KAHIKINUI

STATE FOREST RESERVE

Management Plan 2021

State of Hawai'i
Department of Land and Natural Resources
Division of Forestry and Wildlife
Forestry Management Section

EXECUTIVE SUMMARY

This ten-year management plan for Kahikinui State Forest Reserve (FR) on Maui is one in a series of site-specific natural resource management plans to be prepared by the Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) for individual forest reserves in the State of Hawai'i. These plans present a brief history of the specific forest reserve, a complete record of land transactions and boundary changes over time, a description of natural and cultural resources, as well as an account of infrastructure and intended use(s) of the area. These plans serve to: (1) assist in preparation of regulatory compliance documents required to implement management actions outlined in the plan; (2) support DOFAW efforts to secure funding for plan objectives; (3) prioritize implementation of management objectives; (4) solicit requests for proposals or bids to implement plan objectives; and (5) inform the public of short and long-term goals.

The Kahikinui State Forest Reserve was established by Governor's Proclamation on December 22, 1928. In the report that preceded the establishment of Kahikinui FR, the Territorial Forester described how the majority of the boundary was already protected by existing fence lines constructed on neighboring leased and private lands that were being managed by cattle ranchers, and also by natural barriers that limited the ingress of ungulates. He further described the goats and cattle present in Kahikinui and the intention to remove them to "give the extensive existing grove of koa (*Acacia koa*) trees on Nakula and Nuu a chance to expand," (Judd 1928, p. 177). There were also stands of māmane that they hoped would expand through natural recruitment.

Kahikinui State Forest Reserve is currently comprised of approximately 2916.50 acres of public land, and is located on the leeward slopes of Haleakalā. The reserve used to encompass a large contiguous landscape, but after subsequent withdrawals of land it is now composed of two separate tracts located within the ahupua'a of Papa'anui (713.57 acres) and Nakula (2202.93 acres). Management of the Papa'anui section has already been addressed in the comprehensive plan for Kula FR due to their adjacency. This management plan focuses on forest reserve lands located within the ahupua'a of Nakula, hereinafter referred to as Kahikinui FR.

DOFAW's current management activities within Kahikinui FR include monitoring and maintenance of existing fence lines and forest restoration areas, supplemental outplanting to compensate for mortality, monitoring and control of weeds and ungulates inside the fence, and rehabilitation trials of hard pan erosion scars. DOFAW partners assist with native and endangered wildlife (native plants, forest bird, seabird and bat) monitoring and protection.

Forest reserve management priorities are divided into eight categories and ranked on a qualitative basis, taking into consideration the natural and cultural resources and public use opportunities of the reserves (see Table 21 for forest reserve management priorities). Summary of management goals for the Kahikinui FR are as follows:

- Watershed Values – Increase land holding protected under the Forest Reserve System; erosion reduction and prevention; monitoring forest composition; maintain active role in watershed partnerships; and climate change adaptation.
- Resource Protection – Fire presuppression and mitigation; forest health monitoring (Rapid ʻŌhiʻa Death, insects and diseases); monitor weather conditions as they pertain to fire and other forest health issues; and cultural resource protection.
- Game Animal Management – Promote and regulate public hunting through Chapter 122 and 123, Hawaiʻi Administrative Rules.
- T&E Species Management – Protection and recovery of rare plants and animals.
- Native Ecosystems – Determine landscape level needs for ecosystem restoration; re-evaluate Vegetation Resource Management Guidelines; ungulate control; and climate change adaptation.
- Invasive Species Control – Reduce impact of invasive species; manage incipient and established invasive plant and animal populations; and biosecurity.
- Access, Trails and other Public Uses – Secure public access to the Forest Reserve; increase public information and awareness; and infrastructure management and construction.
- Commercial Activity – Generate income from suitable commercial activities to support natural resource management of the forest reserve. Develop revenue streams for ecosystem services such as carbon sequestration.

Details of specific tactical goals and action items can be found in Table 22 on page 53 of this plan. This plan is intended to describe short-term resource management planning and implementation strategies, as well to serve as a basis for future updates and modifications to accommodate evolving or additional objectives such as wildfire prevention projects and/or improving access and facilities for Kahikinui FR.

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MANAGEMENT PLAN SIGNATURE PAGE

Maui District certification: This plan was prepared by a team of Division of Forestry and Wildlife (DOFAW) staff to provide a management framework for Kahikinui State Forest Reserve.

Scott Fretz – DOFAW Maui District Manager

9/29/21
Date

DOFAW Administrator's approval: I have reviewed the enclosed Forest Reserve Management Plan and concur with the recommendations herein. I agree that resource management implementation will follow those specified in the Management Plan for Kahikinui State Forest Reserve.

David G. Smith – DOFAW Administrator

10/14/21
Date

Department of Land and Natural Resources Board approval: This plan is in accordance with the mandates of the State Forest Reserve System which includes Chapter 183, Hawai'i Revised Statues, and Chapter 13-104, Hawai'i Administrative Rules.

Suzanne D. Case – BLNR Chairperson

Approved by the Board of Land and Natural Resources at its meeting held on August 27, 2021.

DEVELOPMENT PROCESS TIMELINE

Kahikinui State Forest Reserve, Maui

Stage of Development	Date Achieved	Comments
District review	July 2020	Incorporated
DOFAW review	July 2020	Incorporated
Partner agency consultation	April 2021	Incorporated
Public consultation	April 2021	Incorporated
DOFAW approval	August 2021	
BLNR approval	August 2021	

1. INTRODUCTION

The Division of Forestry and Wildlife (DOFAW) conducts on-going planning efforts to develop and update management plans for all forest reserves across the State. The format and content of the respective reserve plans are generally consistent across the State and serve to guide field operations, assist in budgeting and funding concerns, and make the management process transparent for partner organizations and the public. These plans also help to fulfill certain recommendations made in the Hawai'i Tropical Forest Recovery Action Plan, which came about as a result of the 1992 Federal Hawai'i Tropical Forest Recovery Act.

Each district office of DOFAW will have a comprehensive management plan that addresses overall Forest Reserve System issues, goals and objectives for that district. In addition, management plans will be developed for each individual forest reserve, which will in part reflect the Division's management guidelines specific to that area. This document represents the management plan for Kahikinui State Forest Reserve. It addresses concerns and strategies only on the public lands within this forest reserve.

Initial development of this plan consisted of reviewing DOFAW historic and current files found at the Administrative and Maui District office were reviewed. Documents were also obtained from other state agencies including the Department of Land and Natural Resources Land Division and Bureau of Conveyances, the Department of Accounting and General Services (DAGS) Survey Division, as well as the State Archives. Relevant data from the Hawai'i Statewide Geographic Information System (GIS) relating to biological, historical, and environmental resources were referenced extensively to develop this plan.

Additional resources utilized for the development of this plan (including other plans that identified the Forest Reserves or the general area), were the Hawaiian Forester and Agriculturalist, Hawai'i Biodiversity and Mapping Program (HBMP), State of Hawai'i Forest Action Plan, Hawai'i's State Wildlife Action Plan, biological surveys and others. The plan then evolved into its final iteration through discussions with Division staff from all program areas, both at the district and administrative offices, other Divisions and State agencies, DOFAW partners, and the public.

Once finalized by DOFAW, this Management Plan for Kahikinui State Forest Reserve will be submitted for review and approval by the Board of Land and Natural Resources (Board). If approved by the Board, the following actions may be triggered:

1. Preparation of regulatory compliance documents as required for implementation of management actions as outlined in the plan.
2. DOFAW efforts to secure operational and planning funding for plan objectives.
3. Prioritized implementation of plan objectives by DOFAW.
4. Periodic solicitation of requests for proposals or bids for implementation of plan objectives, including issuance of permits, licenses, or contracts as necessary.

2. HISTORY

Figure 1. Kahikinui State Forest Reserve (5000 ft. elevation)

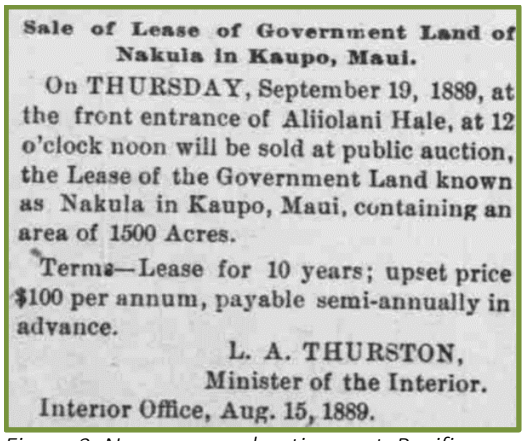
When Kahikinui FR was first established in 1928, it was a contiguous landscape that spanned the moku (district) of Kahikinui and Kaupō on the southern slope of Haleakalā. When lands under the jurisdiction of the Department of Hawaiian Home Lands (DHHL) were withdrawn from the Forest Reserve System in 1984, the forest reserve no longer contained lands within the moku of Kahikinui, however the name of the forest reserve remained the same. The majority of the land that currently comprise Kahikinui FR lies within the moku of Kaupō in the ahupuaʻa of Nakula.

Kaupō was once a well-populated district, supported by abundant ocean resources and intensive dryland agriculture of ʻuala (sweet potato) which is thought to have covered between 12.5 and 15 square kilometers. Production from these dryland fields are estimated to have been able to support a population of 8,000-10,000 people. The ahupuaʻa of Nakula sat to the west of the large agriculture fields, and has been described as drier and less suitable for intensive food production (Kirsch et al. 2009). In the early 1700's, Aliʻi nui Kekaulike, moved his residence to Kaupō, motivated by his ambition to expand his kingdom beyond Maui. Supported by the productive agricultural fields of Kaupō, Kekaulike launched his attacks on the western coast of the island of Hawaiʻi from the landing at Mokulau (Baer 2015).

In the early 1800's the arrival of foreign diseases resulted in a significant loss of the Hawaiian population. Coupled with the shifting of economic strategies to that of supplying western commercial demands, the need for labor intensive dryland agriculture declined. Populations in places like Kaupō decreased rapidly (Baer 2015).

By the mid 1800's the majority of Kaupō (including the ahupuaʻa of Nakula) was controlled by the Aliʻi William Charles Lunalilo. In the Māhele (1848), Lunalilo relinquished Kaupō along with more than half of the land that he controlled to the Mō'ī as government land (Kameʻeleihiwa 1992). In 1891, the Kingdom of Hawaiʻi started issuing leases and permits for large tracts of Nakula for grazing (Figure 2). This practice continued through the political and societal turmoil that ensued after the overthrow of the Hawaiian Kingdom in 1893. Ranching became the dominant land use in the district and persisted well into the 20th century.

Native ecosystems in the districts of Kahikinui and Kaupo were heavily impacted by the decades of cattle grazing. A report in the April 1920, edition of The Hawaiian Forester and Agriculturist describes cattle up so high that they were traveling from Kahikinui, up and over the summit at Papa‘anui into Kula FR. By 1920, the makai lands in Kahikinui and Kaupo were converted to pasture, but there were still dense forests upslope. Bishop museum botanist Charles N. Forbes, in his field notes describes the forest in Kahikinui as being so thick that it was difficult to walk through.



Sale of Lease of Government Land of Nakula in Kaupo, Maui.

On THURSDAY, September 19, 1889, at the front entrance of Aliiolani Hale, at 12 o'clock noon will be sold at public auction, the Lease of the Government Land known as Nakula in Kaupo, Maui, containing an area of 1500 Acres.

Terms—Lease for 10 years; upset price $100 per annum, payable semi-annually in advance.

L. A. THURSTON,
Minister of the Interior.

Interior Office, Aug. 15, 1889.

Figure 2. Newspaper advertisement, Pacific Commercial Advertiser

The latter half of the 17th century also saw a significant expansion of irrigated sugar plantations across the Hawaiian Islands. The demand for fresh water increased dramatically and by 1920, it was estimated that 800 million gallons per day (mgd) of surface water, plus an additional 400 mgd of groundwater were being consumed by the sugar industry (Wilcox 1997). Concurrently, landscape scale deforestation was occuring, in part due to grazing by ungulates such as cattle and goats. Fears of a diminishing water supply for sugar plantations resulted in government regulated protection of forested watersheds starting in 1903, with the designation of the first forest reserve on the island of O‘ahu in 1904.

When the pasture leases in Nakula expired the mauka lands were set-aside by the territorial government as part of Kahikinui FR. Ranching continued on the lands below the forest reserve, but leases contained conditions for mandatory fence construction to keep cattle out of the forests. According to the report written by the Territorial Forester that preceded the establishment of the reserve, the majority of the makai boundary of the forest reserve was already protected by existing fence lines constructed on adjacent leased and private ranch lands and by natural barriers that limited the ingress of ungulates (Judd 1928).

Figure 3. Kahikinui FR māmane

The report also described the significant number of goats and the few cattle that were in Kahikinui at the time. They planned to remove the wild goats and cattle to “give the extensive existing grove of koa trees on Nakula and Nuu a chance to expand,” (Judd 1928, p. 177). There were also stands of māmane that they also hoped would expand through natural recruitment. The overarching goal for Kahikinui FR was to improve the native vegetative cover in the area to “prevent excessive runoff and make available for use in the intervening dry periods water on the lower lands, where it is almost always at a premium,” (Judd 1928, p. 177).

