants used in the NAR program.

NAR staff will follow rare plant collection and reintroduction guidelines recommended by the Hawaii Rare Plant Restoration Group (interagency group of rare plant experts) http://www.hear.org/hrprg/. Rare plants reintroduced into the NAR include *Argyroxiphum kauense, Anoectochilus sandvicensis, Clermontia lindseyana, Clermontia peleana, Cyanea shipmanii, Cyanea stictophylla, Joinvillea ascendens ssp. ascendens, Phyllostegia velutina, Phyllostegia floribunda, Platydesma spathulata, Pritchardia beccariana, Sicyos alba, Schieda diffusa,*and *Stenogne scrophularioides.* Additional rare and endangered species historically known from the NAR and/or nearby will be reintroduced to the Reserve, as appropriate (Table 1). NAR staff will tag and map the locations of all outplanted plants and monitor their survival and growth. They will do additional management of wild and/or reintroduced populations if needed (e.g. fencing wild plants that are not within fenced management units, control of damaging weeds, insects, slugs, plant disease and/or mammalian predators).

Small mammalian predator removal (e.g., removal of rats, mongoose, cats) may provide significant benefits to endangered birds, plants, and endemic invertebrates, but is extremely difficult and costly to implement on a large-scale using currently existing methods. NAR staff may implement predator removal in certain high priority areas (e.g. upper elevation, fenced management units, bird nesting sites) using existing, approved methods (trapping and application of rodenticides using bait stations). New methods for widespread control of these species across large conservation areas are currently being developed and will be implemented if they are approved and offer a cost-effective way to remove predators.

Other management may also benefit forest birds and will be implemented, as feasible. Upper elevations of the NAR in the Kūlani area will be targeted for these actions as these areas provide the most important habitat for native forest birds. NARS staff will work with adjacent landowners (e.g. Kamehameha Schools and State DOD YCA) to eliminate or treat larval habitats for mosquitoes (standing water associated with cattle troughs, water catchment and stock ponds that are located within or adjacent to forest bird recovery areas. Larval habitats associated with residential and agricultural development may be primary sources for mosquitoes responsible for seasonal epizootics of pox and malaria. Reducing or eliminating vespulid wasps (yellow jackets) may also provide benefits to forest birds, as these wasps prey on insects that provide food for forest birds.

The current captive population of ‘alalā is at the point where restoration of a wild population can proceed. The Kūlani portion of the Reserve has been identified as a high priority release site for re-establishment of this species in the wild due to the high quality of native forest and its ungulate-free status. The restoration of a wild population of ‘alalā will require minimizing threats, including implementing control of non-native mammalian predators. Releases and managing (e.g., providing supplemental food) will require semi-permanent infrastructure and a constant, long-term human presence. Holding or release aviaries will need to be erected at

release sites. These will most likely be placed on scaffolding to minimize predator access. DOFAW will attempt to place aviaries in natural openings in the forest; however, some clearing of native vegetation may be necessary. Given the need to have staff on site at all times, the construction of a remote cabin or weatherport will be needed. The release and monitoring team (3 – 5 individuals) will care for, feed, monitor, and track released birds. This team will need to maintain a constant presence at the release site for an undetermined length of time. It is difficult to estimate the length of time that the release and monitoring team will have to remain on site. Much will depend on the availability and use of wild foods by the ʻalalā, their dependence on supplementary food, their health, and how they adjust to their new environment. Other management actions involved with ʻalala release may require additional staff to control predators, monitor ʻio abundance, restore food plants, monitor vegetation recovery, track and control invasive species and check and repair fence.

Nēnē are present in the Kūlani portion of the Reserve and in adjacent areas. NARS staff will assist DOFAW Wildlife Staff in banding and monitoring nēnē in the general area and working with adjacent landowners to enhance overall nēnē efforts across the island of Hawaiʻi. Other actions such as small mammalian predator control and habitat improvement may be implemented in localized areas to protect and manage nēnē.

NARS staff will also implement targeted habitat restoration projects as resources allow. Although the forest canopy in the Reserve is largely intact, certain localized areas that have been disturbed or invaded by weeds may require more intensive management. Non-native pasture grasses will be targeted for control in certain areas to enhance the natural regeneration of native trees and shrubs and prevent fire. *Carex* and other wetlands are also targeted for restoration as these areas were more disturbed by past feral pig activity and are subsequently more highly invaded by weeds. NAR staff and volunteers will eradicate invasive weeds and reintroduce native plant species to restore these wetlands.

Fire Prevention and Response

Objective: Employ appropriate fire management strategies including pre-suppression, suppression, and post-suppression rehabilitation to reduce wildfire occurrence and minimize wildfire impacts.

Actions:

1. Work with Hawaiʻi island Protection Forestor (DOFAW) to update fire response maps to show the Kūlani portion of the NAR to be a DOFAW primary response area.
2. Implement fire prevention measures, including educational outreach to neighbors and signage along roads.
3. Suppress fires safely and aggressively using appropriate means.
4. Continue NAR staff training and certifications for effective and safe fire response.

Due to the high rainfall at Puʻu Makaʻala, fire is not normally a concern for the project area. However, fire management is incorporated as part of this management plan because of the impact fire can have on native communities. It is recognized that, though unlikely, fire may be a

risk in the project area, particularly in the drier Kūlani portion of the Reserve. Thus, strategies to prevent and minimize the impacts of fire are incorporated into this plan.

Many fires are caused by humans, so fire prevention measures will include increased educational efforts for those accessing the property, road or area closures in the event of extreme fire danger and suppression of non-native grasses in fire prone areas. Weed control and planting of common native species will be used to restore certain disturbed areas to prevent fire and/or following damage from fire.

In the event of fire, DOFAW will respond to fires in the Reserve. The most effective control of a fire will be through measures that result in the least amount of impact or disturbance to natural and archeological resources. The method of suppression will be determined by the on-site situation, with special regard to the potential expansion of fire damage to the resources within the Reserve. Minimum impact methods of suppression will be applied whenever such methods are sufficient. Bulldozing or other extreme fire control measures are justified when a fire cannot be otherwise controlled and the bulldozing damage is outweighed by a probable greater loss of natural and archeological resources. NARS staff will maintain current fire response certifications by attending regular required staff trainings.

Monitoring

Objective: Monitor current status and trends of natural resources throughout the NAR as part of a long-term monitoring program.

Actions:

1. Continue ongoing monitoring programs for ungulates, weeds and rare plants to measure the success of management and detect changes in abundance and distribution.
2. Continue ongoing monitoring program for forest birds in the Kūlani portion of the Reserve in cooperation with TMA and the Hawai‘i Forest Bird Interagency Database Project.
3. Develop improved monitoring protocols, data management and analysis for existing monitoring programs.
4. Review and summarize past monitoring data and inventories.
5. Identify critical gaps in natural resource inventories for the NAR and initiate additional surveys.
6. Develop and/or identify appropriate monitoring protocols and implement monitoring for key community indicators that are not currently being monitored (e.g., native vegetation communities, invertebrates etc).
7. In cooperation with partners, monitor climate through weather monitoring.

NAR staff regularly monitors ungulates, weeds and rare plants and are planning on continuing these monitoring programs. Ungulate monitoring is used in fenced units that are being managed for ungulates to detect the presence or absence of ungulates. Units that are free of ungulates are regularly monitored to detect ingress animals. Units with active ungulate control programs are monitored to assess the success of and/or direct control efforts.

Weed monitoring will continue to be conducted every five years along transects in fenced management units and every 10 years in the unfenced sections of the NAR to detect changes in weed distribution and abundance over time as well as detect incipient invaders. Weed control areas are monitored to determine the success of management efforts.

Rare plant monitoring is conducted to assess the survival and growth of wild and re-introduced rare plants. NAR and PEPP program staff monitor rare plants to assess their survival and reproduction, collect propagation materials, search for additional wild individuals and determine whether additional management is necessary.

NAR staff has also monitored changes in native understory diversity and nonnative invasive plant distribution to assess the results of pig removal. This type of monitoring will be continued, as resources permit, to assess the long-term results of management actions.

The TMA has monitored forest birds in the Kūlani portion of the NAR as well as on adjacent Kamehameha Schools land and NARS is planning on working with the TMA to continue these annual surveys. Monitoring transects in the Mauna Loa Boy's School Unit, Pu'u Kipu Unit and Kūlani Cone unit have been monitored annually since the early 1990's. Monitoring data will be provided to the Hawai'i Forest Bird Interagency Database Project for analysis of bird population densities and trends.

NAR staff will refine and modify existing inventory and monitoring programs (monitoring protocols, data management and analysis) for ungulates, birds, weeds and rare plants in order to make the program more effective. It would be valuable to expand the monitoring program as time and resources permit to include surveys and monitoring of invertebrates as well as native plant communities. Establishing and implementing new long-term monitoring programs for key community indicators, especially in the face of new threats such as climate change and the introduction of new diseases and pathogens will be critical to informing future management of native ecosystems and species in the NAR. Collaboration with partners such as researchers, students and adjoining landowners may help improve and expand inventory and monitoring programs if NAR staff time and resources are limited.

Public Access, Outreach and Education

Objective: Provide public access to the Reserve and build public understanding and support for the NAR and the state's unique native resources through outreach and education.

Actions:

1. Enhance public access, hiking opportunities and interpretation of NAR resources by providing public access into the Kūlani portion of the Reserve as well as improving the Wright Road and Army Road trails for pedestrian use.
2. Hire Outreach Specialist to provide periodic interpretive trips to the Reserve for the general public as well as other outreach and educational activities listed below.
3. Maintain and expand opportunities for volunteer service trips, student internships and teacher workshops.

4. Maintain and expand NAR staff presentations and outreach to schools and community groups.

Public access to all portions of the Reserve is allowed for recreational and cultural uses. Recommended public access points are shown in Figure 11; however the public is allowed to access the Reserve in other areas as well (e.g. along Stainback Highway). Current public use of Puʻu Makaʻala primarily includes hiking, bird watching, and hunting. Hunting in portions of the NAR is regulated by Chapter 13-123, Hawaii Administrative Rules (Rules Regulating Game Mammal Hunting), and areas where hunting is allowed are designated as part of Hunting Unit K. Hunters should check with the DOFAW office (19 East Kawili Ave., Hilo, HI 96720) to get current information on hunting rules and any changes in special conditions, bag limits, seasons and open areas. Some public uses of the Reserve, including groups larger than ten individuals, research, scientific collecting, gathering (including Native Hawaiian religious and customary gathering rights) and commercial uses require a Special Use Permit from the Executive Secretary of the NARS Program in Honolulu (808-587-0063) (HAR§ 13-209-4).

Public access to all parts of the Kūlani portion of the NAR will be open for pedestrian use. The primary recommended access points are along Stainback Highway. NAR staff will improve trails into the area by clearing old trails and adding additional directional and interpretive signage along recommended routes (Figure 12). NAR staff will also increase educational and outreach efforts to reduce the risk of the accidental introduction of invasive species from visitors to the NAR (e.g. boot-cleaning stations and educational signage). NARS staff and volunteers will also provide periodic guided educational tours of the Kūlani portion of the NAR for community groups and/or the general public.

New proposed interpretive hiking opportunities within Puʻu Makaʻala will provide opportunities for the public to learn more about the NAR, its unique native species and ecosystems, threats to the NAR, and ongoing management activities. The two areas proposed for improvement (Army Rd. and Wright Rd) already have existing unimproved trails or roads and are the most accessible portions of the Reserve. In addition, trail improvements such as rest areas/benches, viewing platforms, and boardwalks over particularly wet areas of trail and the installation of interpretive signs at points of interest (e.g. significant trees, geologic features, wetlands and lookout areas) will improve the outdoor experience for general users and provide an enjoyable opportunity to learn about Hawaii's native forests.