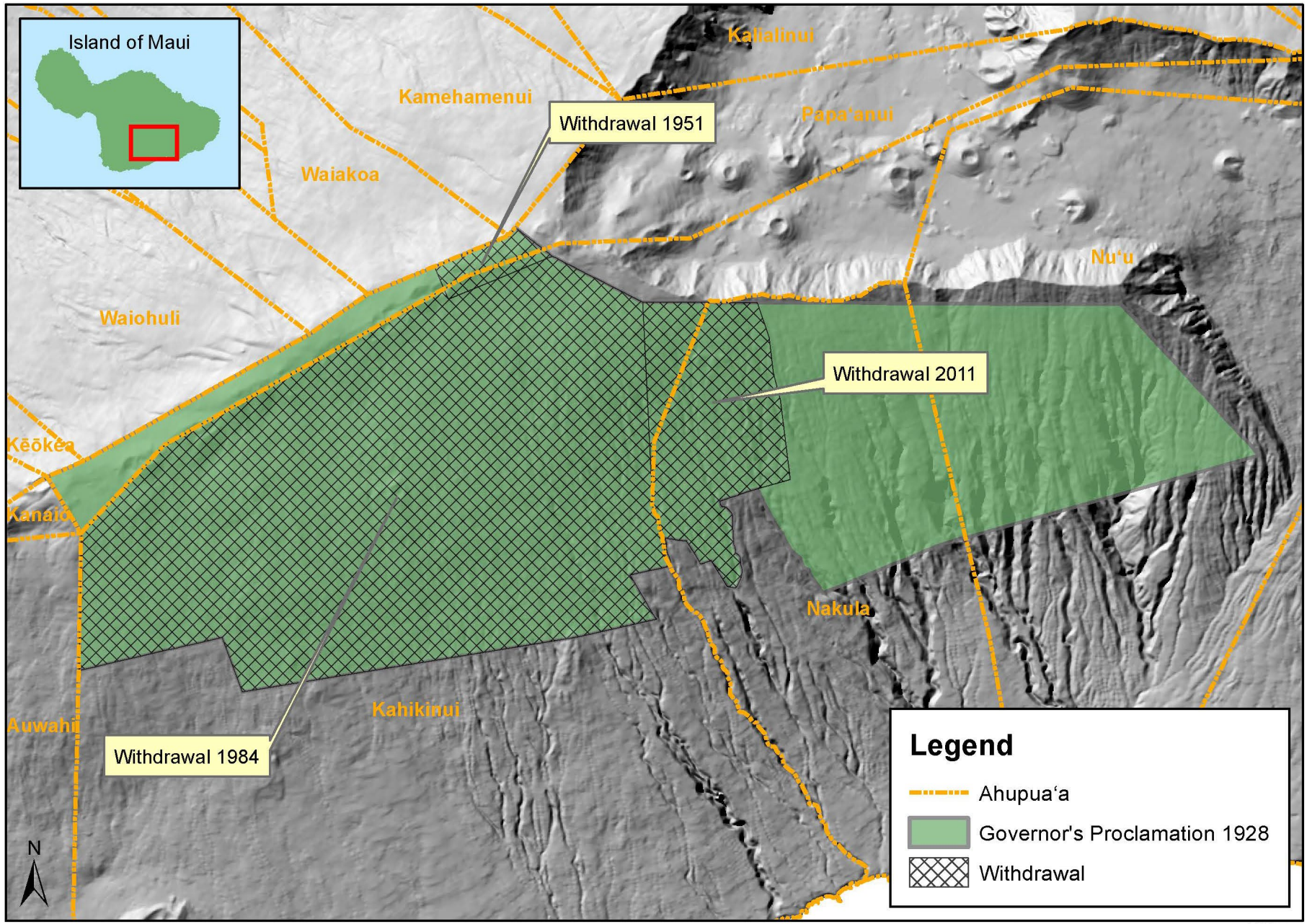
Kahikinui FR was established by a Governor's Proclamation that was signed on December 22, 1928. At its establishment the forest reserve was 16,013 acres. Two significant withdrawal of land from the FR occurred in 1984, when DHHL lands were withdrawn, and again in 2011, when an additional 1,420 acres were withdrawn to create the Nakula Natural Area Reserve. See Table 1 and Figure 4 for a complete record of the lands that were withdrawn from Kahikinui FR.

Table 1. Summary of lands added and withdrawn from Kahikinui FR

Document[1]	Date	Action[2]	Description	Acres	Map # [3]	Tax Map Key[4]
GP	22-Dec-1928	A	Land set aside for establishment of Kahikinui FR	16,013	CSF 4902	(2) 1-8-001:006 (2) 1-8-001:009 (2) 1-9-001:003 (por.) (2) 1-9-001:007 (2) 1-9-001:011 (2) 2-2-007:001 (por.) (2) 2-2-007:005 (2) 2-2-007:007 (2) 2-2-007:008 (por.) (2) 2-2-007:009 (2) 2-2-007:011 (2) 2-2-007:012 (2) 2-2-007:013 (2) 2-2-007:014 (2) 2-2-007:016 (2) 2-2-007:017
EO 1411	17-Jan-1951	W	Withdrawal of Government lands at Papa'anui and Kahikinui for a Repeater and Telephone Station Site	184.20	CSF 11,117	(2) 2-2-007:005 (2) 2-2-007:007 (2) 2-2-007:008 (por.) (2) 2-2-007:009 (2) 2-2-007:011 (2) 2-2-007:012 (2) 2-2-007:013 (2) 2-2-007:014 (2) 2-2-007:016 (2) 2-2-007:017
EO 3270	27-Dec-1984	W	Withdrawal of Hawaiian Home Lands from Kahikinui FR	8,747	N/A	(2) 1-9-001:003 (por.) (2) 1-9-001:007 (2) 1-9-001:011
EO 4364	25-Mar-2011	W	Withdrawal of land at Nakula for the establishment of a Natural Area Reserve	1420.4	CSF 25,037	(2) 1-8-001:006 (por.) (2) 1-8-001:009

[1] Documents: GP = Governor's Proclamation; EO = Executive Order
[2] Action: A = Added to the FR; W = Withdrawn from the FR
[3] CSF = Certified Survey Furnished. Maps are available online at http://ags.hawaii.gov/survey/map-search/
[4] (por.) = portion; Only a portion of the TMK was included in the FR.

Figure 4. Historical changes to Kahikinui Forest Reserve with the year of addition/withdrawal indicated



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Documented Activities/Leases/Deeds/Permits**:** Information on the historical land use agreement issued for Kahikinui FR are listed in Table 2.

Table 2. Historical land use agreements in Kahikinui FR.

Type	Doc. #	Duration	Description	Acres	Map #	Tax Map Key
Lease	GL434	27-Aug-1891 to 30-May-1892	Lease sold at public auction to J.C. Flores and Co., for "The Nakula Mountain Tract."	3900	CSF 381 CSF 420	(2) 1-8-001:006
Lease	GL434	30-May-1892 to 27-August-1900	Lease assigned to H.P. Baldwin	3900	CSF 381 CSF 420	218001006
Lease	GL576	1-Sept-1905 to 1-Sept-1926	Lease for pasture to Haleakalā Ranch Company	1075	CSF 1604	(2) 1-8-001:006 por.

3. FOREST RESERVES DESCRIPTION

3.1 Location and Description

Figure 5. Ephemeral pool in Kahikinui FR

Kahikinui State Forest Reserve currently occupies land in the ahupua'a of Nakula in the moku of Kaupō and is comprised of approximately 2916.50 acres (Table 3) of public land. It is located on the leeward slopes of Haleakalā (Figure 6) on the island of Maui, in the Hāna district. The forest reserve once encompassed a large (16,013 acres) contiguous landscape, but after subsequent withdrawals of land it is now composed of two separate tracts located within the ahupua'a of Papa'anui (713.57 acres) and Nakula (2202.93 acres). Management of the Papa'anui tract has already been addressed in a comprehensive plan with the adjacent Kula FR, and in not included here. This management plan will focus on the remaining forest reserve lands located within the ahupua'a of Nakula, hereinafter referred to as Kahikinui FR.

Kahikinui FR is surrounded primarily by other state and federally owned lands. It is adjacent to the Nakula Natural Area Reserve, Haleakalā National Park, and other state lands under the jurisdiction of DLNR Land Division. A small portion of the southwestern boundary borders land owned by Haleakalā Ranch. The communities in closest proximity to this forest reserve include Kahikinui, Kaupō and Kīpahulu. Kahikinui FR is included in the Leeward Haleakalā Watershed Restoration Partnership. Elevation of Kahikinui FR ranges from approximately 9,000 feet at the summit, to about 2,500 feet at the bottom of the lower gulches. Vegetation is generally characterized by six plant communities: subalpine dry shrubland, subalpine dry grassland, subalpine mesic shrubland, subalpine mesic grassland, mesic grassland, and mesic forest.

Figure 6. Current extent of public lands of Kahikinui State Forest Reserve

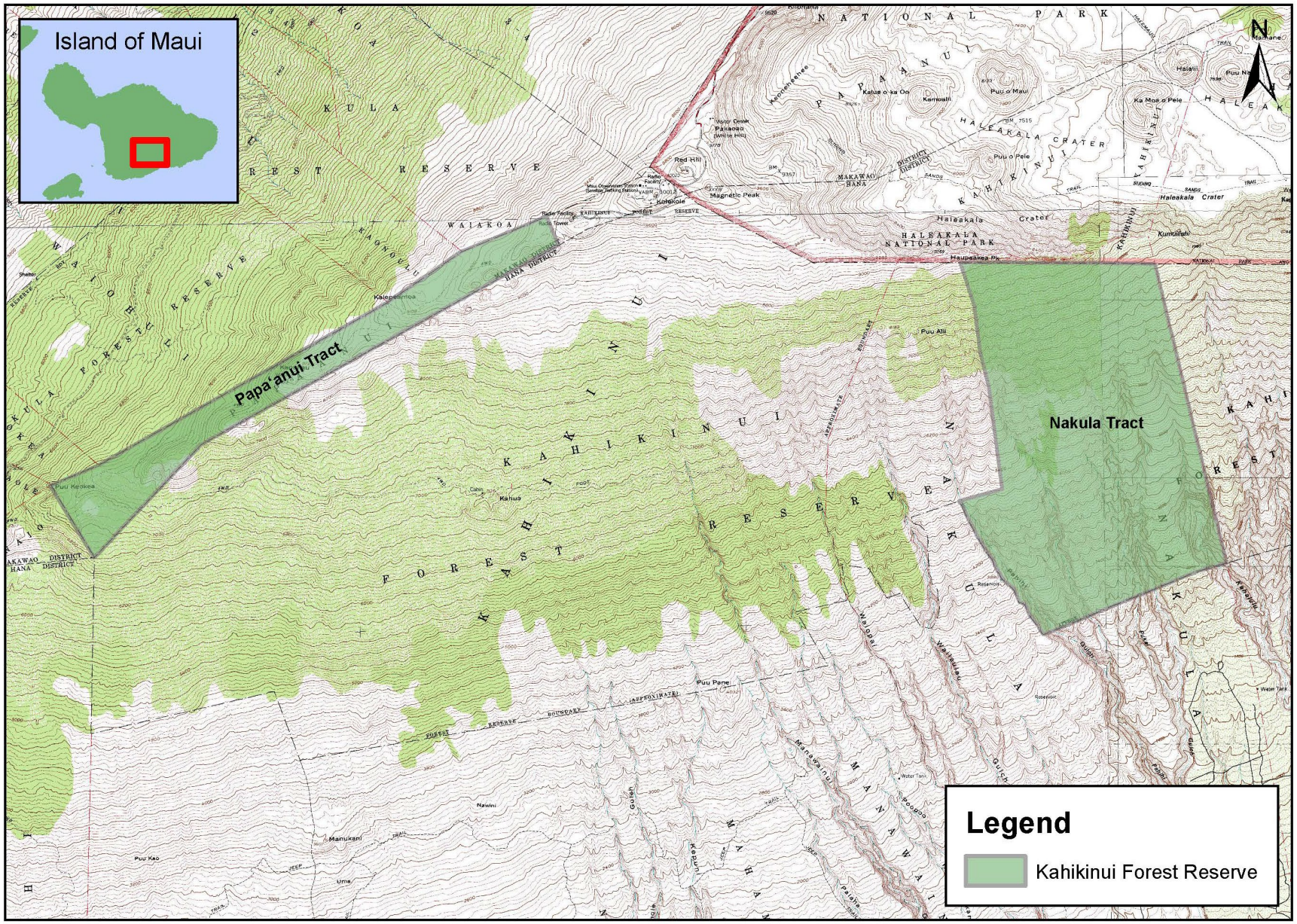

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Table 3. Government Tax Map Key (TMK) parcels comprising public lands of Kahikinui FR

TMK Number	Owner	Tax Acres (entire TMK)	GIS Acres (entire TMK)	GIS Acres (forest reserve)
(2) 1-8-001:006	State of Hawai'i	2130.8	3360.70	2202.93 (Nakula)
(2) 2-2-007:001	State of Hawai'i	5865.87	5610.12	713.57 (Papa'anui)*
			TOTAL	2916.50

*Included here and in Figure 6 for completeness. Refer to the Kula Forest Reserve Management Plan for more information.

3.2 Geology

Figure 7. 'Ōhi'a canopy – view of Pāhihi gulch

The islands of Maui, Moloka'i, Lāna'i, and Kaho'olawe were once all connected and formed one larger landmass known as Maui Nui. As Maui Nui subsided and as the sea levels began to rise, the saddles between the volcanoes submerged, isolating them as separate islands. The island of Maui consists of two volcanoes: Haleakalā, an active volcano dating from approximately 1.1 million years ago that formed east Maui, and an extinct volcano dating from approximately 1.6 million years ago that formed Mauna Kahalawai (West Maui Mountains). Kahikinui FR is located on Haleakalā, which last erupted sometime between the years of 1480 and 1600 (Hawai'i Volcano Observatory, 2003).

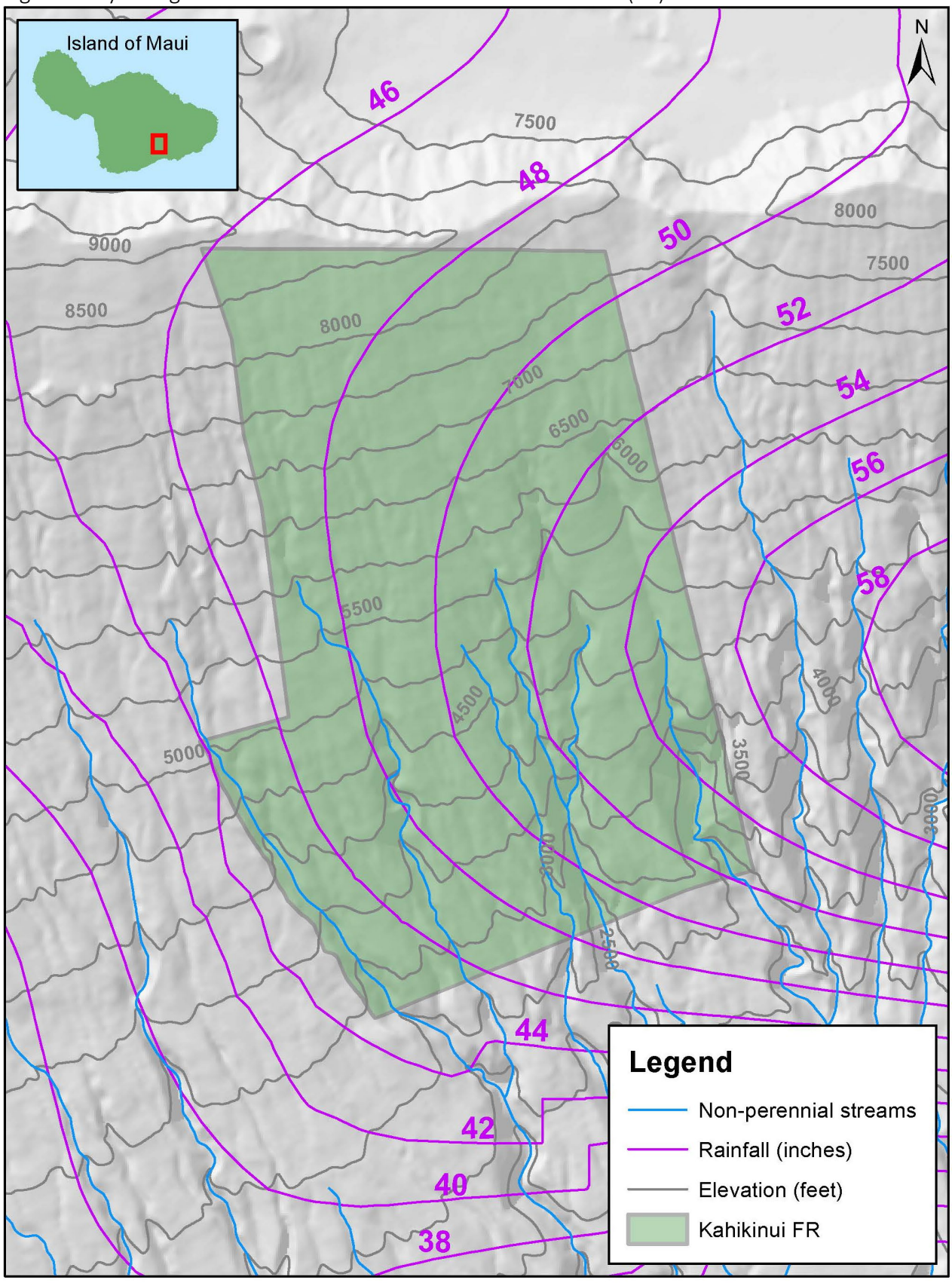
East Maui was formed by three periods of volcanic activity from Hakeakalā Volcano that geologists have designated as the Honomanū Basalt, Kula Volcanics, and Hāna Volcanics. Surface geology of Kahikinui FR consists of lava flows from the Kula Volcanic Series, 140,000 to 780,000 years ago (Sherrod, 2007) during the Middle Pleistocene. Primary geological features of the forest reserve are three prominent gulches named Pāhihi, Pūka'i and Kahalulu.

3.3 Climate

Kahikinui FR is located on the drier leeward side of Haleakalā. Average rainfall in Kahikinui FR ranges from approximately 44 to 55 inches annually (Figure 9), with fog and cloud interception contributing significantly to total precipitation. Precipitation received in Kahikinui FR recharges the Nakula aquifer. There are no perennial streams in Kahikinui FR. Surface water flow is generally restricted to short-duration flash rain events. Maps from 1930, indicate that there was a spring named Punaokeaka located on the southeastern corner of the forest reserve in Kahalulu gulch at around 2,500 feet in elevation.

Figure 8. Kahikinui FR fog

Figure 9. Hydrological features of Kahikinui State Forest Reserve (FR)



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3.4 Soils

The United States Department of Agriculture's Natural Resource Conservation Service (NRCS) has mapped three soil types (Table 4 and Figure 11) in Kahikinui FR, see Appendix A for soil descriptions. This agency provides online soil maps and data at https://websoilsurvey.sc.egov.usda.gov.

Table 4. Soils of Kahikinui FR (NRCS Soil Survey Geographic Database, 2018)

Map unit	Name	Acreage	Percent cover
rVS	Very stony land	1250.5	56.8%
PZVE	Puu Pa very stony silt loam, 7 to 40 percent slopes	569.8	25.9%
rRO	Rock outcrop	382.7	17.3%

3.5 Vegetation

The vegetation in Kahikinui FR has been severely altered by grazing animals, primarily feral cattle and goats, and the subsequent spread of introduced pasture grass species. According the Carbon Assessment of Hawai'i Land Cover Map (Jacobi et al., 2017), the top four vegetation types that cover Kahikinui FR are non-native grassland (49.5%), native mesic shrubland (18.8%), native dry shrubland (17.2%), and open koa-'ōhi'a mesic forest (10.0%; Figure 12).

Table 5. Land cover types of Kahikinui FR

Land cover type	Acreage	% cover
Alien mesic grassland	1090.5	49.5%
Native mesic shrubland	414.8	18.8%
Native dry shrubland	379.3	17.2%
Open koa-'ōhi'a mesic forest	220.2	10.0%
Native wet cliff community	34.8	1.6%
Very sparse vegetation to unvegetated	20.9	0.9%
Closed koa-'ōhi'a mesic forest	17.9	0.8%
Kiawe dry forest and shrubland	12.1	0.5%
Alien dry grassland	9.6	0.4%
Mixed native-alien dry cliff community	1.8	0.1%
Alien mesic shrubland	1.1	0.1%

Figure 10. Plants of Kahikinui FR (top to bottom) Cyrtomium caryotideum; Lobelia hypoleuca; Artemisia mauiensis

Figure 11. Soils of Kahikinui State FR (NRCS Soil Survey Geographic Database, 2018)

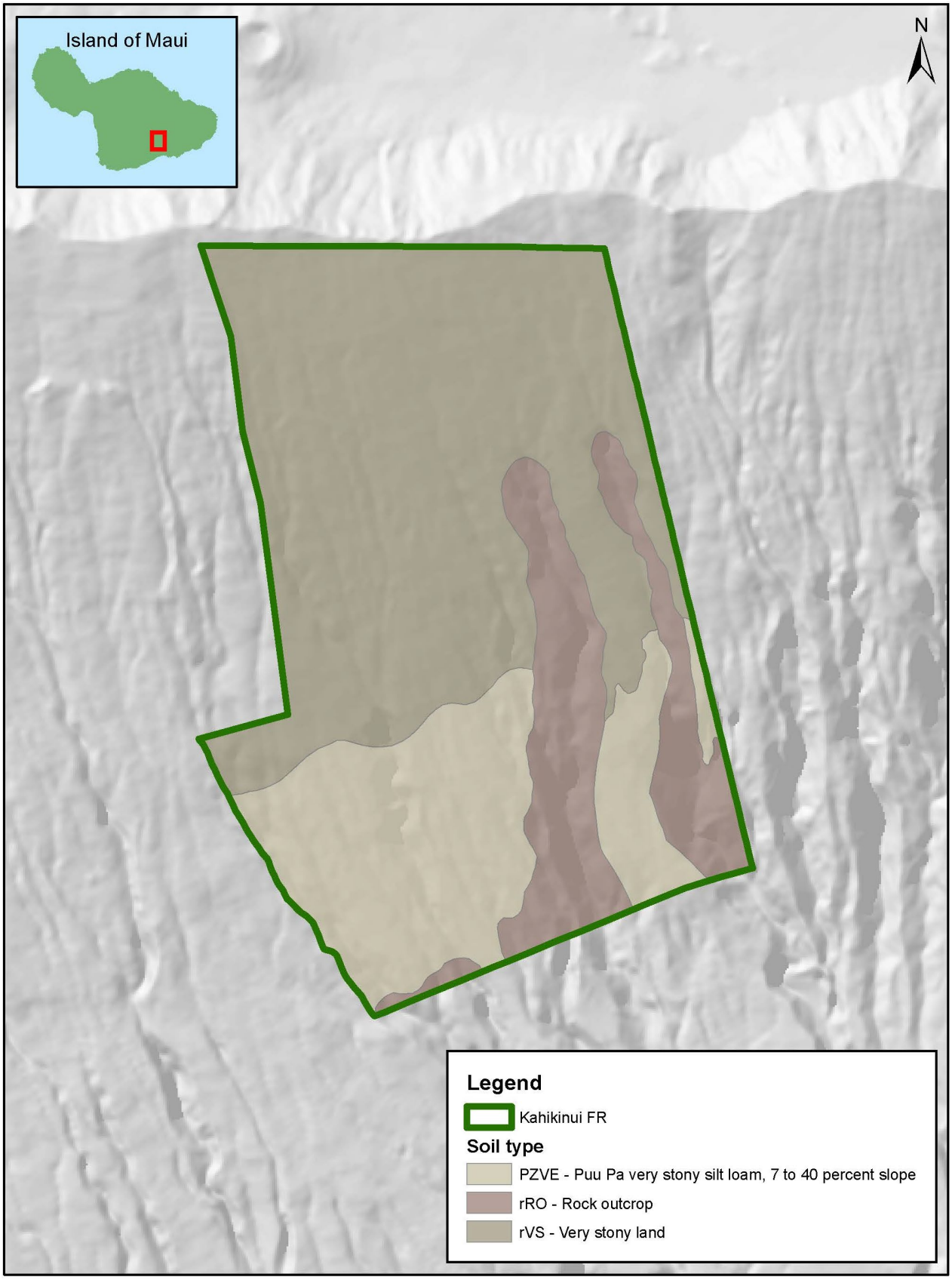

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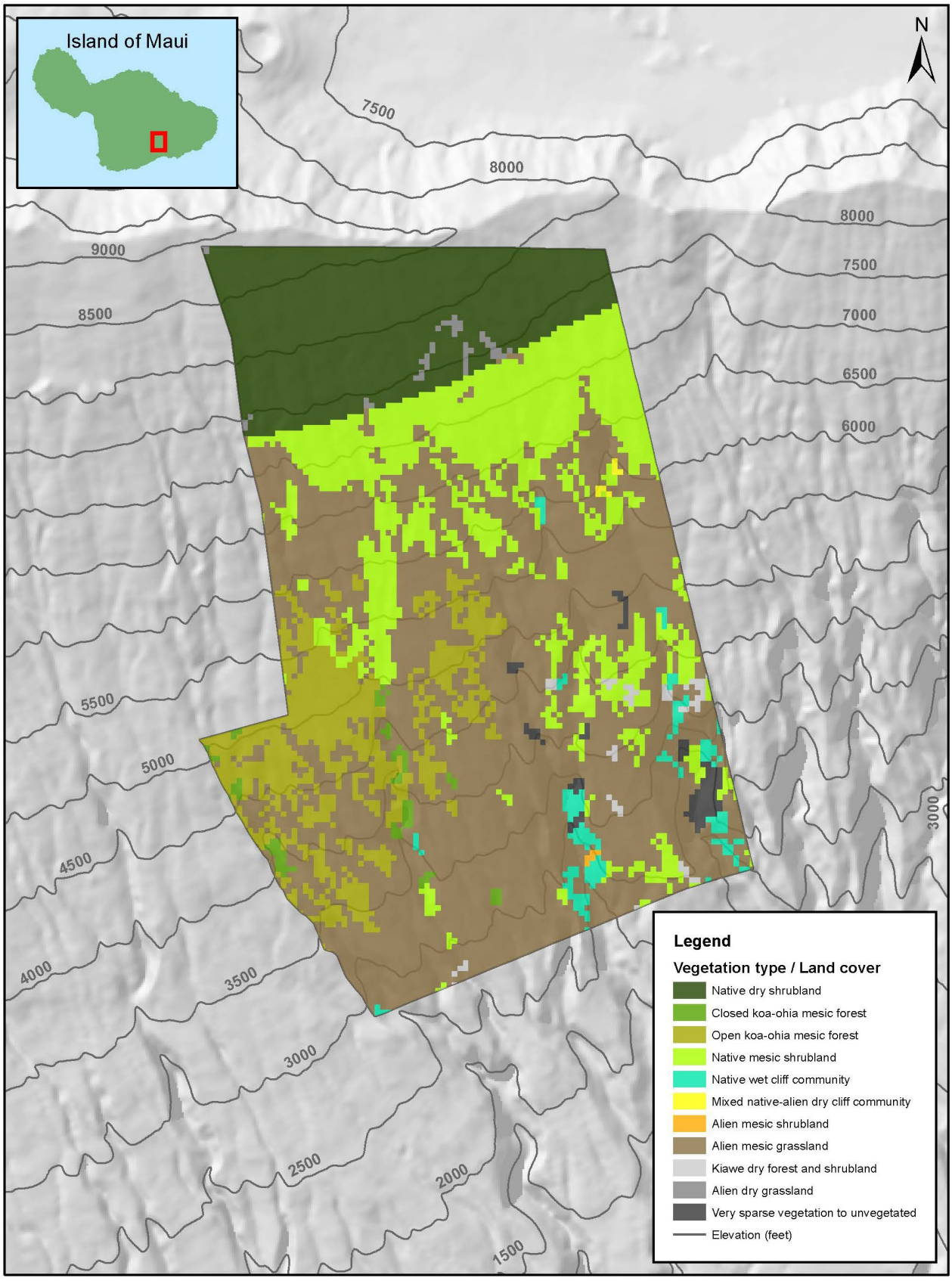
Figure 12. Vegetation cover of Kahikinui State Forest Reserve (Jacobi et al. 2017)



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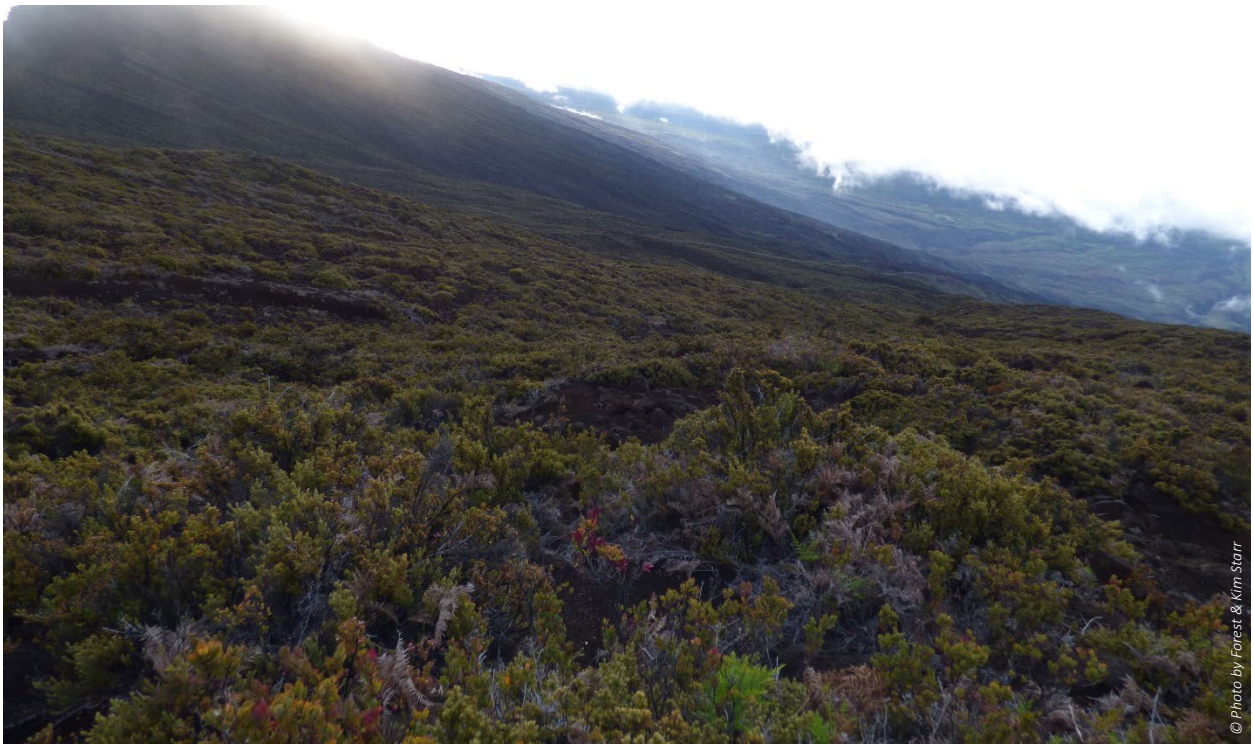


Figure 13. Native shrublands of Kahikinui FR

The largest and most intact native ecosystems remaining in Kahikinui FR are mesic and dry shrublands, located between 6,500 – 9,000 feet in elevation. Pūkiawe (*Leptecophylla tameiameiae*) is the dominant species, but as you ascend in elevation the pūkiawe are less dense and shorter in stature and ʻōhelo shrubs (*Vaccinium reticulatum*) become more abundant. Other native shrubs that are present include pilo (*Coprosma montana*), ʻaʻaliʻi (*Dodonaea viscosa*), kūkaenēnē (*Coprosma ernodeoides*), ʻūlei (*Osteomeles anthyllidifolia*), kūpaoa (*Dubautia menziesii*) and māmane (*Sophora chrysophylla*).