Proposed Interpretive Trail Development Projects (Figures 13 and 14):

- At Wright Road, the current unimproved trail runs perpendicular to a management access road. Constructing a 1-2 mile (1.6 -3.2 km) new connector trail between the existing management access road and unimproved trail and would create a 3-4 mile (4.8-6.3 km) loop trail, located entirely within the fenced Wright Road unit. The newly constructed portion of trail will be located entirely on State land. In addition, the existing management access road and unimproved trail portions of the loop will be improved for public pedestrian use. This loop trail will provide new opportunities for public recreation in the NAR and will also enhance NAR management of the Wright Rd. unit by providing management access.
- At Army Road, an existing four-wheel drive road is currently open for public vehicular access in two sections (mauka and makai). Vehicle access between these two sections is

blocked due to existing ʻAkū unit fencing (although public access is allowed on foot). This area is proposed to be fenced and become an ungulate-free management area (Army Rd. Unit). Proposed fencing will follow the road corridor. When the Army Rd. Unit is fenced, the existing road will be converted to a public trail with improvements such as rest areas, covered picnic tables and interpretive signs. Access will be restricted to pedestrian use. Conversion of the road into a pedestrian trail will provide enhanced opportunities for the general public to learn about and enjoy the native forest.

At Puʻu Makaʻala, volunteer service trips are currently used to promote public understanding and support for conservation. Volunteer groups have regularly assisted with weed control; trail maintenance and restoration projects planting native species. Additionally, local students spend a week every year assisting with management efforts at Puʻu Makaʻala NAR through the Youth Conservation Corps summer program. The NAR program also regularly hires interns to assist with management and provide educational and training opportunities for students. NAR staff will continue these types of programs because they provide educational opportunities for interested groups and individuals to learn more about the Reserve and Reserve management programs. In addition, volunteers and interns contribute useful assistance in labor-intensive activities.

Beginning in 2008, NARS staff partnered with the TMA education program to jointly host standards-based teacher workshops to provide outdoor learning opportunities and lesson plans to local teachers. NAR staff also regularly provides slide shows, presentations and outreach to schools, local groups and at community events. NAR staff is planning on continuing all these activities, and expanding them as resources allow.

Figure 11 - Pu‘u Maka‘ala NAR Access

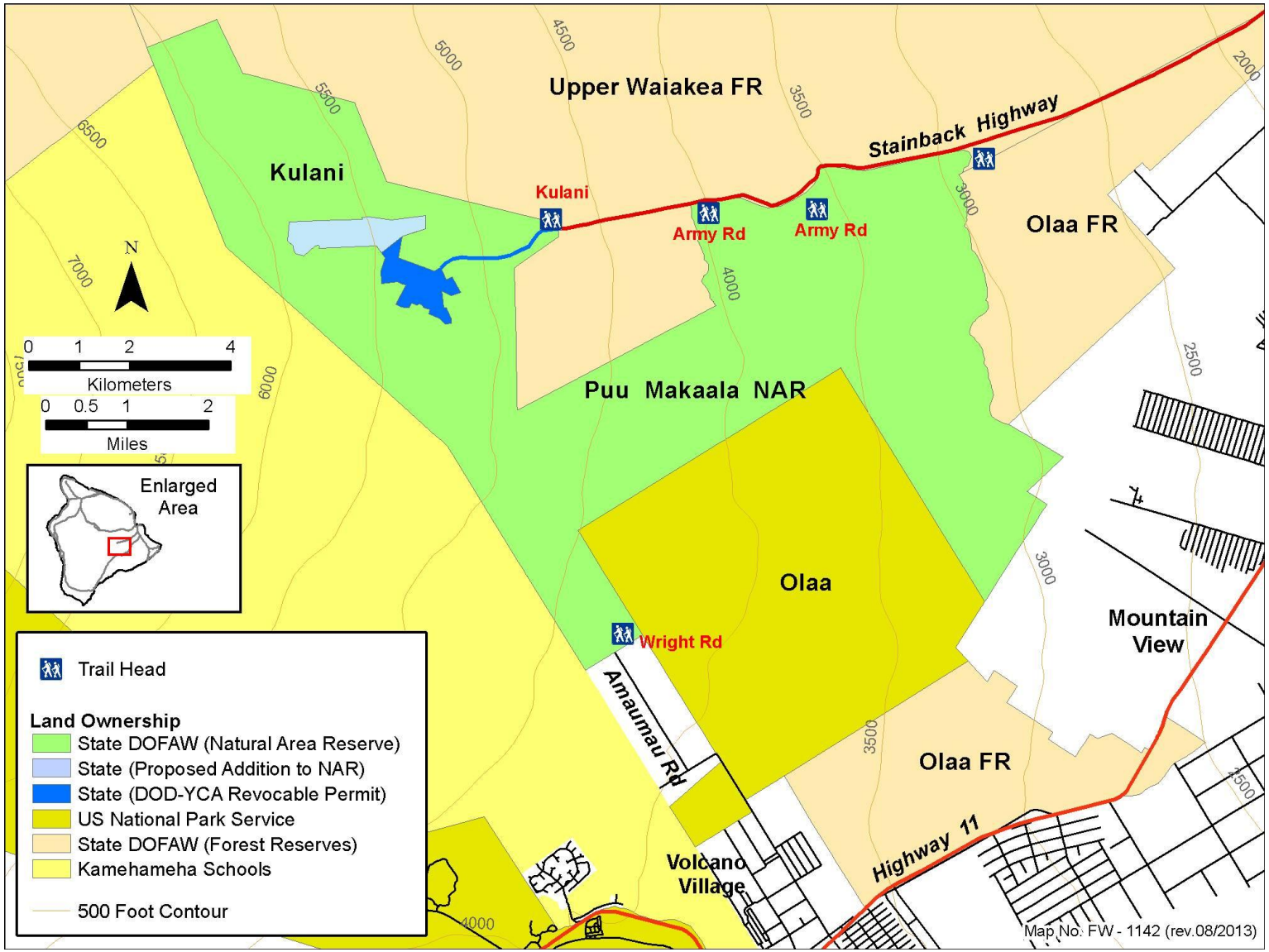


Figure 12. Kulani Access and Proposed Trail Improvement

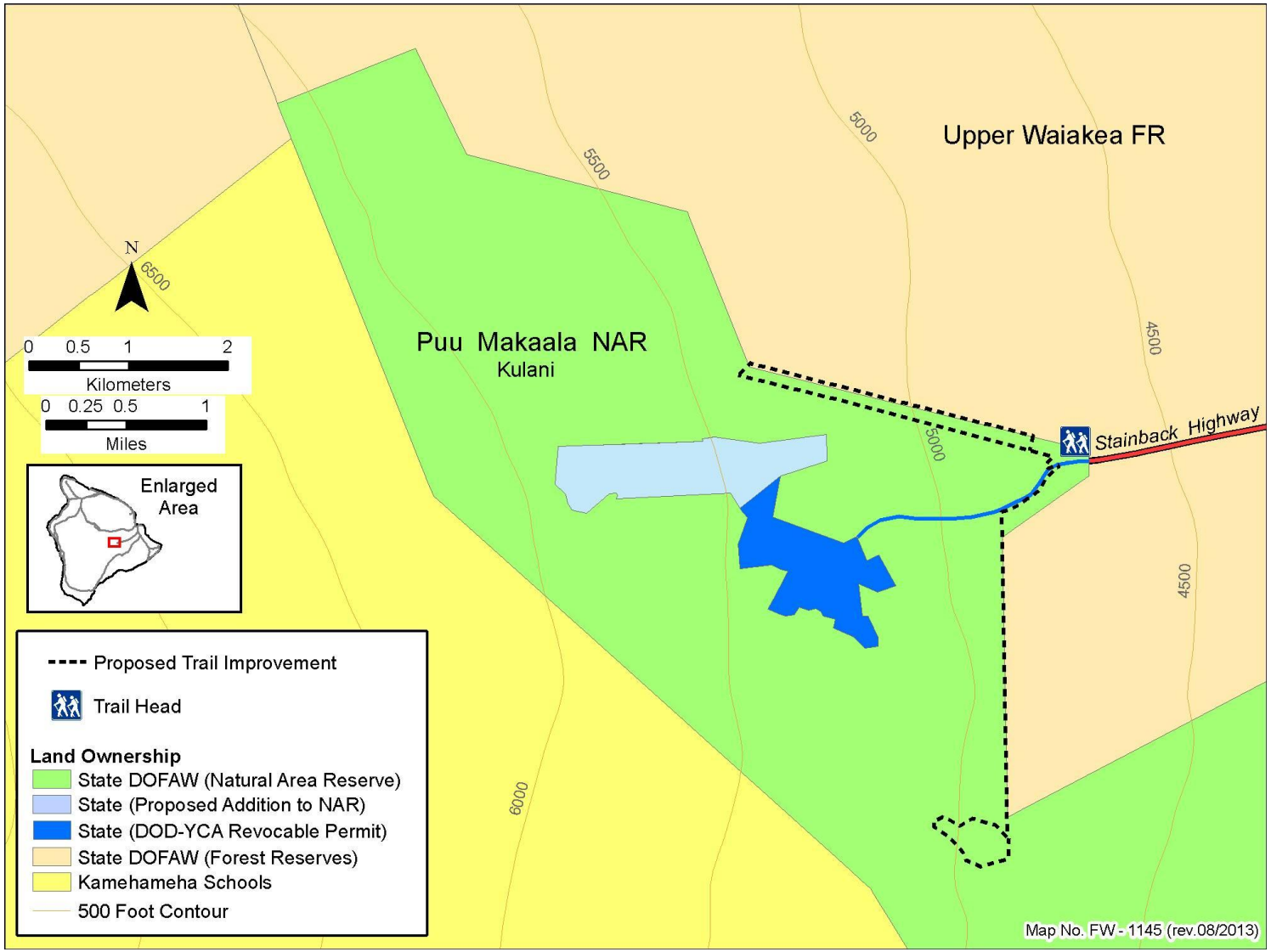


Figure 13. Wright Rd Proposed Trail and Trail Improvement

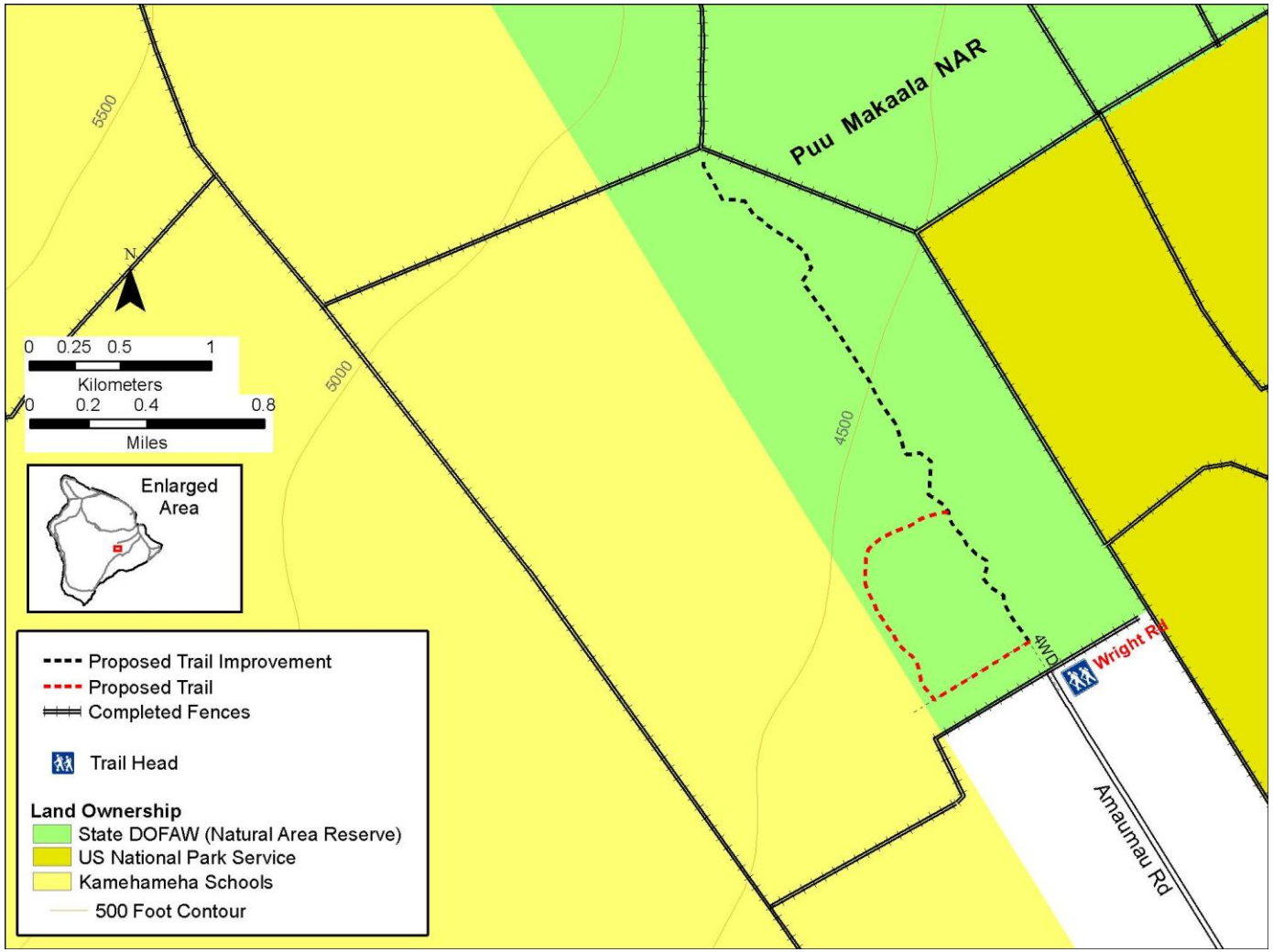
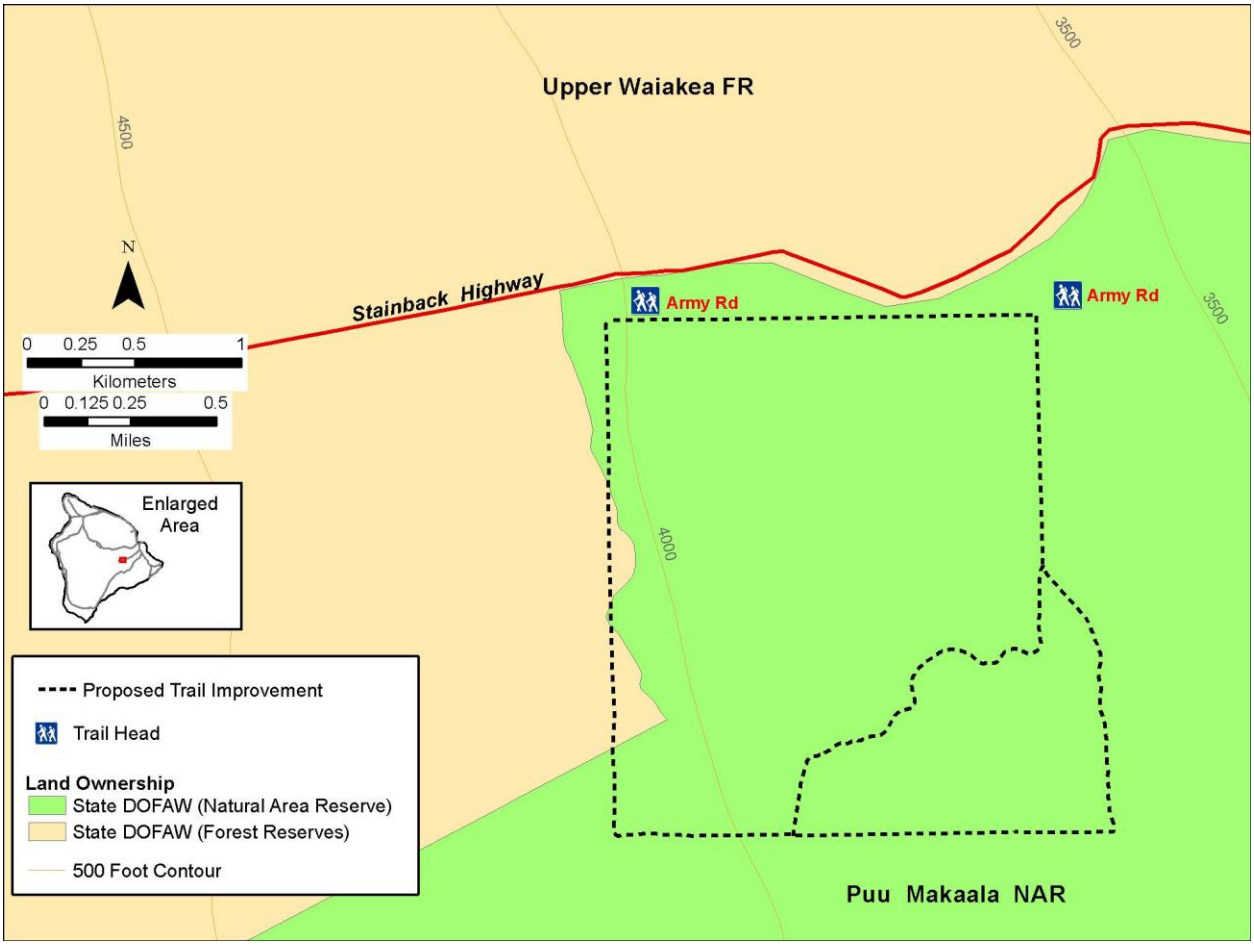


Figure 14. Army Rd. Proposed Trail Improvement



Enforcement

Objective: Ensure effective enforcement of laws that protect Pu‘u Maka‘ala NAR.

Actions:

1. Explore opportunities to collaborate with DLNR’s Division of Conservation and Resource Enforcement (DOCARE) to improve voluntary compliance with laws and strategies to improve the effectiveness of enforcement.
2. Encourage DOCARE to focus on illegal taking of natural resources and vandalism.

The DLNR’s DOCARE is responsible for enforcement of state laws at Pu‘u Maka‘ala, including laws regulating hunting and protection of resources (e.g. illegal harvesting, vandalism etc). Improved collaboration between the NAR program and DOCARE will improve the effective enforcement of laws that protect the Reserve.

Partnership Collaboration

Objective: Collaborate with external partners to support NARS mission and goals.

Actions:

1. Continue partnerships with adjacent landowners through the TMA to address threats and management needs on a regional basis.
2. When the Kūlani Correctional Facility reopens, develop a memorandum of agreement with the Department of Public Safety to address access by DOFAW over the internal roads at Kūlani Correctional Facility, conservation management, the parties' maintenance obligations for the internal roads, and conditions under which public access will be permitted, etc.
3. Work with the DOD-YCA and/or the Department of Public Safety to cooperatively address endangered species issues at the Kūlani facility, joint threats (e.g. invasive species) and to provide environmental service-learning and educational programs for YCA students and/or Kūlani Correctional Facility inmates.
4. Partner with Hawaii County Fire Department to familiarize their staff with locations of management access roads and important resources for protection in case there is an emergency such as fire or rescue.
5. Continue working with other groups collaboratively to address joint management needs (e.g. invasive species management, rare plant management, education, monitoring and research).

Many of the threats to Hawaii's natural resources, such as feral ungulates, invasive weeds, fire, invasive insects, and introduced plant and animal diseases, occur across land ownership boundaries. Working with partners can increase the effectiveness and efficiency of management with limited resources. Continued collaboration with the TMA and TMA members, particularly adjacent landowners (e.g. National Park Serviceand Kamehameha Schools) will enhance the effectiveness of response to regional threats like feral ungulates, weeds and fire.

NARS participation in TMA initiatives for weed control work with adjacent communities, landowners and community organizations will help protect the NAR by providing a better weed buffer and reducing the spread of harmful weeds. TMA members are also collaborating on new weed mapping and monitoring technologies such as remote sensing. Involvement in the TMA will also provide opportunities for sharing of monitoring protocols and/or joint long-term monitoring of natural resources and threats (e.g. bird monitoring across a larger landscape, intensive monitoring of National Park Service resources through the NPS Inventory and Monitoring Program). The NAR will also work with the TMA increase joint educational and outreach efforts in order to reach a larger audience.

NARS staff will also work closely with the DOD-YCA and/or the Department of Public Safety on numerous issues including staff and public access, management of native species and educational opportunities. NARS will also encourage whatever entity is managing Kūlani Correctional Facility to join and participate in the TMA. NARS staff can assist with management of native species, including endangered species present on lands adjacent to the Reserve. It will also be critical to collaborate on the management of threats to the Reserve such

as preventing the establishment of coqui frogs and the removal of invasive weeds. In addition, NARS can provide environmental education, service learning and work training for YCA students and/or Correctional Facility inmates on NARS lands, which will benefit both the students and/or inmates and the land.

Continued collaboration with other groups in addition to the TMA will also assist NAR management in various areas. NAR staff will continue to work closely with the Big Island Invasive Species Committee (BIISC) to jointly address incipient invasive species of plants and animals that threaten the Reserve. NAR staff will continue to work closely with two organizations focused on rare plant recovery (VRPF and PEPP). NAR staff will also work with community groups and volunteers to assist with initial animal control in fenced units, prevent the spread of introduced species (e.g. invasive weeds and coqui), and to restore native habitat and species.

Pu‘u Maka‘ala NAR offers unique opportunities for research, and NAR staff review all research permits before they are approved. NARS staff will work with interested researchers in the academic community as well as scientists so their research can better address critical management needs.

Infrastructure and Other Actions

Objective: Manage existing infrastructure within the NAR and take other actions necessary to protect and effectively manage the NAR.

Actions:

1. Add 342 ac (138 ha) of former Kūlani pasture areas to the NAR to protect and enhance endangered species habitat (Figure 15).
2. Block off access to Mauna Loa Boy’s School structure through fencing and signage to reduce the safety hazard to the public.
3. Investigate the feasibility of renovating or demolishing of Mauna Loa Boy’s School structure to prevent safety hazard to the public.
4. Maintain water infrastructure (e.g. water tanks) in the Kūlani portion of the NAR for fire fighting and weed control activities.
5. Maintain management access roads to support management and educational programs.
6. Develop utility and access easements for entities requiring access through the NAR.