At around 6,500 feet in elevation there is an abrupt change from native shrubland into mesic ʻōhiʻa forests and grassland. ʻŌhiʻa is dominant in the gullies and the ridges are covered by grasses. Native hair grass (*Deschampsia nubigena*) is dominant in the ʻōhiʻa forest understory and also on many of the ridges. Non-native grasses that are also present in this zone include sweet vernal grass (*Anthoxanthum odoratum*), Yorkshire fog (*Holcus lanatus*), Tasmanian wallaby grass (*Rytidosperma semiannulare*) and violet crab grass (*Digitaria violascens*).

Figure 14. ʻŌhiʻa forests and grasslands of Kahikinui FR

Figure 15. Koa reforestation in Kahikinui FR (December 2019) – See Figure 28 for 2015 photo

From 5,500 to 4,500 feet in elevation, koa becomes the dominant tree in some areas, primarily on the west side of the FR. This zone has the highest plant diversity and the most moisture from the nāulu or thick fog/cloud cover that occurs on most days. The forest understory is primarily grass, with moderate plant diversity in steep, rocky, and moist areas. Many of the ridges within this elevation range were deforested and are now covered in grass. The eastern part of the reserve has very few mature koa trees remaining, but the area has been recently planted with koa and in some areas the koa is regenerating naturally. Native hair grass is common in this zone. Non-native grasses in this zone include molasses grass (*Melinis minutiflora*), Yorkshire fog, beardgrass (*Andropogon virginicus*) and smut grass (*Sporobolus indicus*).

The lower portion of the forest reserve, from 4,500 to 2,500 feet in elevation are below the recently constructed fenceline. This dryland ecosystem has been heavily impacted by ungulates and vegetated areas are covered with non-native grasses such as kikuyu (*Cenchrus clandestinus*) and smut grass. Non-native herbs and shrubs like lantana (*Lantana camara*) are also present. There are a few native dry forest shrubs including ʻaʻaliʻi and ʻākia (*Wikstroemia monticola*) and a few native trees such as olopua (*Nestegis sandwicensis)*, halapepe (*Chrysodracon auwahiensis)* and lama (*Diospyros sandwicensis*). The area contains

Figure 16. Declining stand of olopua in Kahikinui FR

steep gulches, erosion scars, and vast areas of exposed soil. For a more detailed description of each vegetation zone and a comprehensive plant list, the biological survey report (Starr 2018) has been included as Appendix B of this plan.

Rare and Endangered Plants**:** Threatened and endangered species in Hawai‘i are listed under and protected by the Federal Endangered Species Act (ESA) and the State Endangered Species Law, Chapter 195D, HRS. There are currently no known wild populations of state or federally endangered plant species in Kahikinui FR. However, there is one small population of the Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) which is considered a threatened plant species under the ESA. A group of fifteen small plants were spotted from a helicopter in 2014 and subsequently twenty seedlings were planted by DOFAW to augment the population.

Figure 17. Haleakalā silversword in Kahikinui FR

3.6 Wildlife

3.6.1 Native Wildlife

Three endangered wildlife species that are protected by both state and federal regulations have been documented to occur in Kahikinui FR (Table 6), the endangered ‘ōpe‘ape‘a or Hawaiian hoary bat (*Lasirus cinereus semotus*), the nēnē or Hawaiian goose (*Branta sandvicensis*), and the ‘ua‘u or Hawaiian petrel (*Pterodroma phaeopygia sandwichensis*). Five additional native birds were documented (Table 7) during forest bird surveys (Scott et al. 1986; Starr 2018), the ‘apapane (*Himatione sanguinea*), Maui ‘amakihi (*Chlorodrepanis virens wilsoni*), pueo (*Asio flammeus sandwichensis*), kolea (*Pluvialis fulva*) and the koa‘e kea or white-tailed tropicbird (*Phaethon lepturus*). Species profiles from the Hawai‘i State Wildlife Action Plan contain information on their biology, distribution, threats and conservation actions, and have all been included as Appendix C of this plan.

Figure 18. Nēnē in Kahikinui FR

The endangered ‘ōpe‘ape‘a is one of two endangered mammals endemic to Hawai‘i and they are present over all of East Maui. The United States Geological Survey (USGS) installed and maintained a series of bat detectors in the Kahikinui FR from 2012 to 2014. Monitoring results show that bats are regularly flying over the forest reserve at night, especially in the koa/‘ōhi‘a forest sections. Detection was low over much of the reserve but was significantly higher in mid-elevation forests. For example, in the higher

Table 6. Rare and endangered plants and animals observed within Kahikinui FR

	Species	Common name	ESA	PEP Species
Plants	*Argyroxiphium sandwicense* subsp. *macrocephalum* (outplanted)	ʻāhinahina	Threatened	No
Animals	*Branta sandvicensis*	nēnē	Endangered	N/A
	Lasirus cinereus semotus	ʻōpeʻapeʻa	Endangered	N/A
	Pterodroma sandwichensis	ʻuaʻu	Endangered	N/A

Table 7. Avian Wildlife found in Kahikinui FR. (Scott et al. 1986; Starr 2018)

Species	Common name	Native Non-native	Game species	Abundance	Injurious species[5]
Acridotheres tristis	common myna	Non-native		Rare	x
Alauda arvensis	Eurasian Skylark	Non-native		Common	
Alectoris chukar	Chukar	Non-native	x	Common	
Asio flammeus sandwichensis	pueo	Native		Rare	
Branta sandvicensis	nēnē	Native		Common	
Chlorodrepanis virens wilsoni	Maui ʻamakihi	Native		Abundant	
Francolinus francolinus	black francolin	Non-native	x	Rare	
Francolinus pondicerianus	gray francolin	Non-native	x	Rare	
Haemorhous mexicanus	house finch	Non-native		Rare	
Himatione sanguinea	ʻapapane	Native		Abundant	
Horornis diphone	Japanese bush warbler	Non-native		Common	x
Leiothrix lutea	red-billed leiothrix	Non-native		Rare	
Lonchura punctulata	scaly-breasted munia	Non-native		Rare	
Mimus polyglottos	Northern mockingbird	Non-native		Rare	
Phaethon lepturus	white-tailed tropicbird	Native		Rare	
Phasianus colchicus	common “ring-necked” pheasant	Non-native	x	Common	
Pluvialis fulva	Pacific Golden-Plover	Native			
Pterodroma phaeopygia sandwichensis	ʻuaʻu	Native		Rare	
Zosterops japonicus	Japanese white-eye	Non-native		Occasional	x

[5] Under Hawaii Administrative Rules 13-124-3 (c), no person shall, or attempt to, 1) Release injurious wildlife into the wild; 2) Transport them to islands or locations within the State where they are not already established and living in a wild state; and 3) Export any such species or the dead body or parts thereof, from the State.

elevation shrubland bat detection was low at 8 pulses per night compared to 130 pulses per night at a station in the mid-elevation koa/ʻōhiʻa forest. On average, there were 37 pulses detected/night/detector in the reserve (Todd et al., 2016).

The Maui Nui Seabird Recovery Project (MNSRP) collaborates with researchers, managers and regulatory agencies to assist in the protection and management of seabirds and their habitats in Maui Nui. In partnership with DOFAW, MNSRP conducts automated acoustic monitoring, ground surveys for burrows and burrow monitoring of native seabirds in upper Kahikinui (above 6,800 feet).

Figure 19. Apapane in Kahikinui FR

Acoustic monitors were deployed in 2013, 2014, 2017 and 2020. Newell's shearwaters (*Puffinus newelli*; NESH) and band-rumped storm petrels (*Oceanodroma castro*; BANP) have not been detected to date. ʻUaʻu (HAPE) acoustic activity was first recorded in 2013, and has increased significantly over time (Table 8). In 2017, 3 locations had high call rates of >1 call per minute. Monitors are currently deployed for the 2020 season.

Figure 20. Kahikinui FR ʻuaʻu pair (2018)

The first standardized ground surveys for ʻuaʻu burrows were conducted in 2012-2013. This initial survey covered 280 acres and three active burrows were found. During routine field activities in 2017, new burrows were discovered. This resulted in MNSRP conducting annual standardized surveys (Table 9). The number of new burrows established by prospective birds is increasing annually. As of 2020, twenty ʻuaʻu burrows have been found. Nineteen were active in 2019 and of those, seven are considered breeding burrows and all had chicks fledge at the end of the season. Burrows have been monitored since 2016 and the results are summarized in Table 10 below (MNSRP 2020).

Table 8. Summary of MNSRP acoustic monitoring in Kahikinui State Forest Reserve

Year	Duration (# nights)	Number of sites	Detection (# of sites)			Notes
			HAPE	NESH	BRSP	
2013	1071	5	1	0	0	HAPE detected near known burrow
2014	401	7	7	0	0	Highest HAPE call rate near known burrow
2017	1133	7	7	0	0	High rates of > 1 calls/min detected at 3 of 7 locations

Table 9. HAPE burrow searching results

Year	Total area searched (ha)	Search hours	HAPE burrows found
2012/2013	80.8	58	3
2017	9	4	2
2018	21.4	8	4
2019	2	2	8

Table 10. HAPE burrow monitoring results by year

Burrow #	2016	2017	2018	2019
6	1	1	1	1
7	1	1	2	1
8	3	1	1	1
18		5	4	6
28			4	4
30			4	1
31			4	1
32			4	1
34			1	4
35			5	4
36			5	4
37			5	4
56				5
57				5
58				5
64				2
65				5
66				5
68				5
69				5

Key

1	Successful
2	Probably successful
3	Failed
4	Occasional non-breeder
5	Prospecting
6	Seasonally inactive

Figure 21. Native Yellow face bees Hylaeus nivicola, Kahikinui FR (7700 ft.)

3.6.2 Native Invertebrates

While a complete arthropod and gastropod inventory of Kahikinui FR has not been done, conspicuous and notable insects, arachnids and snails were documented during the 2018 biosurvey (Table 11). Native yellow faced bees, (*Hylaeus* spp.) important pollinators for native plant species such as the Haleakalā silversword, are abundant in the native shrublands of Kahikinui FR. They were once abundant across the Hawaiian Islands but can now only be found in abundance in a few places such as the subalpine habitat of East Maui.

Two species of endemic fruit flies (family Tephritidae) in the genus *Trupanea* (*T. cratericola* and *T. limpidapex*) have recently been documented to occur on *Dubautia* plants in Kahikinui FR. Native Tephritid surveys in 2010 and 2011, found that the native sub-alpine habitat of East Maui contained the largest population on the island. Native Tephritid flies seem to be restricted to areas with intact native ecosystems and seem to have vanished from the lowlands (Starr 2011). Native planthopper species in the genus *Nesosydne* were also observed on *Dubautia*.

Figure 22. Insects of Kahikinui FR - 1. Koa butterfly; 2. Larvae of Hyposmocoma sp.; 3. Omiodes continuatalis; 4. Native Ectemnius wasps.

A native koa butterfly (*Udara blackburni*) was observed feeding on nectar from the highly invasive fireweed (*Senecio madagascariensis*) flowers near the makai boundary of the forest reserve. It is one of only two species of butterflies that are native to Hawai‘i. The koa butterfly is about an inch long, the upper sides of the wings blue and the undersides are an iridescent green. The larvae are known to feed on koa and ‘a‘ali‘i leaves.

Native leaf roller moths (*Omiodes continuatalis*) were observed in the mid elevation grassland zone of the forest reserve. Once thought to be extinct, this species was “rediscovered” during biological surveys conducted in 2003 (Haines et al. 2004). This species has not been recently collected on the islands of O‘ahu and Kaua‘i, but are locally abundant in certain locations which includes mid-elevation habitats of East Maui. Leaf roller moths bind plant material together with their silk to create a refuge. They shelter in this refuge as they feed on their host plant. The larvae of *O. continuatalis* are known to feed on both native and non-native grasses which has likely contributed to its continued persistence.

Native fancy-cased moths (*Hyposmocoma* spp.) are abundant over much of Kahikinui. These case making moths live in a broad range of habitat types. With an estimated 400 endemic species, they account for one third of the moth and butterfly diversity in Hawaii and is a great example of evolutionary radiation. Fancy-cased moth larvae observed in the forest reserve were found sheltered on larger stones and cliff faces. Most of them had “burrito” shaped cases and a few had “cigar” shaped cases (Haines et al. 2014).