NARS will be pursuing the administrative process to add 342 ac (138 ha) of state lands to the NAR, including approval of the BLNR and an executive order from the Governor (Figure 15). DOFAW currently has a Right-of-Entry permit over this area for data collection, surveys and conservation activities. This area was formerly used for cattle ranching by the Kūlani Correctional Facility. These former pastures have not been used for cattle since 2005 and ranching is not an environmentally appropriate use of this land as it the native forest is naturally recovering and the area is known habitat for endangered plants and animals. This proposed addition is particularly important for endangered forest birds, as it provides high elevation forest habitat above the mosquito line. This area provides excellent opportunities for public service

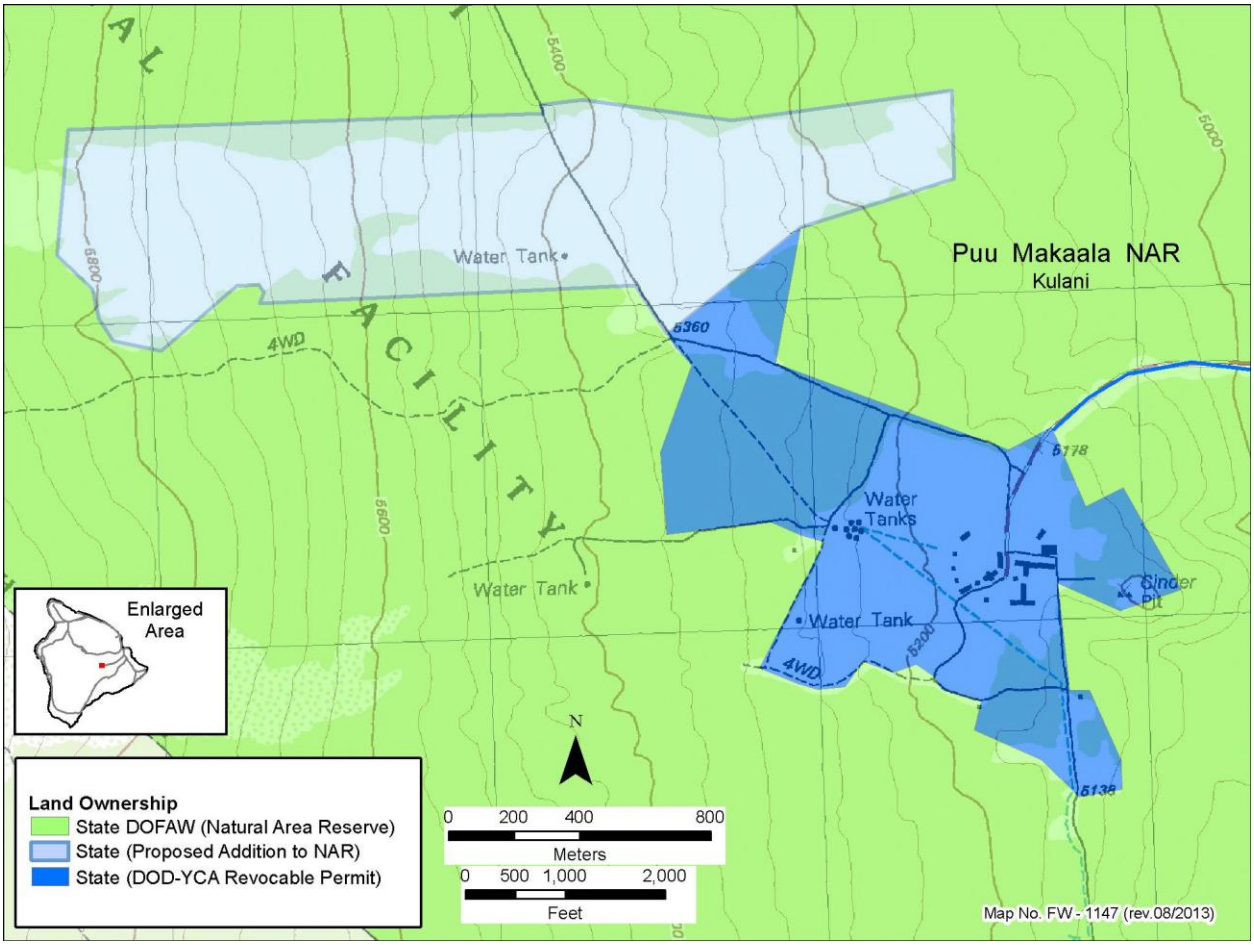
trips to work on tree planting and other restoration actions, and restoration of this area with koa-ʻōhiʻa forest will provide a critical link to connect surrounding intact forests.

The Reserve contains the Mauna Loa Boy's School facility which has not been maintained and is in currently in severe disrepair. In the short-term, this structure may need to be blocked off with fencing and signage to reduce public safety hazard. NAR staff will investigate the cost and feasibility of renovating or demolishing this structure to remove it as a public safety hazard and implement the most feasible option. The Mauna Loa Boy's School area was also previously used for military training and was investigated in 2010 by the U.S. Army following the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The Army's report concludes that the majority of the area does not pose a significant threat to public health or the environment. However, a small burn pile area near the Boys' School structure does contain levels of copper that exceed the US Environmental Protection Agency and the Hawaii Department of Health guidelines. The Army will be doing a follow-up study on the feasibility or remediating the 0.25 acre burn pile site. The burn pile site will be blocked from public access until the area is remediated and determined safe for public access.

Other former correctional facility infrastructure is also present in the Reserve (e.g. old ranch fencing, water tanks, water catchments, and roads). NAR staff would like to maintain some of this infrastructure; particularly management roads and water catchment for resources management purposes (e.g. fire fighting and weed control).

Various entities using Kūlani Cone as well as portions of the NAR for communications and utilitities purposes do not have a utility and/or access easement through the NAR and other adjacent state lands. NAR staff will request that these entities work with DLNR Land Division to develop utility and access easements.

Figure 15. Proposed Addition to Pu‘u Maka‘ala NAR



BUDGET

NAR staff for the island of Hawai‘i work on all eight NAR on the island, including Pu‘u Maka‘ala. In 2009, NAR staff include five DOFAW staff, four University of Hawai‘i contractors (Pacific Cooperative Studies Unit) and 1-3 interns. The budget below assumes current budget levels/existing staff will provide labor, materials and supplies for many of the ongoing and proposed management actions. New funding will be required to hire additional NAR staff and/or contractors to complete major new proposed projects including new fence construction and the expansion of weed management into these new fenced units.

Item	Estimated Cost (15 years)	Comments (annual cost)	Existing or New cost
Ungulate Management Program			
Fence Inspection/Maintenance and Ungulate Monitoring (existing fenced units)	$225,000	$15K/year for staff, supplies/materials	existing budget
New Fence Construction (17 miles)	$1,500,000	labor (additional staff and/or contractors), materials and	new cost $1,700,000

		helicopter @ 100K/mile	
Animal Control/Monitoring (new fenced units)	$225,000	$15K/year for staff, supplies and materials	existing budget
Weed Management program			
Weed Management (existing fenced units)	$900,000	$60K/year for staff, supplies and materials	existing budget
Weed Management (new fenced units)	$300,000	5 years@$60K/year for staff, supplies/ materials	new cost $300,000
Habitat Protection and Rare Species Restoration Program	$75,000	$5K/year for staff, supplies (outplanting rare plants)	existing budget
Fire Prevention and Response	$75,000	$5K/year for staff, training/equipment	existing budget
Monitoring (weeds/rare plants)	$75,000	$5K/year for staff	existing budget
Outreach and Education			
Volunteer service trips , teacher workshops, general education	$150,000	$10K/year for staff, supplies/outreach materials	existing budget
Interpretive Trail Development	$75,000	$5K/year staff, trail materials (e.g. (signs)	existing budget
Enforcement	----------	minimal cost	existing budget
Partnership Collaboration	$150,000	$10K/year for staff, supplies, materials	existing budget
Infrastructure	$150,000	$10K/year for staff, supplies, materials	existing budget
Estimated Total	$3,900,000	$2,100,000 ($140,000/year existing budget)	$2,000,000 new cost

REFERENCES

Ainsworth, A., B. Stevens, L. Hadway, N. Agorastos, I. Cole and C.M. Litton. 2009. Vegetation response to eight years of feral pig (*Sus scrofa*) removal in Puʻu Makaʻala Natural Area Reserve, Hawaiʻi. Manuscript in prep.

County of Hawaiʻi. 2005. General plan. Available at: http://www.cohplanningdept.com/community-planning/general-plan/

Giambelluca, T.W., Nullet, M.A., and Schroeder, T.A. 1986. Hawaii Rainfall Atlas, Report R76, Hawaii Division of Water and Land Development, Department of Land and Natural Resources, Honolulu. vi + 267 p.

Giffin, J. 1972. Ecology of the feral pig on the island of Hawaii. Project No. W-15-3, Study No. 11 1968-State of Hawaii, Division of Fish and Game.

Gillespie, Rosemary G. 1992. Distribution and diversity of an endemic lineage of invertebrate predators in the Natural Area Reserves of Hawaiʻi. Report to the Natural Area Reserves System.

Gorresen, P.M., Camp, R.J., Pratt, T.K., and Woodworth, B.L., 2005, Status of forest birds in the central windward region of Hawaiʻi Island: population trends and power analyses: U.S. Geological Survey, Biological Resources Discipline, Open-File Report 2005-1441, 81 p. Available at: http://pubs.usgs.gov/of/2005/1441/report.pdf

Jacobi , J.D. 1989. Vegetation maps of the upland plant communities on the islands of Hawai‘i, Maui, Molokai, and Lanai. Cooperative National Park Resources Studies Unit Technical Report 68. University of Hawai‘i at Manoa and National Park Service.

McEldowney, H. 1979. Archeological and historical literature search and research design: lava flow control study, Hilo, Hawai‘i. Department of Anthropology, B.P. Bishop Museum, Honolulu. Prepared for U.S. Army Engineer Division, Pacific Ocean.

Maly, K. and O. Maly. 2004. He Mo‘olelo ‘Āina: A cultural study of the Pu‘u Maka‘ala Natural Area Reserve, Districts of Hilo and Puna, island of Hawai‘i. Prepared by Kumu Pono Associates LLC for State of Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife, Natural Area Reserves Program.

Maly, K. and O. Maly. 2005. He wahi mo‘olelo no Keauhou a me na wahi pana ma laila: A collection of traditions, historical accounts and kama‘āina recollections of Keauhou and its storied places; with notes from adjoining lands in Ka‘ū and Puna, island of Hawai‘i. Prepared by Kumu Pono Associates for Kamehameha Schools.

‘Ōla‘a-Kīlauea Management Group. 1999. ‘Ōla‘a-Kīlauea Management Area: Natural resources management plan. Prepared by ‘Ōla‘a Kīlauea Partnership. Available at: http://hawp.org/_library/documents/three-mountain-alliance/olaa%20kilauea%20partnership%20management%20plan%201999.pdf

‘Ō la‘a-Kīlauea Management Group. 1999. Final environmental assessment for the ‘Ōla‘a-Kīlauea Management Area: Natural resources management plan. Prepared for State of Hawai‘i Department of Land and Natural Resources Division of Forestry and Wildlife Natural Area Reserves System as part of the ‘Ōla‘a-Kīlauea Partnership.

Palmer, D. D. 2003. Hawai‘i’s ferns and fern allies. University of Hawai‘i Press. Honolulu.

Preston, David J. 1995. A preliminary arthropod survey of Pu‘u Maka‘ala Natural Area Reserve, Hawai‘i Island, Hawai‘i. Bishop Museum: Honolulu.

Price, J. S. M. Gon III, J. D. Jacobi, and D. Matsuwaki, 2007 Mapping Plant Species Ranges in the Hawaiian Islands: Developing a Methodology and Associated GIS layers. Hawai‘i Cooperative Studies Unit Technical Report HCSU-008. University of Hawai`i at Hilo. 58 pp., incl. 16 Figures and 6 Tables.

Pukui, Mary Kawena and Samuel H. Elbert. 1986. *Hawaiian Dictionary.* University of Hawai‘i Press: Honolulu.

Rechman, Robert B. 2001. Archeological inventory survey and limited cultural assessment for the proposed wastewater treatment facility at Kūlani Correctional Facility (TMK: 3-2-4-08:9).

Scott, M.J., S. Mountainspring, F.L Ramsey, and C.B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology No. 9, Cooper Ornithological Society. Allen Press, Lawrence, Kansas.

Sherrod, David R., J. Sinton, S.E. Watkins, and K.M. Brunt. 2007. Geologic map of the State of Hawai‘i. Available at: http://pubs.usgs.gov/of/2007/1089/

State of Hawai‘i. 1981. Executive Order No. 3102: Setting aside land for public purposes. Honolulu, Hawai‘i.

State of Hawai‘i. 2008. Department of Business, Economic Development, and Tourism. State GIS database.

State of Hawai‘i. 2010. Executive Order No. 4338: Setting aside land for public purposes. Honolulu, Hawai‘i.

State of Hawai‘i Department of Accounting and General Services. 2002. Final environmental assessment and finding of no significant impact for Kūlani wastewater treatment plant.

State of Hawai‘i Department of Land and Natural Resources. 1981. Conservation District Use Permit #1340.

State of Hawai‘i Department of Land and Natural Resources. Natural Area Reserves Commission. 1978. Natural Area Reserve recommendations: Pu‘u Maka‘ala Natural Area Reserve.

State of Hawai‘i Department of Land and Natural Resources Division of Forestry and Wildlife Natural Area Reserves System. 1989. Pu‘u Maka‘ala Natural Area Reserve management plan.

State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife, Natural Area Reserve System. 1992. Long-term monitoring of the resources and threats of Pu‘u Maka‘ala Natural Area Reserve.

State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife, Natural Area Reserves Program. 1999. Environmental assessment for fence construction, Anunu Unit, Pu‘u Maka‘ala Natural Area Reserve.

State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife, Natural Area Reserves Program. 2003. Environmental assessment for fence construction, Wright Road Unit, ‘Ōla‘a -Kīlauea Partnership.

State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife, Natural Area Reserves Program. 2003-2009. Field notes.

State of Hawai‘i Department of Land and Natural Resources Division of Forestry and Wildlife. 2005. Hawai‘i’s comprehensive wildlife conservation strategy.

State of Hawai‘i Department of Land and Natural Resources Division of Forestry and Wildlife. 2007. Technical Report No. 07-01. Review of methods and approach for control of non-native ungulates in Hawaii.

State of Hawai‘i Department of Land and Natural Resources. The rain follows the forest - a plan to replenish Hawaii’s source of water.

Stone, C.P. 1985. Feral ungulates in Hawai‘i: Toward controlling the adverse effects of introduced vertebrates. In Stone, C.P. and J.M. Scott (eds.). *Hawaii’s Terrestrial Ecosystems: Preservation and Management.*

Stone, C.P., Cuddihy, L.W., and J.T. Tunison. 1992. Responses of Hawaiian ecosystems to the removal of feral pigs and goats. Pp. 666-704 in C.P. Stone, C.W. Smith, and J.T. Tunison (eds.). *Alien Plant Invasions in Native Ecosystems of Hawai`i: Management and Research*. University of Hawai‘i Cooperative National Park Resources Studies Unit, University of Hawai‘i Press, Honolulu.

Three Mountain Alliance Management Plan. 2007. Available at: http://hawp.org/_library/documents/three-mountain-alliance/tma%20mgmt%20plan.final.2.pdf

Three Mountain Alliance Weed Management Plan. 2009. Available at: http://hawp.org/_library/documents/three-mountain-alliance/tmaweedplanjune2009.pdf

Tunison, J.T. and C.P. Stone. 1992. Special ecological areas: an approach to alien plant control in Hawai‘i Volcanoes National Park. Pp. 781-798 In C.P. Stone, C.W. Smith, and J.T. Tunison. (eds.). *Alien Plant Invasions in Native Ecosystems of Hawai‘i: Management and Research*. University of Hawai‘i Cooperative National Park Resources Studies Unit, University of Hawai‘i Press, Honolulu.

U.S. Army Garrison Hawaii, DPW-ENV. November 2010. Remedial Investigation Report, Kulani Boys’ Home (PTA-002-R-01), Stakeholder Draft.

United States Natural Conservation Service. 2009. Draft soil maps for the island of Hawai‘i.

United States Department of the Interior Geological Survey. 2005. Biocomplexity of introduced avian diseases in Hawai‘i: Threats to biodiversity of native forest ecosystems. Prepared by B.L.. Woodworth, C. T. Atkinson, M. D. Samuel, D. A. LaPointe, P. C. Banko, and J. A. Ahumada. USGS Fact Sheet 2005-3139.
Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/bioc.pdf

United States Department of the Interior Geological Survey. 2006a. Feral cats: Too long a threat to Hawaiian wildlife. Prepared by S.C. Hess and P.C. Banko. USGS Fact Sheet 2006-3006. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/cats.pdf

United States Department of the Interior Geological Survey. 2006b. Hawai‘i forest bird interagency database project: Collecting, understanding, and sharing population data on Hawaiian forest birds. Prepared by T.K. Pratt, B.L. Woodworth, R.J. Camp, P.M. Gorresen. USGS Fact Sheet 2006-3013. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/birds.pdf

United States Department of the Interior Geological Survey. 2006c. Feral pigs, introduced mosquitoes, and the decline of Hawai‘i’s native birds. Prepared by D.A. LaPointe. USGS Fact Sheet 2006-3029. Available at: http://www.usgs.gov/ecosystems/pierc/files/factsheets/pigs.pdf

U.S. Fish and Wildlife Service. 1996. Big Island Plant Cluster Recovery Plan. U.S. Fish and Wildlife Service, Portland, OR. 202+ pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1996/960926a.pdf.

U.S. Fish and Wildlife Service. 1998a. Big Island II: Addendum to the Recovery Plan for the Big Island Plant Cluster. U.S. Fish and Wildlife Service, Portland, OR. 115 pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1998/980511a.pdf.

U.S. Fish and Wildlife Service. 1998b. Final Recovery Plan for Four Species of Hawaiian Ferns. U.S. Fish and Wildlife Service, Portland, OR. 89 pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1998/980410e.pdf.

U.S. Fish and Wildlife Service. 1998c. Recovery Plan for the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*). U.S. Fish and Wildlife Service, Portland, OR. 59 pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1998/980511b.pdf.

U.S. Fish and Wildlife Service. 1999. Recovery Plan for the Multi-island Plants. U.S. Fish and Wildlife Service, Portland, OR. 305 pp. Available at: http://ecos.fws.gov/docs/recovery_plans/1999/990710.pdf.

U.S. Fish and Wildlife Service. 2003. Final designation and nondesignation of critical habitat for 46 plant species from the island of Hawai‘i, HI. Federal Register Final Rule (68 FR 39623 39672). Available at: http://ecos.fws.gov/docs/federal_register/fr4117.pdf

U.S. Fish and Wildlife Service. 2006. Revised Recovery Plan for Hawaiian Forest Birds. Region 1, Portland, OR. 622 pp. Available at: http://ecos.fws.gov/docs/recovery_plan/060922a.pdf

U.S. Fish and Wildlife Service. 2009. Final designation Critical Habitat for 12 Species of Picture-Wing Flies from the Hawaiian Islands. Federal Register Final Rule (73 FR 73795

73895). Available at: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=I0R1

Wagner, W. L., Herbst, D. R., and Sohmer, S.H. 1999. Manual of the flowering plants of Hawai‘i. University of Hawai‘i Press, Bishop Museum, Honolulu.

Walker, Ronald. 1978. A History of the Division of Fish and Game. Unpublished.

Warshauer, Kent. 2001. Riddle of the relic. How to get there from here: the story of Kūlani Road. The History of Kūlani Road Part II. June 24 and July 1. Hawai‘i Tribune Herald.

Warshauer, Kent. 2001. Riddle of the relic. Boy’s camp had short, notorious history. April 24. Hawai‘i Tribune Herald.

Warshauer, Kent. 2002. Riddle of the relic. Army Road has interesting history. September 8. Hawai‘i Tribune Herald.

Appendix A – Plant Species List

These species lists (native plants, non-native plants are ferns) were compiled by updating the plant species list from the previous management plan (1989), consulting available literature sources to update names and consulting with NAR staff. Some species included on the list (particularly rare species and high priority weed species) may not be present in the NAR, however they are historically and/or currently known from adjacent areas.

Status: Federal and State endangered species list
- END Endangered
- T Threatened
- C Candidate species
- SOC Species of Concern (unofficial)

Affinity:
- N Non-native
- P Polynesian introduction
- I Indigenous
- E Endemic

<u>Native Plants</u> (Endemic and Indigenous)

Taxon	Common/Hawaiian name	Family	Affinity	Status
Acacia koa	koa	Fabaceae	E	
Agrostis avenacea	he‘upueo	Poaceae	I	
Alyxia stellata	maile	Apocynaceae	E	
Anoectochilus sandvicensis	jewel orchid	Orchidaceae	E	SOC
Antidesma platyphyllum	hame	Euphorbiaceae	E	
Argyroxiphum kauense	Mauna Loa silversword	Asteraceae	E	END
Astelia menziesiana	pa‘iniu, kakuaha	Liliaceae	E	
Broussaisia arguta	kanawao	Hydrangeaceae	E	
Carex alligata		Cyperaceae	E	
Carex echinata		Cyperaceae	I	
Carex macloviana		Cyperaceae	I	
Carex montis-eeka		Cyperaceae	E	
Carex thunbergii		Cyperaceae	I?	
Carex wahuensis		Cyperaceae	E	
Charpentiera obovata	pāpala	Amaranthaceae	E	
Cheirodendron trigynum	‘ōlapa	Araliaceae	E	
Clermontia hawaiiensis	‘ōhā kēpau, ‘ōhā wai nui	Campanulaceae	E	
Clermontia lindseyana	‘ōhā wai	Campanulaceae	E	END
Clermontia montis-loa	‘ōhā wai	Campanulaceae	E	
Clermontia parviflora	‘ōhā wai	Campanulaceae	E	
Clermontia peleana	‘ōhā wai	Campanulaceae	E	END
Coprosma ernodeoides	kūkaenēnē	Rubiaceae	E	
Coprosma granadensis	mākole	Rubiaceae	E	
Coprosma montana	pilo	Rubiaceae	E	
Coprosma ochracea	pilo	Rubiaceae	E	

Coprosma pubens		Rubiaceae	E	
Coprosma rhynchocarpa	pilo	Rubiaceae	E	
Cyanea shipmanii	hāhā	Campanulaceae	E	END
Cyanea copelandii	hāhā	Campanulaceae	E	END
Cyanea floribunda	hāhā	Campanulaceae	E	
Cyanea giffardii	hāhā	Campanulaceae	E	SOC
Cyanea pilosa var. longipedunculata	hāhā	Campanulaceae	E	
Cyanea platyphylla	ʻakūʻakū	Campanulaceae	E	END
Cyanea stictophylla	hāhā	Campanulaceae	E	END
Cyanea tritomantha	ʻakū	Campanulaceae	E	
Cyrtandra giffardii	haʻiwale	Gesneriaceae	E	END
Cyrtandra lysiosepala	haʻiwale	Gesneriaceae	E	
Cyrtandra paludosa	moa, hahala	Gesneriaceae	E	
Cyrtandra platyphylla	ʻilihia	Gesneriaceae	E	
Cyrtandra tintinnabula	haʻiwale	Gesneriaceae	E	END
Deschampsia nubigena		Poaceae	E	
Dianella sandwicensis	ʻukiʻuki	Liliaceae	I	
Dichanthelium hillebrandianum		Poaceae	E	
Dubautia scabra	naʻenaʻe	Asteraceae	E	
Eleocharis obtusa	spikerush, kohekohe, pīpīwai	Cyperaceae	I	
Embelia pacifica	kilioe	Myrsinaceae	E	
Eurya sandwicensis	ānini	Theaceae	E	SOC
Fimbristylis dichotoma		Cyperaceae	I	
Fragaria chiloensis var. sandwicensis	ʻōhelo papa	Rosaceae	E	
Freycinetia arborea	ʻieʻie	Pandanaceae	I	
Gardenia remyi		Rubiaceae	E	C
Ilex anomala	kāwaʻu	Aquifoliaceae	I	
Joinvillea ascendens ssp. ascendens	ʻohe	Joinvilleaceae	E	C
Kadua accuminata	au, pilo	Rubiaceae	E	
Kadua affinis	manono	Rubiaceae	E	
Kadua centranthoides		Rubiaceae	E	
Korthalsella complanata	hulumoa, kaumahana	Viscaceae	I	
Labordia hedyosmifolia	kāmakahala	Loganiaceae	E	
Leptecophylla tameiameiae	pūkiawe	Ericaceae	I	
Liparis hawaiensis	ʻawapuhiakanaloa	Orchidaceae	E	SOC
Ludwigia octovalvis	primrose willow, kāmole	Onagraceae	Pol?	
Luzula hawaiiensis	wood rush	Juncaceae	E	
Machaerina angustifolia	ʻuki	Cyperaceae	I	
Melicope clusiifolia	kolokolo mokihana	Rutaceae	E	
Melicope hawaiensis	mokihana kūkae moa	Rutaceae	E	
Melicope pseudoanisata	ālani	Rutaceae	E	
Melicope radiata	ālani	Rutaceae	E	
Melicope volcanica	ālani	Rutaceae	E	
Metrosideros polymorpha	ʻōhiʻa, ʻōhiʻa lehua	Myrtaceae	E	