Native species of jumping plant lice, or psyllids specific to ‘ōhi‘a are present across the entire habitat range in the reserve. These plant lice form galls, or abnormal growths on ‘ōhi‘a leaves, stems and flower buds. Spiders are present in small numbers in the forest reserve, notable species are the native wolf (*Lycosa hawaiiensis*) and crab spiders (*Mecaphesa* sp.). Native predatory *Ectemnius* wasps that provision their nests with flies for their young, are found to occur near the makai boundary of the forest reserve.

Figure 23. Psyllid galls on ‘ōhi‘a leaves; native psyllid (bottom-left)

Native tornatellid snails (*Tornatellides* sp.) were also encountered during the biological survey. This genus of snails is found in a variety of habitats from the Northwestern Hawaiian Islands to the main Hawaiian Islands. Tornatellids are able to utilize habitat which has seen significant human induced disturbance and change. These snails are known to be eaten by the larvae of a native moth *Hyposmocoma molluscivora* which captures the snail with silk and eats them alive. Further surveys would undoubtedly turn up more mollusk species in the reserve.

Figure 24. Tornatellid in Kahikinui

Table 11. Invertebrates found in Kahikinui FR (Starr 2018)

Species	Common name	Native/Non-native
Lycosa hawaiiensis	Hawaiian wolf spider	Endemic
Mecaphesa sp.	crab spider	Endemic
Coccinella septemnervia	Seven-spot lady bird	Non-native
Olla abdominalis	Ash-grey lady bird	Non-native
Naupactus godmani	Fuller's rose weevil	Non-native
Gonocephalum adpressiforme	Gonocephalum	Non-native
Eutreta xanthochaeta	Lantana stem galler	Non-native
Procecidochares alani	Hamakua pamakani stem galler	Non-native
Procecidochares utilis	Maui pamakani stem galler	Non-native
Trupanea cratericola	Hawaiian fruit fly	Endemic
Trupanea limpidapex	Hawaiian fruit fly	Endemic
Nesosydne sp.	On Dubatia	Endemic
Nysius sp.	On ʻōhiʻa	?
Pariaconus sp. nr. *gibbosus*	ʻŌhiʼa leaf pit gall psyllid	Endemic
Pariaconus sp. nr. *kupua*	ʻŌhiʻa stem/flower bud gall psyllid	Endemic
Pariaconus sp. nr. *mauiensis*	ʻŌhiʼa stem/flower bud gall psyllid	Endemic
Pariaconus sp. nr. *montgomeri*	ʻŌhiʻa leaf closed gall psyllid	Endemic
Apis mellifera	honey bee	Non-native
Hylaeus nivicola	yellow-faced bee	Endemic
Cardiocondyla kagutsuchi	cardiocondyla ant	Non-native
Pheidole megacephala	big-headed ant	Non-native
Ectemnius sp.	Ectemnius	Endemic
Odynerus sp.	Odynerus moth	Endemic
Hyposmocoma sp.	Fancy cased moths – burrito case type	Endemic
Hyposmocoma sp.	Fancy cased moths – cigar/carnivorous	Endemic
Omiodes continuatalis	Hawaiian grass leafroller	Endemic
Thyrocopa sp.	flightless moth	Endemic
Tornatellides sp.	tornatellid snails	Endemic
Vanessa cardui	painted lady butterfly	Non-native
Abaeis nicippe	sleepy orange butterfly	Non-native
Pieris rapae	cabbage butterfly	Non-native
Udara blackburni	koa butterfly	Endemic
Danaus plexippus	monarch butterfly	Non-native

3.6.3 Non-Native Wildlife

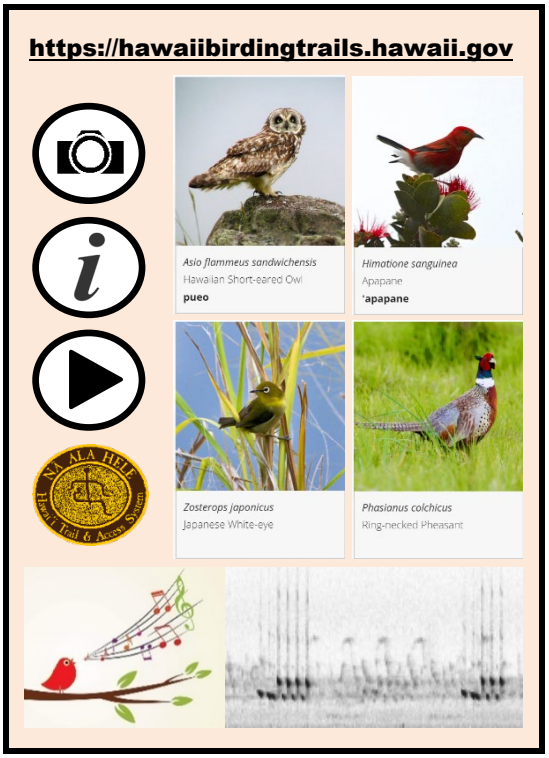


Figure 25. Nā Ala Hele birding website

Figure 26. Goats in Kahikinui FR

A wide variety of introduced birds exist across the island of Maui. Twelve non-native forest and game birds are known to occur in Kahikinui FR and they are all listed in Table 7 above. Additional information for both non-native and native bird species including photographs and bird call recordings, can be found on the Nā Ala Hele birding trails website (Figure *25*). Only Hawai'i Island trails are featured on this website, but the birds resource information covers many species that are found statewide.

There are a total of nine non-native mammals that have been documented in Kahikinui FR and all are listed below in Table 12. Ungulates and rodents make up the majority of these species and goats are the most visibly abundant species outside the fenced exclosure.

Conspicuous non-native insects were also documented during the 2018 biosurvey and are listed in Table 11 above. Most notable are two species of non-native ants, the big-headed ant (*Pheidole megacephala*), and *Cardiocondyla kagetsuchi*. Big-headed ants are more likely to be found in lowland areas, below 4,000 ft. An ant survey of part of the reserve in 2008 found one additional ant species, *Hypoponera opaciceps*. All ants found in Hawai'i are introduced species and can have significant negative impacts on native arthropod biodiversity.

Table 12. Mammals found in Kahikinui FR

Species	Common name	Native/Non-native	Game species
Axis axis	axis deer	Non-native	X
Bos taurus	cow	Non-native	
Capra hircus	goat	Non-native	X
Felis catus	cat	Non-native	
Herpestes auropunctatus	mongoose	Non-native	
Lasirus cinereus semotus	ʻōpeʻapeʻa	Native	
Mus musculus	House mouse	Non-native	
Rattus rattus	Black rat	Non-native	
Rattus exulans	Polynesian rat	Non-native	
Sus scrofa	pig	Non-native	X

3.7 Critical Habitat

As outlined by the ESA, Critical Habitat is defined as "specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rule" (USFWS 2004). The entire Kahikinui State Forest Reserve (2,203 acres) has been designated as Critical Habitat. There are four units (Figure 29) that are defined by ecosystem type, Subalpine, Montane Mesic, Montane Dry and Lowland Dry. Overlapping subsets of endangered species are assigned to each unit, a total of 41 plant species and two species of forest birds, the 'ākohekohe (*Palmeria dolei)* and the kiwikiu (*Pseudonestor xanthophrys*). See Table 13 for a list of these species and which critical habitat units have been designated for their conservation. None of these species are currently known to occur in Kahikinui FR.

Figure 27. Kiwikiu

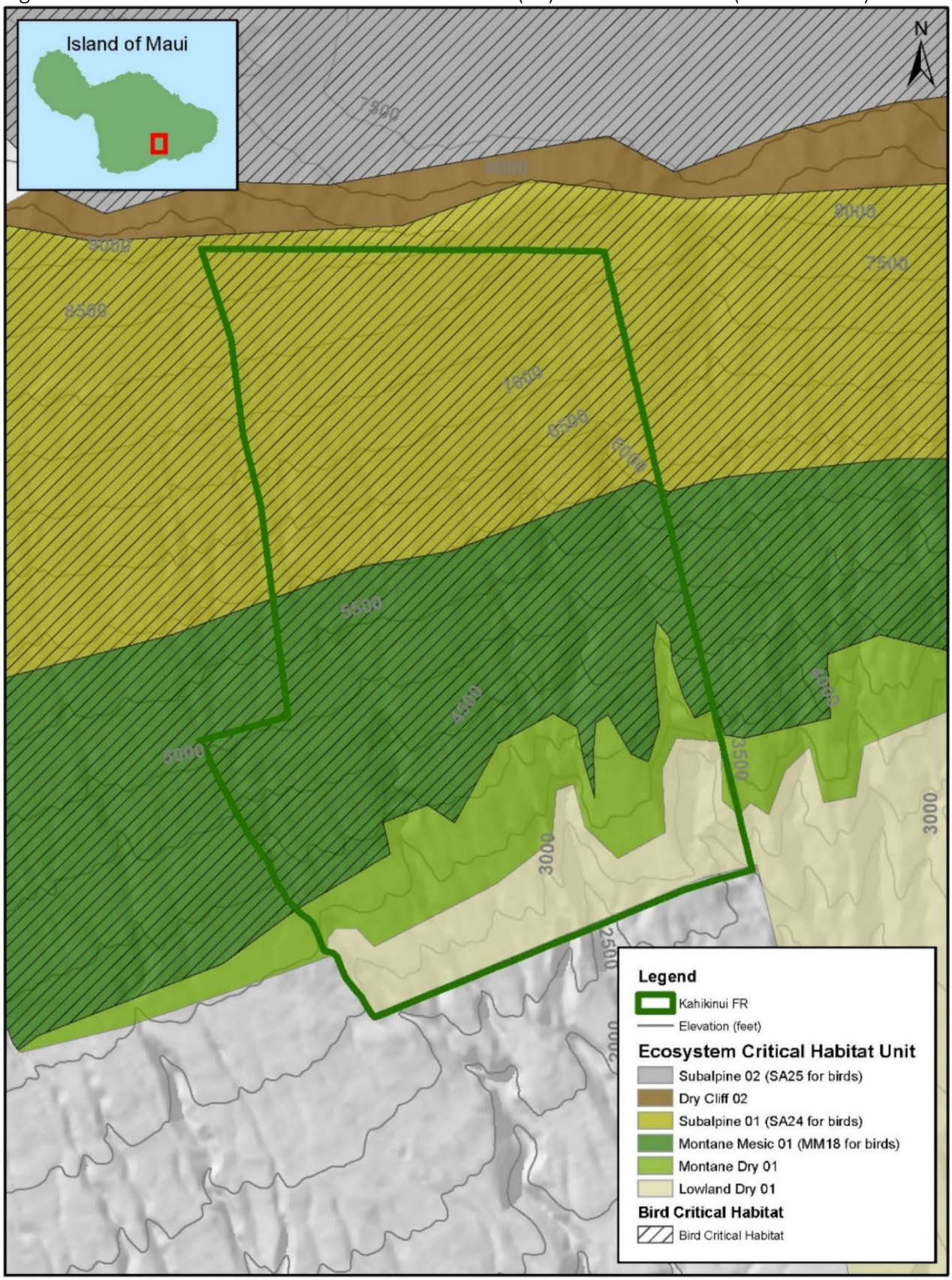
Table 13. Ecosystem Critical Habitat Designation in Kahikinui FR (USFWS 2016)

Species	Critical Habitat Ecosystem Unit			
Plants	Subalpine 01	Montane Mesic 01	Montane Dry 01	Lowland Dry 01
Alectryon macrococcus		x	x	x
Argyroxiphium sandwicense ssp. *macrocephalum*	x	x		
Asplenium dielerectum		x		
Asplenium peruvianum var. *insulare*	x	x		
Bidens campylotheca ssp. p*entamera*		x		
Bidens micrantha ssp. *kalealaha*	x	x		x
Bonamia menziesii				x
Canavalia pubescens				x
Cenchrus agrimonioides				x
Clermontia lindseyana		x		
Colubrina oppositifolia				x
Ctenitis squamigera				x
Cyanea glabra		x		
Cyanea hamatiflora ssp. *hamatiflora*		x		
Cyanea horrida		x		
Cyanea kunthiana		x		
Cyanea mceldowneyi		x		
Cyanea obtusa		x		
Cyrtandra ferripilosa		x		
Cyrtandra oxybapha		x		
Diplazium molokaiense		x		
Flueggea neowawraea				x

Species	Critical Habitat Ecosystem Unit			
Plants	Subalpine 01	Montane Mesic 01	Montane Dry 01	Lowland Dry 01
Geranium arboreum	*x*	*x*	*x*	
Geranium multiflorum	*x*	*x*		
Hibiscus brackenridgei				*x*
Huperzia mannii		*x*		
Melanthera kamolensis				*x*
Melicope adscendens		*x*		*x*
Melicope knudsenii			*x*	
Melicope mucronulata			*x*	*x*
Neraudia sericea		*x*		*x*
Nototrichium humile				*x*
Phyllostegia bracteata	*x*	*x*		
Phyllostegia mannii		*x*		
Santalum haleakalae var. *lanaiense*		*x*	*x*	*x*
Schiedea haleakalensis	x			
Sesbania tomentosa				*x*
Solanum incompletum				*x*
Spermolepis hawaiiensis				*x*
Wikstroemia villosa		*x*		
Zanthoxylum hawaiiense	*x*	*x*	*x*	*x*
Birds	Subalpine 24	Montane Mesic 18	N/A	N/A
Palmeria dolei	x	*x*		
Pseudonestor xanthophrys	x	*x*		

Figure 28. Kahikinui FR (December 2015) – See Figure 15 for 2019 photo

Figure 29. Critical Habitat in Kahikinui Forest Reserve (FR) Also see Table 13 (USFWS 2016)



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3.8 Archaeological and Historical Sites

Figure 30. Cave in Kahikinui FR

In 2011, an archaeological assessment was done for the fence alignments and proposed trail and cabin installation in Kahikinui FR. Archaeological field surveys for historic or cultural properties found one "possible habitation cave" west of the eastern fence alignment. The report states that the cave is sizeable enough to accommodate temporary occupation, but there was no cultural material exposed on the surface to confirm human use. No other historic or cultural properties were found in the forest reserve (State of Hawai'i 2004).

In the event that any surface and/or subsurface evidence of historic properties, including cultural deposits or features, human remains, lava tubes, structural remnants or concentrations of artifacts are identified during any management activities, work will cease immediately in the area of the discovery. The discovery will be protected from further disturbance, and the State Historic Preservation Division (SHPD) will be consulted regarding appropriate documentation. If historic properties are present which require mitigation, the SHPD will request that a detailed mitigation plan (e.g., archaeological monitoring plan [AMP] or a preservation plan [PP]) be submitted to the SHPD for review and acceptance prior to initiation of project work, along with written and photographic documentation providing verification that appropriate interim protection measures have been implemented.