Morelotia gahniiformis		Cyperaceae	I	
Myoporum sandwicense	naio	Myoporaceae	I	
Myrsine lessertiana	kōlea lau nui	Myrsinaceae	E	
Myrsine sandwicensis	kōlea lau li`i	Myrsinaceae	E	
Nothocestrum longifolium	`aiea	Solanaceae	E	
Oreobolus furcatus		Cyperaceae	E	
Peperomia cookiana	ʻalaʻala wai nui	Piperaceae	E	
Peperomia hypoleuca	ʻalaʻala wai nui	Piperaceae	E	
Peperomia latifolia	ʻalaʻala wai nui	Piperaceae	E	
Peperomia macraeana	ʻalaʻala wai nui	Piperaceae	E	
Peperomia membranacea	ʻalaʻala wai nui	Piperaceae	E	
Perrottetia sandwicensis	olomea	Celastraceae	E	
Phyllostegia ambigua		Lamiaceae	E	SOC
Phyllostegia brevidens		Lamiaceae	E	SOC
Phyllostegia floribunda		Lamiaceae	E	C
Phyllostegia macrophylla		Lamiaceae	E	SOC
Phyllostegia racemosa	kīponapona	Lamiaceae	E	E
Phyllostegia velutina		Lamiaceae	E	E
Phyllostegia vestita		Lamiaceae	E	
Phytolacca sandwicensis	pōpolo kū mai	Phytolaccaceae	E	
Pipturus albidus	māmaki	Urticaceae	E	
Pittosporum confertiflorum	hōʻawa	Pittosporaceae	E	
Pittosporum hawaiiense	hōʻawa	Pittosporaceae	E	SOC
Pittosporum terminalioides	hōʻawa	Pittosporaceae	E	
Plantago pachyphylla	laukahi kuahiwi	Plantaginaceae	E	
Platydesma spathulata	pilo kea	Rutaceae	E	
Pritchardia beccariana	loulu	Arecaceae	E	
Psychotria hawaiiensis	kōpiko ʻula, ʻopiko	Rubiaceae	E	
Pycreus polystachyos		Cyperaceae	I	
Rubus hawaiensis	ʻākala	Rosaceae	E	
Rubus macrei	ʻākala	Rosaceae	E	
Rumex giganteus	pāwale, uhauhakō	Polygonaceae	E	
Rhynchospora chinensis	kuolohia	Cyperaceae	I	
Rhynchospora rugosa	puʻukoʻa	Cyperaceae	I	
Santalum paniculatum		Santalaceae	E	
Scaevola chamissoniana	naupaka, naupaka kuahiwi	Goodeniaceae	E	
Schiedea diffusa		Caryophyllaceae	E	SOC
Sicyos alba	ʻānunu	Cucurbitaceae	E	E
Sisyrinchium acre	mauʻu lāʻili	Iridaceae	E	SOC
Smilax melastomifolia	hoi kuahiwi, akaʻawa	Smilacaceae	E	
Solanum americanum	pōpolo, glossy nightshade	Solanaceae	I	
Sophora chrysophylla	māmane	Fabaceae	E	
Stenogyne calaminthoides		Lamiaceae	E	
Stenogyne macrantha		Lamiaceae	E	SOC
Stenogyne scrophularioides	mōihi	Lamiaceae	E	

Stenogyne sessilis		Lamiaceae	E	
Tetraplasandra kavaiensis	ʻohe ʻohe	Araliaceae	E	
Tetraplasandra oahuensis	ʻohe mauka	Araliaceae	E	
Touchardia latifolia	olonā	Urticaceae	E	
Trematolobelia grandifolia		Campanulaceae	E	SOC
Uncinia uncinata		Cyperaceae	I	
Urera glabra	ōpuhe	Urticaceae	E	
Vaccinium calycinum	ōhelo kau lāʻau	Ericaceae	E	
Vaccinium reticulatum	ōhelo	Ericaceae	E	
Vicia menziesii		Fabaceae	E	E
Viola maviensis		Violaceae	E	
Wikstroemia sandwicensis	ʻākia	Thymelaeceae	E	
Xylosma hawaiiense	maua	Flocourtiaceae	E	
Zanthoxylum kauaense	aʻe, mānele	Rutaceae	E	SOC

Non- Native Plants

Taxon	Common/Hawaiian name	Family
Ageratina riparia	Hamakua pamakani, mist flower	Asteraceae
Ageratum conyzoides	maile hohono	Asteraceae
Agrostis stolonifera	redtop, creeping bentgrass	Poaceae
Amaranthus spinosus	spiny pigweed, pakai kuku	Amaranthaceae
Anagallis arvensis	scarlet pimpernel	Primulaceae
Andropogon virginicus	broomsedge	Poaceae
Anemone hupehensis	Japanese anenome	Ranunculaceae
Anthoxanthum odoratum	sweet vernalgrass	Poaceae
Arenaria serpyllifolia	thyme-leaved sandwort	Caryophyllaceae
Arundina graminifolia	bamboo orchid	Orchidaceae
Axonopus fissifolius	narrow-leaved carpetgrass	Poaceae
Bidens alba	Spanish needle	Asteraceae
Bidens pilosa	Spanish needle	Asteraceae
Brassica rapa	radish	Brassicaceae
Brugmansia candida	angel's trumpet	Solanaceae
Buddleja asiatica	dog tail, Asiatic butterfly bush	Buddlejaceae
Buddleja davidii	butterfly bush	Buddlejaceae
Bulbostylis capillaris		Cyperaceae
Cannabis sativa	pakalolo, marijuana	Cannabaceae
Cardamine flexuosa	bittercress	Brassicaceae
Castilleja arvensis	indian paintbrush	Scrophulariaceae
Centaurium erythraea	bitter herb, European centaury	Gentianaceae
Centella asiatica	Asiatic pennywort, pohe kula	Apiaceae
Cerastium fontanum	chickweed	Gentianaceae
Cestrum nocturnum	night blooming jasmine	Solanaceae
Cirsium vulgare	bull thistle	Asteraceae
Clidemia hirta	Koster's curse	Melastomataceae
Commelina diffusa	honohono, makolokolo	Commelinaceae
Conyza bonariensis	hairy horseweed	Asteraceae

Conyza canadensis	Canada fleabane	Asteraceae
Cotoneaster pannosus		Rosaceae
Crassocephalum crepidioides		Asteraceae
Crocosmia x crocosmiiflora	montbretia	Iridaceae
Cuphea carthagenensis	tarweed	Lythraceae
Cyperus halpan		Cyperaceae
Cyperus trinervous		Cyperaceae
Dactylis glomerata	orchardgrass, cocksfoot	Poaceae
Desmodium incanum	Spanish clover, kaʻimi	Fabaceae
Digitaria ciliaris	Henry's crabgrass	Poaceae
Digitaria eriantha	pangola grass	Poaceae
Digitaria pentzii		Poaceae
Digitaria violascens	smooth or violet crabgrass	Poaceae
Dissotis rotundifolia		Melastomataceae
Drymaria cordata	pipili	Caryophyllaceae
Ehrharta stipoides	meadow ricegrass	Poaceae
Emilia sonchifolia	Flora's paintbrush	Asteraceae
Epilobium billardierianum	willow herb	Onagraceae
Epilobium ciliatum		Onagraceae
Eragrostis brownii	sheepgrass	Poaceae
Eragrostis elongata	lovegrass	Poaceae
Erechtites valerianifolia	fireweed	Asteraceae
Erigeron karvinskianus	daisy fleabane	Asteraceae
Euchiton sphaericus	Japanese cudweed	Asteraceae
Festuca rubra	red fescue	Poaceae
Fragaria vesca	European strawberry	Rosaceae
Fraxinus uhdei	tropical ash	Oleaceae
Fuchsia magellanica	hardy fuchsia, earring flower	Onagraceae
Geranium homeanum		Geraniaceae
Gnaphalium japonicum		Asteraceae
Gnaphalium purpureum	purple cudweed	Asteraceae
Hedychium coronarium	white ginger	Zingiberaceae
Hedychium flavescens	yellow giner	Zingiberaceae
Hedychium gardnerianum	kāhili ginger	Zingiberaceae
Holcus lanatus	velvetgrass	Poaceae
Hydrocotyle bowlesioides	marsh pennywort	Apiaceae
Hydrocotyle verticillata	pohe	Apiaceae
Hyparrhenia rufa	thatching grass, jaragua	Poaceae
Hypericum kouytchense	St. John's wort	Clusiaceae
Hypericum mutilum	St. John's wort	Clusiaceae
Hypericum parvulum	St. John's wort	Clusiaceae
Hypochoeris radicata	hairy cat's ear	Asteraceae
Juncus acuminatus	rush	Juncaceae
Juncus bufonius	common or toad rush	Juncaceae
Juncus effusus	Japanese mat rush	Juncaceae
Juncus ensifolius	rush	Juncaceae

Juncus planifolius	rush	Juncaceae
Juncus polyanthemos	rush	Juncaceae
Juncus tenuis	path rush	Juncaceae
Kyllinga brevifolia	kili‘o‘opu	Cyperaceae
Leucanthemum vulgare	ox-eye, white, or field daisy	Asteraceae
Lonicera japonica	honeysuckle	Caprifoliaceae
Lotus subbiflorus		Fabaceae
Lotus uliginosus		Fabaceae
Ludwigia palustris	marsh purslane	Onagraceae
Lythrum maritimum	loosestrife	Lythraceae
Melinus minutiflora	molasses grass	Poaceae
Melinus repens	Natal redtop	Poaceae
Morella faya	faya	Myrsinaceae
Myosotis discolor	forget me not	Borginaceae
Oenothera stricta	evening primrose	Onagraceae
Oxalis corniculata	yellow wood sorrel	Oxalidaceae
Panicum repens	torpedo grass, quack grass	Poaceae
Paspalum conjugatum	Hilo grass	Poaceae
Paspalum dilatatum	dallis grass	Poaceae
Paspalum urvillei	vasey grass	Poaceae
Passiflora edulis	liliko`i, passion fruit	Passifloraceae
Passiflora ligularis	sweet granadilla	Passifloraceae
Passiflora tarminiana	banana poka	Passifloraceae
Pennisetum clandestinum	kikuyu grass	Poaceae
Persicaria capitatum	knotweed	Polygonaceae
Persicaria punctatum	water smartweed	Polygonaceae
Phaius tankarvilleae	Chinese ground orchid	Orchidaceae
Physalis peruviana	poha, cape gooseberry	Solanaceae
Phytolacca octandra	southern pokeberry	Phytolaccaceae
Pinus spp.		Pinaceae
Plantago australis	dwarf plantain	Plantaginaceae
Plantago lanceolata	narrow-leafed plantain	Plantaginaceae
Plantago major	laukahi, broad-leafed plantain	Plantaginaceae
Pluchea symphytifolia	sourbush	Asteraceae
Poa annua	annual bluegrass	Poaceae
Poa pratensis	Kentucky bluegrass	Poaceae
Polygala paniculata	milkwort	Polygalaceae
Prunella vulgaris	selfheal, heal-all	Lamiaceae
Prunus cerasifer x salicina		Rosaceae
Psidium cattleianum	strawberry guava	Myrtaceae
Psidium guajava	common guava	Myrtaceae
Pycreus sanguinolentus		Cyperaceae
Pyrocantha angustifolia	firethorn	Rosaceae
Ranunculus plebeius	common Australian buttercup	Ranunculaceae
Ranunculus repens	creeping buttercup, butter daisy	Ranunculaceae
Rhynchospora caduca	beak rush	Cyperaceae

Rubus argutus	blackberry	Rosaceae
Rubus ellipticus	yellow Himalayan raspberry	Rosaceae
Rubus glaucus		Rosaceae
Rubus niveus	hill or mysore raspberry	Rosaceae
Rubus rosifolius	thimbleberry	Rosaceae
Rumex acetosella	sheep sorrel	Polygonaceae
Rumex crispus	curly or yellow dock	Polygonaceae
Sacciolepis indica	Glenwood grass	Poaceae
Salvia spp.		Lamiaceae
Schizachyrium condensatum	beardgrass	Poaceae
Senecio madagascariensis	fireweed	Asteraceae
Senecio sylvaticus	wood groundsel	Asteraceae
Sequoia sempervirens		Taxiodaceae
Setaria gracilis	yellow or perennial foxtail	Poaceae
Setaria palmifolia	palmgrass	Poaceae
Sonchus asper	prickly sow thistle	Asteraceae
Sonchus oleraceus	sow thistle	Asteraceae
Spermacoce mauritiana		Rubiaceae
Sporobolus africanus	smutgrass, African dropseed	Poaceae
Sporobolus indicus	West Indian dropseed	Poaceae
Stachytarpheta dichotoma	ōwi, ōi	Verbenaceae
Stenotaphrum secundatum	St. Augustine grass, buffalo grass	Poaceae
Taraxacum officinale	dandelion	Asteraceae
Themeda villosa	Lyon's grass	Poaceae
Tibouchina herbacea	Cane tibouchina	Melastomataceae
Tibouchina longifolia	glorybush	Melastomataceae
Tibouchina urvilleana	Lasiandra, princess flower	Melastomataceae
Trifolim dubium	small hop clover	Fabaceae
Trifolim repens	white clover	Fabaceae
Tropaeolum majus	nasturtium	Tropaeolaceae
Verbascum thapsus	common mullein	Scrophulariaceae
Verbena litoralis	hauʻowi, ōwi, ōi	Verbenaceae
Veronica plebeia	trailing or common speedwell	Scrophulariaceae
Veronica serpyllifolia	thyme-leaved speedwell	Scrophulariaceae
Vulpia bromoides	brome fescue	Poaceae
Vulpia myuros	rat tail fescue	Poaceae
Xyris platyleis	yellow eyed grass	Xyridaceae
Youngia japonica	oriental hawksbeard	Asteraceae

<u>Ferns</u> (native and non-native)

Taxon	Common/Hawaiian name	Family	Affinity	Status
Adenophorus hymenophylloides	pai, palai huna	Grammitidaceae	E	
Adenophorus periens	palai laʻaū	Grammitidaceae	E	END
Adenophorus pinnatifidus		Grammitidaceae	E	
Adenophorus tamariscinus	wahine noho mauna	Grammitidaceae	E	

Adenophorus tripinnatifidus		Grammitidaceae	E	
Adiantum hispidulum		Pteridaceae	N	
Adiantum raddianum	rough maidenhair fern	Pteridaceae	N	
Amauropelta globulifera	palapalai a Kamapua‘a	Thelypteridaceae	E	
Angiopteris evecta	mule's-foot fern	Marattiaceae	N	
Asplenium acuminatum	lola	Aspleniaceae	E	
Asplenium adiantum-nigrum	‘iwa‘iwa	Aspleniaceae	I	
Asplenium aethiopicum	‘iwa‘iwa a Kāne	Aspleniaceae	I	
Asplenium contiguum		Aspleniaceae	E	
Asplenium horridum	‘iwa, ‘alae	Aspleniaceae	I	
Asplenium insiticium	pi‘ipi‘i lau manamana, ‘anali‘i	Aspleniaceae	I	
Asplenium lobulatum	pi‘ipi‘i lau manamana	Aspleniaceae	I	
Asplenium macraei	‘iwa‘iwa lau li‘i	Aspleniaceae	E	
Asplenium monanthes		Aspleniaceae	I	
Asplenium normale		Aspleniaceae	I	
Asplenium peruvianum var. insulare		Aspleniaceae	E	END
Asplenium polyodon	pūnana manu	Aspleniaceae	I	
Asplenium schizophyllum		Aspleniaceae	E	
Asplenium sphenotomum		Aspleniaceae	E	
Asplenium spp.		Aspleniaceae	E	
Asplenium trichomanes	‘oāl‘i	Aspleniaceae	E	
Asplenium unilaterale	pāmoho	Aspleniaceae	I	
Athyrium microphyllum	‘ākōlea	Athyriaceae	E	
Botrychium subbifoliatum	makou	Ophioglossaceae	E	
Christella cyatheoides	kakawaiō, kikawaioa, pakikawaiō	Thelypteridaceae	E	
Christella dentata	pai‘i‘ihā	Thelypteridaceae	N	
Christella parasitica		Thelypteridaceae	N	
Cibotium chamissoi	hapu‘u, meu	Dicksoniaceae	E	
Cibotium glaucum	hapu‘u, hapu‘u pulu	Dicksoniaceae	E	
Cibotium menziesii	hapu‘u ‘i‘i	Dicksoniaceae	E	
Coniogramme pilosa	lo‘ulu	Pteridaceae	E	
Ctenitis latifrons	‘ākōlea	Dryopteridaceae	E	
Cyrtomium caryotudeum	kā‘ape‘ape, āhina kuahiwi	Dryopteridaceae	I	
Deparia petersonii		Athyriaceae	N	
Dicranopteris linearis	uluhe	Athyriaceae	I	
Diplazium sandwichianum	hō'i'o	Athyriaceae	E	
Diplopterygium pinnatum	uluhe lau nui	Gleicheniaceae	E	
Dryopteris fusco-atra	‘i‘i	Dryopteridaceae	E	
Dryopteris glabra	kīlau, hohiu	Dryopteridaceae	E	
Dryopteris hawaiiensis		Dryopteridaceae	E	
Dryopteris sandwicensis		Dryopteridaceae	E	
Dryopteris unidentata var. paleacea	‘akole	Dryopteridaceae	E	
Dryopteris unidentata var.	‘akole	Dryopteridaceae	E	

unidentata				
Dryopteris wallichiana	ʻiʻo nui, laukahi	Dryopteridaceae	E	
Elaphoglossum crassifolium	hoe a Maui, ʻekaha	Lomariaopsidaceae	E	
Elaphoglossum paleaceum	mākuʻe	Lomariaopsidaceae	I	
Elaphoglossum pellucidum	hoe a Maui, ʻekaha ʻula	Lomariaopsidaceae	E	
Elaphoglossum wawrae	laukahi, hoe a Maui, ʻekaha ʻula	Lomariaopsidaceae	E	
Gonocormus prolifer		Hymenophyllaceae	I	
Grammitis hookeri	mākuʻe lau liʻi	Grammitidaceae	I	
Grammitis tenella	kolokolo, mahinalua	Grammitidaceae	E	
Huperzia filiformis		Lycopodiaceae	I	
Huperzia phyllantha	wawaeʻiole	Lycopodiaceae	I	
Huperzia serrata	wawaeʻiole	Lycopodiaceae	I	
Hypolepis hawaiiensis	olua	Dennstaedtiaceae	E	
Lellingeria saffordii	kihe	Grammitidaceae	E	
Lepisorus thunbergianus	pākahakaha, ʻekaha ākōlea	Polypodiaceae	I	
Lycopodium cernua	wawaeʻiole	Lycopodiaceae	I	
Lycopodium venustulum	wawaeʻiole	Lycopodiaceae	I	
Macrothelypteris torresiana		Thelypteridaceae	N	
Marattia douglasii	pala	Marattiaceae	E	
Mecodium recurvum	`ōhi`a kū	Hymenophyllaceae	E	
Microlepia strigosa	palapalai	Dennstaedtiaceae	I	
Nephrolepis cordifolia	narrow swordfern	Nephrolepidaceae	I	
Nephrolepis exaltata subsp. hawaiiensis	ni`ani`au, `ōkupu-kupu, pāmoho, kupukupu	Nephrolepidaceae	E	
Nephrolepis multifora	scaly swordfern	Nephrolepidaceae	N	
Nothoperanema rubiginosa	pauoa	Dryopteridaceae	E	
Ophioderma pendulum	puapua moa	Ophioglossaceae	I	
Pityrogramma austroamericana	gold fern, goldback fern	Pteridaceae	N	
Pityrogramma calomelanos	silver fern, silverback fern	Pteridaceae	N	
Pneumatopteris sandwicensis	hōʻiʻo-kula	Thelypteridaceae	E	
Polypodium pellucidum	ʻae, ʻae lau nui	Polypodiaceae	E	
Polystichum hillebrandii	kaʻupu, papaʻoi	Dryopteridaceae	E	
Pseudophegopteris keraudreniana	waimaka-nui, ʻalaʻalai	Thelypteridaceae	E	
Psilotum complanatum	moa	Psilotaceae	I	
Psilotum nudum	pipi	Psilotaceae	I	
Pteridium aquilinum	kīlau, bracken fern	Dennstaedtiaceae	E	
Pteris cretica	ʻoālʻi, Cretan brake	Pteridaceae	I	
Pteris excelsa	waimakanui, ʻiwa	Pteridaceae	I	
Pteris irregularis	māna	Pteridaceae	E	
Sadleria cyatheoides	ʻamaʻu, maʻu	Blechnaceae	E	
Sadleria pallida	ʻamaʻu, maʻu	Blechnaceae	E	
Sadleria souleyetiana	ʻamaʻu, maʻu	Blechnaceae	E	
Selaginella arbuscula	lepelepe a moa	Sellaginellaceae	E	
Selaginella kraussiana	spreading selaginella	Sellaginellaceae	N	
Sphaerocionium lanceolatum	palai hinahina	Hymenophyllaceae	E	

Sphaeropteris cooperi	Australian tree fern	Cyatheaceae	N	
Sphenomeris chinensis	pala‘ā	Lindsaeaceae	I	
Sticherus owhyensis		Gleicheniaceae	E	
Vandenboschia davallioides	kilau	Hymenophyllaceae	E	

Appendix B - Pu‘u Maka‘ala Birds (birds historically/currently found in or near the NAR).

Taxon	Common Name	Status
Acridotheres tristis	common myna	non-native
Alauda arvensis	Eurasian skylark	non-native
Asio flammeus sandwichensis	pueo, Hawaiian owl	endemic
Branta sandvicensis	nēnē, Hawaiian goose	endemic - endangered
Buteo solitarius	‘io, Hawaiian hawk	endemic - endangered
Callipepa californica	California quail	non-native
Cardinalis cardinalis	northern cardinal	non-native
Carpodacus mexicanus	house finch	non-native
Cettia diphone	Japanese bush warbler	non-native
Chasiempis sandwichensis	‘elepaio	endemic
Francolinus erckelii	Erckel’s francolin	non-native
Garrulax canows	hwamei, melodious laughing thrush	non-native
Geopelia striata	zebra dove	non-native
Hemignathus munroi	‘akiapōlā‘au	endemic - endangered
Hemignathus virens	‘amakihi	endemic
Himatione sanguinea	‘apapane	endemic
Leiothrix lutea	red-billed leoithrix	non-native
Lonchura punctulata	nutmeg mannikin	non-native
Lophura leucomelanos	kalij pheasant	non-native
Loxops coccineus	Hawai‘i ‘ākepa	endemic - endangered
Oceanodroma castro	‘akē‘akē, band-rumped storm petrel	indigenous - candidate
Oreomystis mana	Hawai`i creeper	endemic - endangered
Phaeornis obscurus	‘ōma‘o	endemic
Phasianus colchicus	ring-necked pheasant	non-native
Pluvialis fulva	kōlea, Pacific golden plover	indigenous
Psittirostra psittacea	‘ō‘ū	endemic – endangered
Pterodroma sandwichensis	‘ua‘u or Hawaiian petrel	endemic - endangered
Vestiaria coccinea	‘i‘iwi	endemic
Zosterops japonicus	Japanese white-eye	non-native

Appendix C - Insects and related arthropods, including land snails, collected and/or recorded from Pu'u Maka'ala NAR (Preston 1995).