3.9 Access

There is no legal public access to Kahikinui FR through adjacent private, federal, and DHHL lands. There are no improved public trails in the reserve and the only vehicular access is through DHHL lands which were withdrawn from the FRS by Executive Order 3270 in 1984. This vehicular access route starts at the base of Kula FR, goes over the summit and ends on DHHL lands at the Kahua cabin. There is a trail that heads east from Kahua cabin towards Kahikinui FR (Figure 33). Withdrawal of the DHHL lands effectively landlocked the remaining forest reserve lands in Nakula. Helicopters are used to access the reserve for management activities.

Restricted Watershed[6]**:** There are no restricted watershed areas on the island of Maui.

[6] Rule Regulating Restricted Watersheds - Hawai'i Administrative Rules 13-105

Figure 31. Fenceline in Kahikinui FR

3.10 Infrastructure

Infrastructure in Kahikinui FR (Figure 33) is minimal and was installed for watershed protection and to support management activities. This includes seven miles of ungulate proof fencing with fence apron and bird mitigation tape, that encompasses the mauka section of the reserve, approximately 1,200 acres. There are 16 helicopter landing zones that are used to transport staff and materials needed for forest management.

3.11 Public Use Opportunities

Current public use opportunity in Kahikinui FR is very limited due to it's remoteness. There are no public camping grounds or cabins, no improved hiking trails, and horseback riding, off-road vehicles and bicycles are not allowed. Regulations are in place to allow for public hunting and forest product collection, as described below. However, these uses are impacted by the lack of a legal and/or practical public access route.

Hunting**:** DOFAW manages public hunting on all forest reserve lands on Maui and regulates hunting days, seasons, bag limits, and means of take. The Division of Conservation and Resources Enforcement (DOCARE) enforces hunting regulations found in Chapter 121, HAR Rules Regulating the Hunting of Wildlife on Public Lands and Other Lands, Chapter 122, HAR Rules Regulating Game Bird Hunting, and Chapter 123, HAR Rules Regulating Game Mammal Hunting. Kahikinui FR is part of hunting unit C. To obtain a copy of current hunting rules and regulation visit, https://dlnr.hawaii.gov/dofaw/rules/.

Game mammals found in the reserve are feral pigs (*Sus scrofa*), goats (*Capra hirca*), and axis deer (*Axis axis*). Population numbers are low in areas that fencing and ungulate control actions are occurring. Game birds in hunting unit C include: Common pheasant (*Phasianus colchicus*), black francolin (*Francolinus francolinus*), chukar partridge (Alectoris chukar), and gray francolin (*Francolinus pondicerianus*).


Figure 32. Common pheasant

Figure 33. Infrastructure and Access to Kahikinui State Forest Reserve (FR)

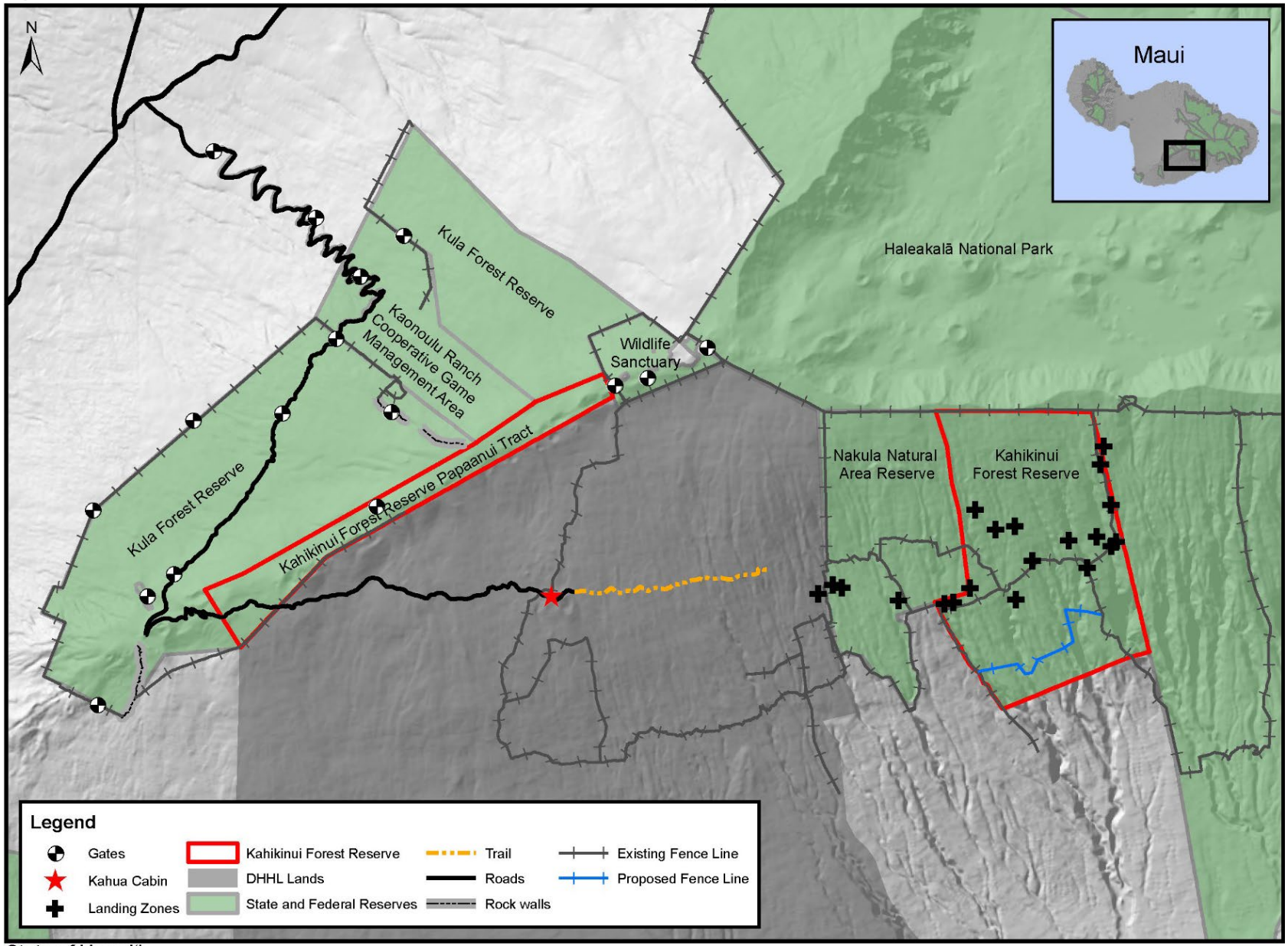

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Figure 34. ʻŌhiʻa lehua of Kahikinui FR

Forest Product Collection**:** Non-timber forest products may be gathered from the Forest Reserve System. Examples of items that can be collected include, but is not limited to:

- Ferns
- Flowers
- Fruits
- Greenery

Gathering of material from plant species that are not on federal or state threatened and endangered species lists is permitted and regulated by DOFAW through standard Forest Reserve System permit procedures as described in Chapter 13-104, HAR. Gathering of non-listed species or common materials requested in quantities that are determined by DLNR as representing personal use, is regulated through issuance of a Collection Permit free of charge. If quantities are determined to represent commercial use, a Commercial Harvest Permit may be issued at a fee. Consult the Forest Product Price List on the DOFAW website for information on personal versus commercial use quantities, as well as current commercial use pricing.

https://dlnr.hawaii.gov/forestry/files/2013/09/2018-12-11_DLNR_Forest-Products-Price-List.pdf

Collection of:

- Listed threatened, endangered, or other rare species, or
- Common invertebrate species, or
- Any migratory bird species,

are prohibited under state laws Chapter 183D and 195D, HRS and subject to regulation under applicable HAR. Applications for permits for such activities may be submitted to the "Administrator," at the DOFAW Honolulu office. In these cases, a separate Access Permit may be required which is obtained through the district manager at the DOFAW Maui office. Both addresses follow:

Administrator
Division of Forestry and Wildlife
1151 Punchbowl Street, Room 325
Honolulu, Hawaiʻi 96813
Phone (808) 587-0166

Maui District Manager
Division of Forestry and Wildlife
685 Haleakalā Hwy
Kahului, Hawaiʻi 96732
Phone (808) 984-8100

The collection of any federally listed or migratory bird species is also subject to federal permits. Contact the USFWS for additional information.

3.12 Traditional and Customary Rights

Traditional and customary rights of the native Hawaiian people are protected under Hawai'i law. In the Constitution of the State of Hawai'i, Article XII, Section 7, "The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupua'a tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights." For any inquiries regarding traditional and customary rights, please contact the Forestry Manager at the DOFAW Maui Office:

Forestry Manager
Division of Forestry and Wildlife
685 Haleakalā Hwy
Kahului, Hawai'i 96732
Phone (808) 984-8100

3.13 Revenue

According to Section 183-1.5, HRS, the Department shall:

"Devise and carry into operation, ways and means by which forests and forest reserves can, with due regard to the main objectives of title 12, be made self-supporting on whole or in part."

Commercial permits for non-timber forest products and small scale salvaging of dead or down timber can be issued for Kahikinui FR. However, its remote location and lack of vehicular access make it a less desirable location for this activity. Each application for a commercial salvage permit shall be considered on its own merits, including its effect on the premises, natural resources and the public's use and enjoyment of the forest reserve. The raw material value of any commercial salvage permit issued for Kahikinui FR cannot exceed $10,000.

DOFAW is exploring options for new revenue streams, including those associated with ecosystem services to supplement funding of natural resource management activities of forests and other natural areas under its jurisdiction. Carbon sequestration, the capture and long-term storage of atmospheric carbon dioxide to mitigate for global climate change, is an ecosystem service for which a market for both compliance and voluntary carbon offsets, already exists. Reforestation at Kahikinui FR is currently undergoing a rigorous certification process as a reforestation/afforestation carbon project under a voluntary carbon standard.

4. THREATS

4.1 Invasive Plants

Invasive plants are non-native species that can invade natural areas, grow and reproduce rapidly, reduce native biodiversity and alter ecosystem functions. Invasive plant species that are present in Kahikinui FR that have the potential to disrupt the ecosystem are listed in below in Table 14. For a brief description of each species, their statewide distribution and impacts see Appendix D.

Based on potential impacts, distribution in the FR, and available control methods, DOFAW has set a management objective (control, containment or eradication) for each species.

- Invasive plant management objectives:
- Control – Reduce populations and/or the vigor of individuals
- Containment – Stops or minimizes population growth and geographic spread
- Eradication – Elimination of populations within geographic area
- EDRR (Early detection rapid response) – These species are not established in the area but are a serious threat to watershed function and/or native ecosystems. Early detection, rapid assessment and rapid response is a critical defense against the establishment of invasive populations.

Figure 35. Bocconia frutescens

Some non-native plant species are also designated as a noxious weed by the Hawai'i Department of Agriculture. A noxious weed is defined as a plant species which is, or may be likely to become, injurious, harmful, or deleterious to the agricultural industry or natural resources of the state. Selling or transporting noxious weeds, their seeds or vegetative reproductive parts is prohibited under state law Chapter 152, HRS and subject to regulation under Chapter 4-68, HAR.

Table 14. Invasive plants species that occur in Kahikinui FR

Species	Common name	DOFAW Objective	Regulatory Status
Bocconia frutescens	tree poppy	Eradication	Hawai'i Noxious Weed List
Sphaeropteris cooperi	Australian tree fern	Eradication	None
Grevillea robusta	Silky oak	Eradication	None
Schinus terebinthifolius	Christmas berry	Eradication	None
Senecio madagascariensis	fireweed	Control	Hawai'i Noxious Weed List
Tibouchina herbacea	Cane tibouchina	Eradication	Hawai'i Noxious Weed List

4.2 Invasive Animals

The Division of Forestry and Wildlife has a dual mandate to, 1) Conserve, manage and protect native and endangered species and their ecosystems, and 2) Preserve, protect and promote public hunting. The hunting program in Hawai'i is based entirely on non-native animal species. Introduced game mammals such as goats (*Capra hircus*), axis deer (*Axis axis*), and pigs (*Sus scrofa*) contribute to the degradation of native ecosystems and watershed health. Impacts of introduced mammals varies across landscapes, dependent on ecosystem type, what animal species are present, their population levels, and the type and intensity of any control measures being used.

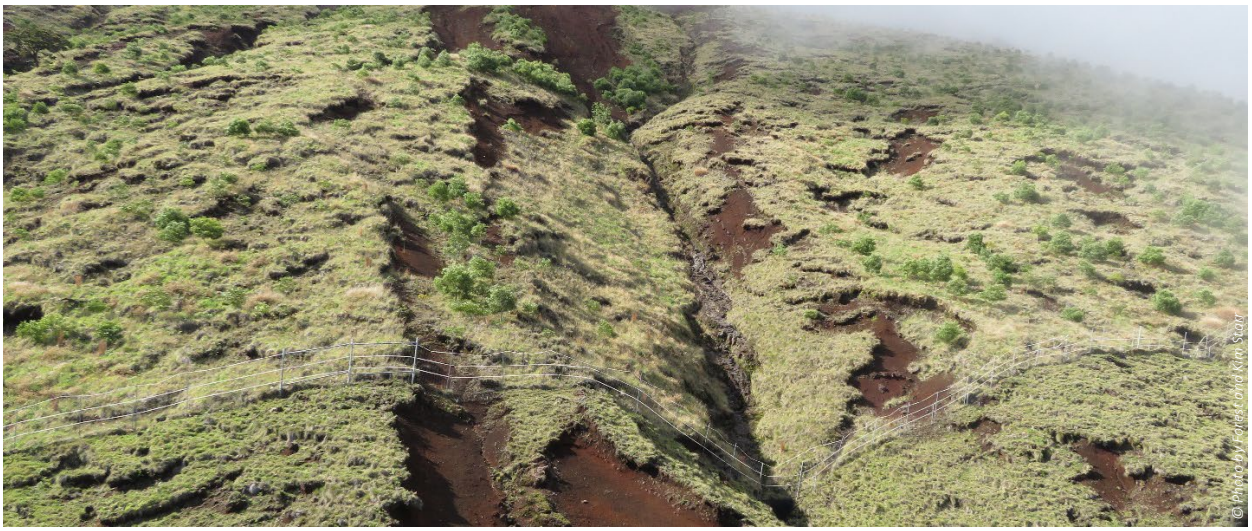


Figure 36. Koa reforestation inside Kahikinui FR fence

To prevent native ecosystem impacts by ungulates in Kahikinui FR a fence exclosure was built around the upper 1,200 acres, encompassing the native shrublands and areas targeted for forest restoration. The management goal for all ungulate species inside the fence is eradication. The lower 1,000 acres of Kahikinui FR are dominated by non-native grasses, herbs and shrubs. This area will remain open for game mammal hunting for the time being. There are plans to build additional ungulate proof fencing (Figure 33) to mitigate environmental degradation that is occurring. Most concerning is the level of soil erosion (Figure 37) in areas being overgrazed by goats. Goat populations are not being controlled to a sustainable level likely due to the lack of easy public access. Public hunting opportunity for game mammals will be decreased by the proposed fence extension. However, bird hunting opportunities will still be available.