TAXA	STATUS[1]
ACARI	
Oribatulidae	?
undetermined mites	?
AMPHIPODA	
Talitridae	?
ARANEAE	
COLLEMBOLA	
Entomobryidae	
Entomobrya spp.	end?
Isotomidae	
Folsomia sp.	end?
Sminthuridae	
nr. *Sminthurides* sp.	?
COLEOPTERA	
[2]Aglycyderidae	end
Anobiidae	
Mirosternus lugubris Perkins, 1910	end
Xyletobius collingei Perkins, 1910	end
Carabidae	
Mecyclothorax sp. nr. *paradoxus* (Blackburn, 1879)	end
Mecyclothorax sp. nr. *proximus* Britton, 1948	end
Ciidae	
Cis sp. nr. *setarius* Sharp, 1885	end?
Nitidulidae	
Euptinus hawaiiensis Sharp, 1878	end
Staphylinidae	
Atheta sp.	adv?
Myllaena cognata Sharp, 1908	end
DIPTERA	
Calliphoridae	
Calliphora vomitoria (Linnaeus, 1758)	adv
Dyscritomyia spp.	end
Eucalliphora latifrons (Hough, 1899)	adv
Lucilia cuprina (Wiedemann, 1830)	adv
Cecidomyiidae	?
Ceratopogonidae	
Forcipomyia prob. *hardyi* Wirth & Howarth, 1982	end
Chironomidae	
Orthocladius sp. A	end
Orthocladius sp. B	end
Chloropidae	
Rhodesiella sp.	end?
Dixiidae	adv
Dolichopodidae	
Campsicnemus flaviventer Hardy & Kohn, 1964	end
Campsicnemus fumipennis Parent, 1937	end
Campsicnemus impariseta Hardy & Kohn, 1964	end
Campsicnemus longiquus Tenorio, 1969	end
Campsicnemus penicillatus Parent, 1934	end
Campsicnemus pychnochaeta Hardy & Kohn, 1964	end
Campsicnemus scolimerus Hardy & Kohn, 1964	end

Campsicnemus new sp. A (white specimens)	end
Eurynogastersp. A	end
Drosophilidae	
Drosophila suzukii group	adv
[2]*Drosophila* spp. (picture wing group)	end
Scaptomyza spp.	end
Ephydridae	
Scatella sp.	end
Muscidae	
[2]*Lispocephala confluens* (Malloch, 1928)	end
Lispocephala dexioides (Grimshaw, 1901)	end
Lispocephala ingens (Grimshaw, 1901)	end
Phoridae	
Chonocephalus sp.	end
Megaselia spp.	end
Psychodidae	
Clogmia albipunctata (Williston, 1893)	adv
Psychoda spp.	end?
Sarcophagidae	
Ravinia lherminieri (Robineau-Desvoidy, 1830)	adv
Sciaridae	
Bradysia sp.	end?
Sphaeroceridae	
Leptocera abdominiseta (Duda, 1925)	adv
Leptocera sp.	end?
Stratiomyidae	
Wallacea albiseta Meijere, 1907	adv
Syrphidae	
Allograpta exotica (Weidemann, 1830)	pur
Tipulidae	
Limonia grimshawi (Alexander, 1919)	end
Limonia perkinsi (Grimshaw, 1901)	adv
Limonia stygipennis (Alexander, 1919)	end
Limonia n. sp.	End
Limnotes sp.	adv
HETEROPTERA	
Lygaeidae	
Neseis sp.	end
[2]Miridae	
Hyalopeplus pellucidus (Stål, 1859)	end?
Orthtotylus spp.	end
Sarona sp.	end
Nabidae	
Nabis oscillans Blackburn, 1888	end
HOMOPTERA	
Aphididae	
Aphis sp.	adv
Cicadellidae	
Nesophrosyne spp.	end
Cixiidae	
Iolania perkinsi Kirkaldy, 1902	end
Oliarus sp. A	end
Oliarus sp. B	end
[2]Delphacidae	
Leialoha sp.	end

Nesosydne sp. A	end
Nesosydne sp. B	end
Nesothoe sp.	end
Flatidae	
Siphanta acuta (Walker, 1851)	adv
Psylidae	
Megatrioza sp. A	end
Megatrioza sp. B	end
Trioza sp. A	end
Trioza sp. B	end
Trioza n. sp. [Nishida, et al, 1980]	end
HYMENOPTERA	
Agaonidae	
Parapristina verticillata (Waterston, 1921)	pur
Pleistodontes froggatti Mayr, 1906	pur
Aphelinidae	
Aphelinus sp. A	pur?
Aphelinus sp. B	pur?
Aphelinidae	
Aphytis nr. *chrysomphali* (Mercet, 1912)	pur?
Encarsia sp. A	pur?
Encarsia sp. B	pur?
Encarsia sp. C	pur?
Bethylidae	
Sclerodermus sp.	end
Sierola sp. A	end
Sierola sp. B	end
Sierola sp. C	end
Braconidae	
Bracon terryi (Bridwell, 1919)	adv
Opius dissitus Muesebeck, 1963	pur
Opius sp. A	pur?
Opius sp. B	pur?
Chalcididae	
Brachymeria sp.	pur?
Colletidae	
Hylaeus sp.	end
Diapriidae	
Coptera silvestrii (Kieffer, 1913)	pur
Dryinidae	
nr. *Tetrodontochelys* sp.	adv?
Encyrtidae	
Anagyrus sp. A	pur?
Anagyrus sp. B	pur?
Anagyrus sp. C	pur?
Anagyrus sp. D	pur?
nr. *Metaphycus* sp.	pur?
nr. *Ooencyrtus* sp.	pur?
Eucoilidae	
Pseudeucoila sp. A	end
Pseudeucoila sp. B	end
Eulophidae	
Aprostocetus sp.	pur?
Chrysocharis sp.	pur?
Diglyphus begini (Ashmead, 1904)	adv

Eupelmidae	
[2]*Eupelmus* sp. A	end
Eupelmus sp. B	end
Eupelmus sp. C	end
Eupelmus sp. D	end
Eupelmus sp. E	end
Eurytomidae	
Eurytoma sp.	adv
Ichneumonidae	
Diadegma blackburni (Cameron, 1883)	adv
Diadegma sp.	adv
[2]*Enicospilus nigrolineatus* Ashmead, 1901	end
Enicospilus sp. A	end
Enicospilus sp. B	end
Ichneumon purpuripennis Cresson, 1877	pur
Spolas nr. *hawaiiensis* (Ashmead, 1901)	end
Spolas sp. A	end
Spolas sp. B	end
Mymaridae	
Anagrus sp. A	pur?
Mymaridae	
Anagrus sp. B	pur?
Polynema sp.	end
Platygasteridae	
Amitus spiniferus (Brethes, 1914)	pur
Fidiobia sp.	pur?
Platygaster acciculosis Drake, 1969	adv
Proctotrupidae	
Brachyserphus hawaiiensis (Ashmead, 1901)	adv?
Exallonyx trifoveatus Kieffer, 1908	adv
Pteromalidae	
Spalangia sp. A	?
Spalangia sp. B	?
Scelionidae	
Baeus sp.	pur
Sphecidae	
Ectemnius sp. A	end
Ectemnius sp. B	end
Trichogrammatidae	
Trichogramma spp.	pur
Vespidae	
Odynerus sp.	end
Vespula pensylvanica (Saussure, 1857)	adv
ISOPODA	
Philosciidae	
Littorophiloscia sp.	end?
Porcellionidae	
Porcellio sp.	adv
LEPIDOPTERA	
Carposinidae	
Carposina sp. A	end
Carposina sp. B	end
Cosmopterigidae	
Hyposmocoma sp. A	end
Hyposmocoma sp. B	end

Hyposmocoma sp. C	end
Hyposmocoma sp. D	end
Hyposmocoma sp. E	end
Hyposmocoma sp. F	end
Hyposmocoma sp. G	end
Hyposmocoma sp. H	end
[2]Crambidae	
Eudonia sp. A	end
Eudonia sp. B	end
Eudonia sp. C	end
Crambidae	
Eudonia sp. D	end
Eudonia sp. E	end
Mestolobes minuscula (Butler, 1881)	end
Mestolobes sp.	end
Omiodes accepta (Butler, 1877)	end
Omiodes asaphombra Meyrick, 1899	end
Udea argoscelis (Meyrick, 1899)	end
Gelechiidae	
Crasimorpha infuscata Hodges, 1964	pur
[2]Geometridae	
Eupithecia monticolens Butler, 1881	end
Scotorythra artemidora Meyrick, 1899	end
Scotorythra brunnea (Warren, 1896)	end
Scotorythra euryphaea Meyrick, 1899	end
Scotorythra pachyspila Meyrick, 1899	end
Noctuidae	
Haliophyle euclidias (Meyrick, 1899)	end
Hypena laceratalis Walker, 1858	pur
Pseudoschrankia n. sp.	end
Schrankia sp.	end
Oecophoridae	
Stoeberhinus testaceus Butler, 1881	adv
Thyrocopa sp.	end
Sphingidae	
Hyles wilsoni (Rothschild, 1894)	end
Tineidae	
Decadarchis sp. A	adv
Decadarchis sp. B	adv
Opogona omoscopa (Meyrick, 1893)	adv
Tortricidae	
Amorbia emigratella Busck, 1910	adv
Bactra straminea (Butler, 1881)	adv
Bradleyella sp.	end
[2]*Cydia* sp. A	end
Cydia sp. B	end
Cydia sp. C	end
Spheterista sp.	end
NEUROPTERA	
Chrysopidae	
Anomalochrysa nr. *debilis* Perkins, 1899	end
Chrysoperla comanche (Banks, 1938)	adv
Hemerobiidae	
Micromus brunnescens (Perkins, 1899)	end

Micromus vagus (Perkins, 1899)	end
ODONATA	
[2]Coenagrionidae	
Enallagma civile (Hagen, 1862)	adv
Megalagrion amaurodytum peles (Perkins, 1899) (current name *Megalagrion koelense*)	end
Megalagrion calliphya microdemas (Perkins, 1899)	end
Megalagrion hawaiiense (McLachlan, 1883)	end
ORTHOPTERA	
Gryllidae	
Laupala spp.	end
Paratrigonidium sp.	end
PSOCOPTERA	
Ectopsocidae	
Ectopsocus sp. A	adv
Ectopsocus sp. B	adv
Elipsocidae	
Kilauella nr. *erythrosticta* (Perkins, 1899)	end
Palistreptus spp.	end
Lepidopsocidae	
Lepidopsocus nr. *maculatus* Thornton, Lee & Chui, 1972	adv
Psocidae	
Ptycta sp. A	end
Ptycta sp. B	end
Ptycta sp. C	end
LAND SNAILS	
Amastra armata	nat
Auriculella westerlundiana	nat
Cooke concha sp.	nat
Cookeconcha thaanumi	nat
Euconulus gaetanoi	nat
Euconulus thaanumi	nat
Hawaiia minuscula	adv
Hiona rufobrunnea	nat
Leptachatina sp.	nat
Leptachatina arborea	nat
Nesopupa anceyana	nat
Oxychilus alliarius	adv
Philonesia sp.	nat
Philonesia sericans	nat
*Succinea thaanumi**	nat

[1] Status codes: adv = adventive, end = endemic, nat = native, pur = purposely introduced
[2] Notable records.

* Brown et al. 2003. Oviposition behavior and offspring emergence patterns in *Succinea thaanumi*, an endemic Hawaiian land snail. Ethology 109:905-910.