Table 15: Animal species that occur in Kahikinui FR and their potential impacts

Species	Common Name	Potential impacts
Axis axis	axis deer	Vegetation damage and death from browsing and bark stripping
Bos taurus	feral cattle	Browse, graze and trample vegetation, and have caused landscape scale deforestation across the state.
Capra hircus	feral goats	Goats have had the most destructive impact on native vegetation on the south slope of Haleakalā as a whole. Goats limit the reproduction of most native species, resulting in deforestation and watershed deterioration.
Culex spp. (especially *Culex quinquefasciatus*)	mosquitos	Vectors for diseases that are a threat to public safety and native wildlife.

Species	Common Name	Potential impacts
Felis catus	feral cats	Predators of native and game birds and are vectors of toxoplasmosis, a zoonotic disease
Herpestes auropunctatus	mongoose	Predators of native and game birds.
Rattus spp.	rats	Predators of native plant fruits/seeds and native and game birds.
Sus scrofa scrofa	feral pigs	Disturb vegetative ground cover by browsing, trampling, rooting and wallowing. In extreme cases this can negatively impact groundwater recharge. They also facilitate invasion and establishment of weedy plant species and create breeding habitat for mosquitos that are vectors for human and avian diseases.

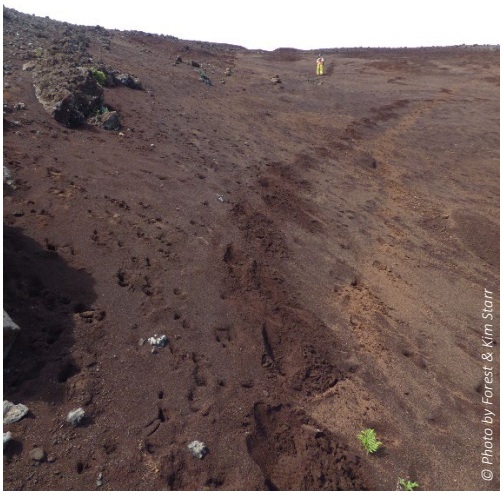


Figure 37. Bare soil in Kahikinui FR

DOFAW has set a management objective for each animal species for inside and outside of the fenced unit, based on potential impacts, distribution in the FR, and available control methods.

Animal management objectives:

- Game species – Manage population levels to stay within carrying capacity
- Control – Reduce populations and/or the vigor of individuals
- Eradication – Elimination of populations within geographic area

Table 16. DOFAW management objectives for animal species in Kahikinui FR

Species	DOFAW Management Objective	
	Inside Fenced unit	Outside Fenced unit
Axis axis (axis deer)	Eradicate	Game species
Bos taurus (feral cattle)	Eradicate	Eradicate
Capra hircus (goats)	Eradicate	Game species
Culex spp. (mosquitoes)	Control	Control
Felis catus (feral cats)	Control	Control
Herpestes auropunctatus (mongoose)	Control	Control
Rattus spp. (rats)	Control	Control
Sus scrofa scrofa (feral pigs)	Eradicate	Game species

4.3 Insects & Disease

Introduction of insects and disease are a serious threat to the natural areas of Hawai‘i. Of particular concern are those that could cause widespread dieback of predominant forest canopy species such as koa and ‘ōhi‘a. With globalization and an increased dependence on imports, approximately 20 insect species become established in Hawai’i every year (State of Hawai‘i 2010).

Recent notable introduction of insects and disease include a rust species (*Puccinia psidii*) that decimated stands of rose apple (*Sygyzium jambos*) and has severely impacted the endangered plant species nīoi (*Eugenia koolauensis*). The erythrina gall wasp (*Quadrastichus erythrinae*) infested introduced and native populations of *Erythrina* or wiliwili to varying degree across the state. Koa wilt (*Fusarium oxysporum* f.sp *koae*) is a soil borne disease that is causing dieback and decline of koa primarily in lowland plantation stands on former agricultural land.

Figure 38. Prosapia bicincta – two-line spittle bug

Of particular concern is the two-line spittle bug (*Prosapia bicincta*) that is causing heavy damage and loss of pasture in parts of Kona on the island of Hawai‘i. Approximately 142,468 acres of Kikuyu/pangola pastures have been impacted by late 2018, and in some areas are dying and being replaced with pamakani, fireweed, hilo grass and other weeds.

The two-line spittle bug has not been detected on the island of Maui, but is still a concern as large tracts of Kahikinui FR are covered in kikuyu grass. Kikuyu is an aggressive non-native grass that forms dense, monotypic mats that can suppress establishment of native and non-native plant species alike. Kikuyu is arguably beneficial as it suppresses the growth of a more diverse weedy vegetative cover that could be more difficult to control and replace with native species. Reforestations projects across leeward Haleakalā have be able to successfully replace mats of kikuyu with native trees and shrubs. Large scale dieback of kikuyu could be problematic.

The largest epidemic threatening forests of Hawai‘i is rapid ‘ōhi‘a death (ROD). ROD has been found on Hawai‘i Island, Kaua‘i, Maui and O‘ahu and is caused by two pathogenic fungi, *Ceratocystis lukuohia* and *Ceratocystis huliohia*. The highly aggressive *C. lukuohia* has been detected on Hawai‘i Island and Kaua‘i and the less aggressive *C. huliohia* has been found on all four islands. Hundreds of thousands of ‘ōhi‘a trees have been killed by this disease and over 135,000 acres of ‘ōhi‘a forest have been affected.

Aerial surveys for ROD symptomatic trees are being done statewide. Surveys on Maui started on April 21, 2016, and were initially done semi-annually. Field staff collect samples from accessible symptomatic trees spotted during surveys. Samples are sent to a lab to confirm the presence of *Ceratocystis*. In July 2019, *C. huliohia* was detected on Maui in a single tree located 53 miles east of Wailuku. Response was quick and the tree was destroyed. Aerial surveys for east Maui and leeward Haleakalā are now being done quarterly and thus far there haven’t been any new

detections of ROD on the island. For more information on what can be done to help prevent the spread of ROD, visit http://www.rapidohiadeath.org.

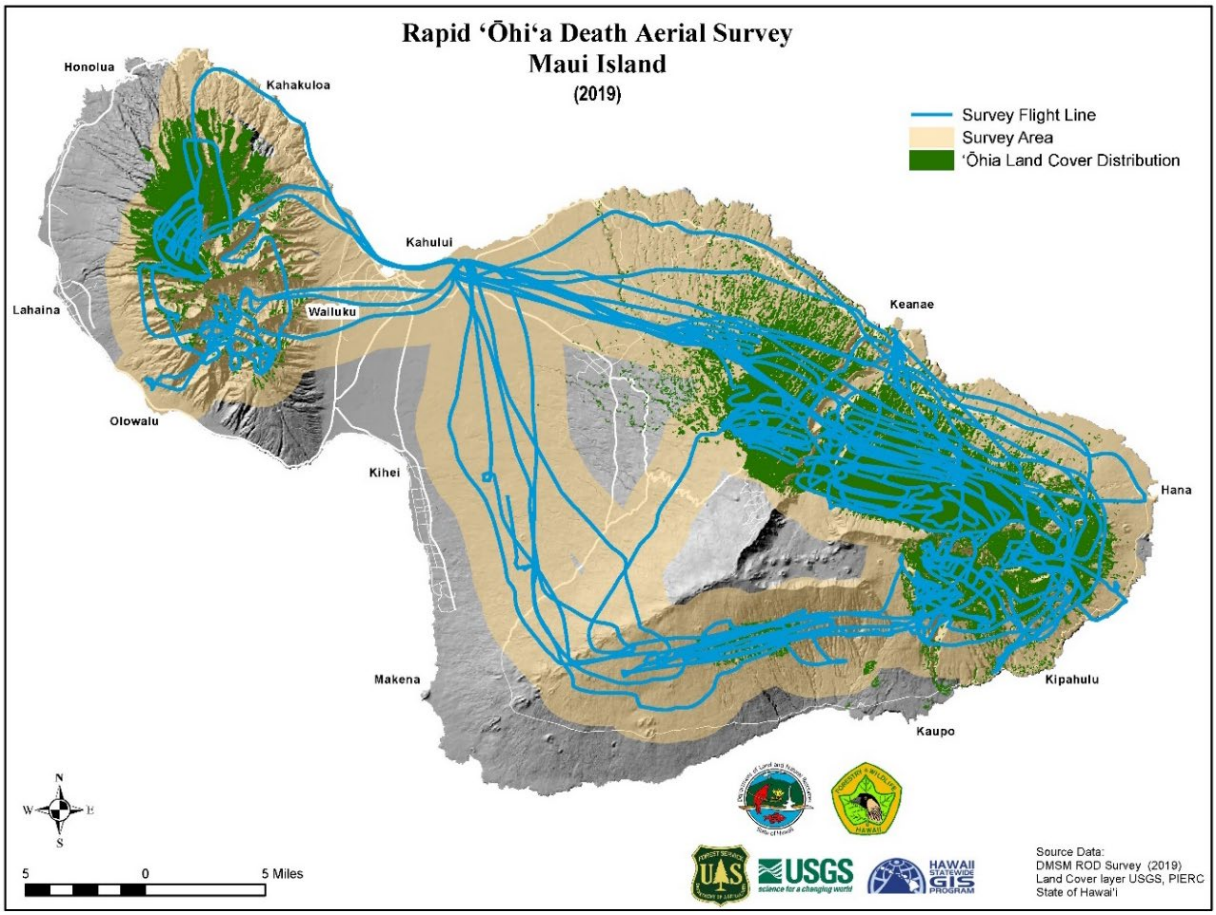


Figure 39. Maui Rapid ʻŌhiʻa Death Aerial Surveys (November 2019)

Based on potential impacts, distribution in the FR, and available control methods, DOFAW has set a management objective (control, containment or eradication) for insects and diseases that are of concern:

- Control – Reduce populations and/or the vigor of individuals
- Containment – Stops or minimizes population growth and geographic spread
- Eradication – Elimination of populations within geographic area
- EDRR (Early detection rapid response) – These species are not established in the area but are a serious threat to watershed function and/or native ecosystems. Early detection, rapid assessment and rapid response is a critical defense against the establishment of invasive populations.

Table 17. DOFAW management objectives for insects and disease in Kahikinui FR

Species	Common Name	DOFAW Objective
Ceratocystis huliohia *Ceratocystis lukuohia*	rapid ʻōhiʻa death	EDRR
Prosapia bicincta	two-lined spittle bug	EDRR

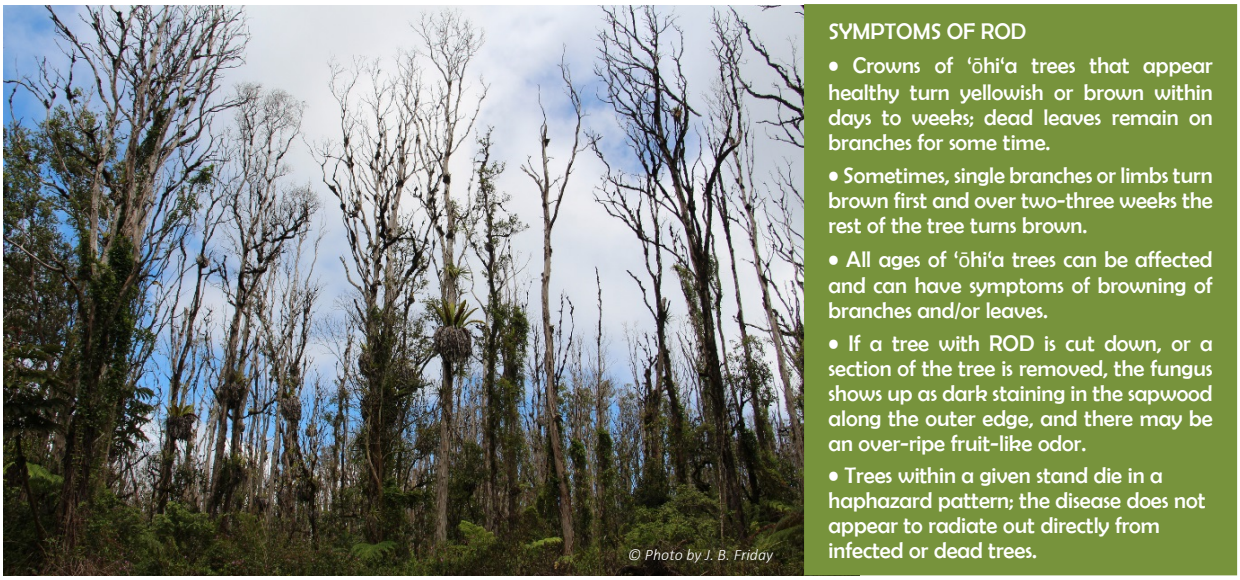


Figure 40. ʻŌhiʻa killed by ROD in lower Puna on the island of Hawaiʻi

4.4 Fire

Wildfires are a serious threat to human safety and property, and impact native ecosystems, watersheds and near shore coastal environments statewide. Native terrestrial ecosystems are not adapted to wildfire and are often replaced by fire adapted introduced species of grasses and shrubs. Approximately 25% of the total land mass in Hawaiʻi (Trauernicht 2014) are now cover by these fire-prone fuels. This combined with an increase in human caused ignition has resulted in a fourfold increase of area burned by wildfires in Hawaiʻi annually (Trauernicht and Pickett 2016).

The risk of wildfire ignition within Kahikinui FR is relatively low due to its remote location and difficulty of access (Figure 41). However, the threat of wildfire is still present. Brush fires do occur along Piʻilani Hwy less than four miles from the reserve. The slopes below the forest reserve are covered with flammable grasses and shrubs. Prevailing winds make it unlikely that wildfire would travel upslope to the forest reserve, but it is still possible under certain weather conditions. The only recorded wildfire in Kahikinui FR occurred in 2016, at approximately 5,200 feet in elevation. Thick fog made it difficult to locate but also resulted in a slow-moving smoldering fire that burned only half an acre. The cause of ignition is unknown.

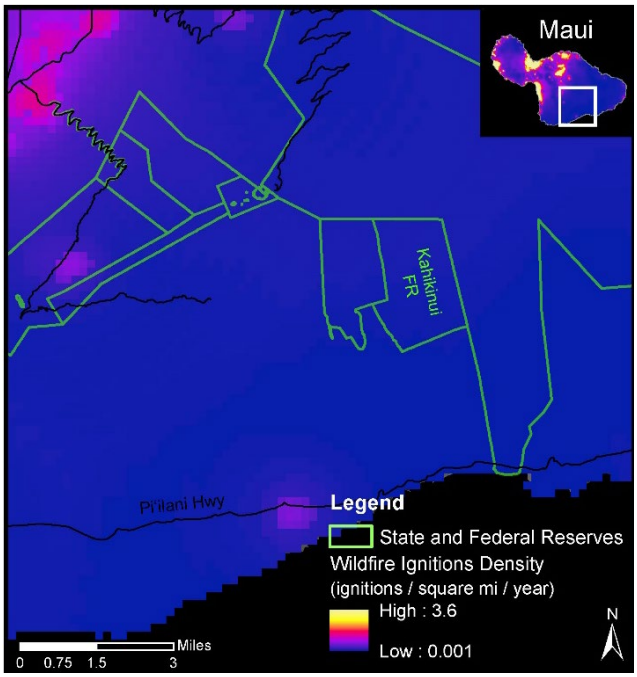


Figure 41. Wildfire ignition density (Trauernicht and Lucas 2016)

4.5 Climate Change

According to the 2012 Pacific Islands Regional Climate Assessment (PIRCA), documented indicators of climate change in the region include increasing air temperature (more significant at higher elevation), decrease in rainfall across much of the region, decrease in ground water discharge to streams, changes to frequency and intensity of climatic extremes, mean sea level rise (Western Pacific), changes in species distributions, increasing ocean surface temperature and changing ocean chemistry. Potential impacts to our communities and natural environments include shifts in rainfall patterns, a decrease in freshwater supplies, increase in extreme weather events, flooding and erosion, increase in non-native biological invasions, increase in frequency and size of wildfires, and an increased risk of species extinction (Keener et al. 2012).

The primary mitigation for climate change is reduction in emissions and enhancement of carbon sinks. Maintaining and increasing carbon storage within our forests will help decrease atmospheric carbon. In terms of reducing emissions, Governor David Ige signed into law the most aggressive clean energy goal in the nation. To achieve energy self sufficiency utilizing 100% renewable sources by 2045. In 2018, the State of Hawai‘i took this commitment further by pledging to achieve carbon neutrality, also by 2045.

Forest ecosystems in Hawai‘i will face new climatic conditions associated with climate change. Individual species and ecosystems types may be more vulnerable to climate change if they are not able to adapt or migrate to suitable habitats. Researchers have started climate vulnerability assessment for Hawai‘i species, but additional information is needed at local scales to determine impacts within individual watersheds and forest reserves.

In 2018, the Pacific Island Climate Change Cooperative (PICCC) and EcoAdapt completed the Hawaiian Islands Climate Vulnerability and Adaptation Synthesis (Figure 42). Through literature reviews, expert elicitation, vulnerability mapping, and workshops with resource managers and conservation planners, the synthesis provides information to improve understanding of climate change impacts, to increase capacity to reduce impacts, and to facilitate decision-making by land managers (Gregg 2018).

The climate synthesis contains summaries of adaptation strategies and actions for habitats types and ecosystem services. Summaries that are relevant for Kahikinui FR (dry forest, mesic and wet forests, alpine/subalpine, cultural knowledge and values, flood and erosion control, fresh water and food and fiber) have been excerpted and included as Appendix E of this plan. To anticipate and mitigate climate

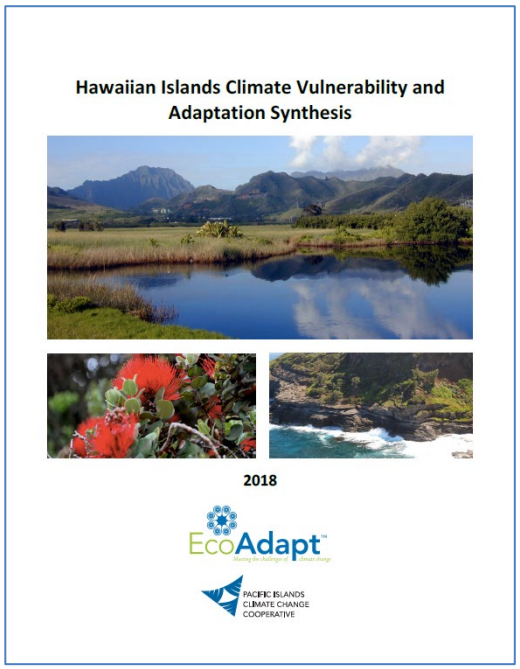


Figure 42. Hawai‘i climate synthesis: http://piccc.net/project/climate-synthesis-supporting-the-hitai/

change impacts, all strategies and action items were reviewed and if applicable, incorporated into management objectives for Kahikinui FR.

5. MANAGEMENT

5.1 Past Planning

The Division of Forestry completed the first management plan for Kahikinui State Forest Reserve in the early 1990s. The objective of this plan was to: (1) To maintain and increase hunting opportunity through cooperative agreements with neighboring landowners, and (2) Develop and maintain additional access into remote areas for various recreational use.

Related Plans: Plans that contain relevant information on the resources and management strategies pertinent to the management of Kahikinui are listed below.

- Leeward Haleakalā Watershed Restoration Partnership (LHWRP) Management Plan
- Hawai'i's State Wildlife Action Plan
- State of Hawai'i Forest Action Plan
- DOFAW Draft Management Guidelines
- Nakula Natural Area Reserve Management Plan
- Maui Invasive Species Committee Strategic Plan
- USFWS Endangered Species Recovery Plans
- Kaheawa Wind Power II Wind Energy Generation Facility Habitat Conservation Plan

5.2 Summary of Management Activities

Early management of Kahikinui FR centered on fencing and removal of cattle from the reserve. In 1920, fences and stonewalls were built by Raymond Ranch and by the forest ranger, starting from above Polipoli Spring in Kula FR, up towards and along the summit to Kalepeamoa (Judd 1921). This was done to prevent cattle from going over the mountain from Kahikinui. Pasture leases for lands makai of Kahikinui FR were reissued with mandatory fence construction conditions to keep cattle out of the forest reserve starting in 1928. Correspondence in forestry records document non-compliance with these fencing requirements and cattle ingress into the forest reserve. Construction, maintenance and integrity of these fence lines was inconsistent. Spurts of functional fencing through time may have slowed the decline of deforestation on leeward Haleakalā but never halted it completely.

In 1964, DLNR issued a revocable permit for pasture to Haleakalā Ranch for a 341 acre portion of Kahikinui FR that is now a part of the Nakula Natural Area Reserve (RP3533 reissued as RP5645 in 1978). The Ranch also held a long-term lease (GL3701 - expired March 18, 1982) for adjacent lands, which is why they requested the permit. Both the ranch and agency believed these lands were suitable for pasture. This permit did not require fencing and cattle were grazing in the FR.

In October 1981, the district forester Bob Hobdy and five other botanists did a "patrol" of Kahikinui FR. They hiked through remnant forests between 4,000 and 5,000 feet in elevation,

between Manawainui and Wailaulau gulch. Signs of cattle were abundant throughout the area, and goats and pig signs were also common. Goats seemed to be the most abundant as hundreds were seen in small herds. Much of the forest was gone at this point, with only remnant patches left in the gulches. Browsing pressure was high and effectively suppressing forest recruitment (Hobdy 1981).

Ecosystem protection management goals were quickly set and put into motion. In April 1982, RP5645 was cancelled, and six months later two miles of five strand barbed wire fence was constructed from Waiopae gulch to Kahalulu gulch at about 5,000 feet in elevation. With no vehicular access to the work site, staff and materials had to be flown in by helicopter. This fenceline is no longer maintained and has been replaced by fenced enclosure (Hobdy 1982).

Figure 43. Fence construction in 1982

Natural resource management of Kahikinui FR has always been difficult because of its remoteness. The only vehicular access route starts at the base of Kula FR, goes over the summit, and ends on DHHL lands at Kahua cabin. The eastern sections of the forest reserve are only accessible by foot or helicopter. In 1984, vehicular access was lost when the DHHL lands were withdrawn from the forest reserve by Executive Order 3270. A State and Federal task force concluded that the Territorial and State government did not have the legal authority to set-aside DHHL lands for other uses including forest reserves. As a result, DHHL lands in the Forest Reserve System were withdrawn statewide.

Figure 44. Soil erosion in Kahikinui FR

With little to no access for public hunting, the goat population in Kahikinui reached unsustainable levels. In the early 1980s, Biologist estimated that the goat population in Kahikinui was about 22,000. DOFAW attempted to increase public hunting opportunity through cooperative agreements with neighboring landowners, but after little success eventually resorted to aerial goats hunts to reduce the severe impacts to vegetative cover and soil erosion.

In 1991, watershed partnerships started to coalesce on the island of Maui starting with the East Maui Watershed Partnership. Watershed partnerships are voluntary alliances of both public and private landowners committed to the common value of protecting forested watersheds for water recharge, conservation, and other ecosystem services through collaborative management.

Kahikinui FR is part of the Leeward Haleakalā Watershed Restoration Partnership (LHWRP) which formed in 2003. LHWRP is an alliance of 11 public and private landowners and supporting agencies encompassing 43,000 contiguous acres of Leeward Haleakalā. The goal of LHWRP is to help restore the mauna lei, the band of native koa forests that once encompassed Haleakalā

Figure 45. Natural regeneration of koa in Kahikinui FR (August 2016)

from Makawao to ʻUlupalakua to Kaupo between 3,500 and 6,500 feet in elevation. Reforestation of this pastureland back to native forest will reduce soil erosion, increase water supply recharge, re-establish endangered species habitat, mitigate wildfire threats by removing fire adapted invasive plants, and support many other natural and cultural benefits.

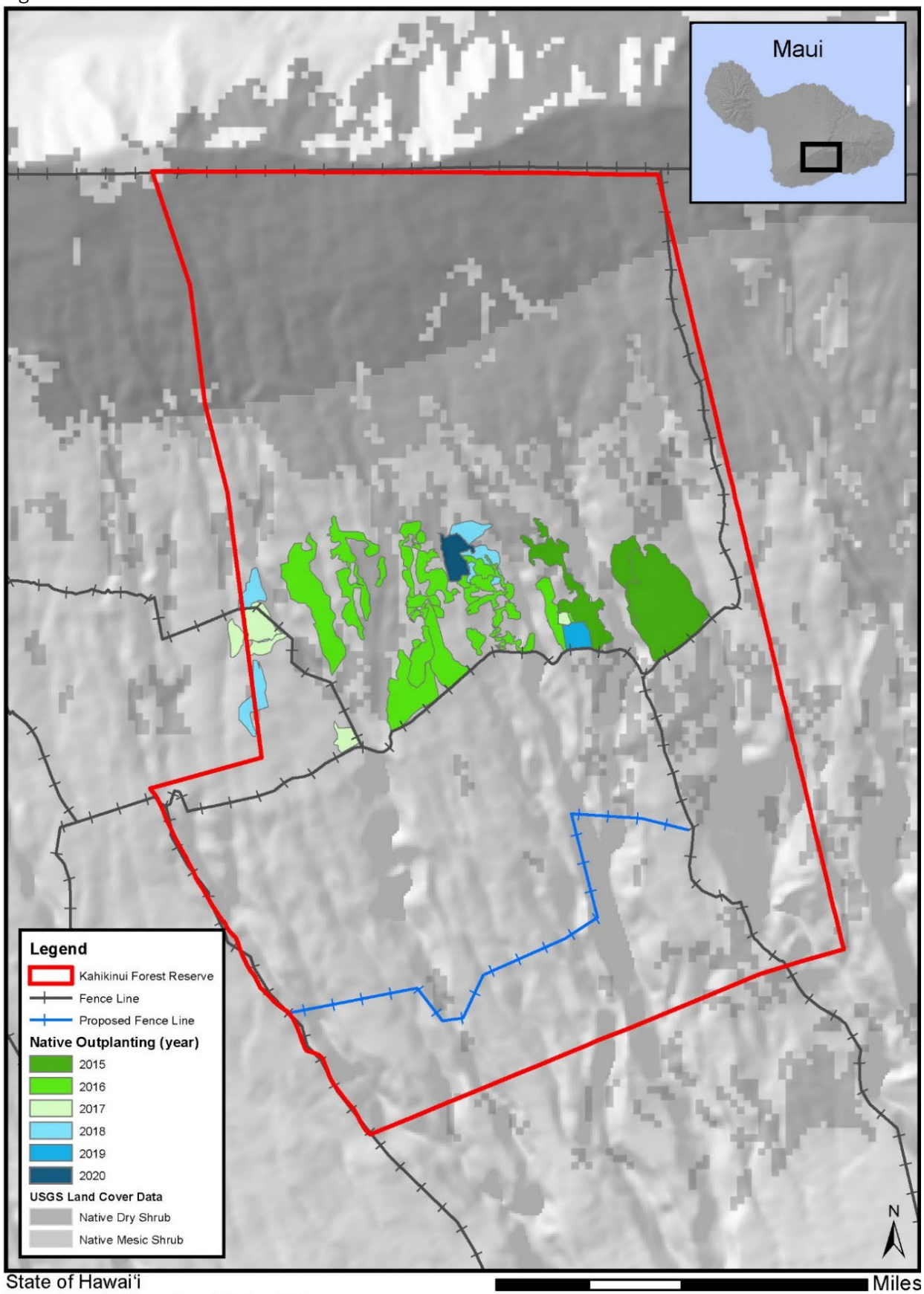
DOFAW and partners, with additional financial support from Kaheawa Wind Power II along with grants awarded by the United States Forest Service (USFS) and the Arbor Day Foundation, have been actively doing forest restoration in Kahikinui FR since 2014. Collectively, 13.5 miles of ungulate proof fencing, including fence apron and bird mitigation tape has been constructed. These fence exclosures encompass 2,676 acres of both the Nakula NAR and Kahikinui FR, of that 1,200 acres is forest reserve.

Without a forest canopy to shelter under, ungulate removal utilizing the ACETA (aerial capture, eradication and tagging of animals) methodology took less than a year. All ACETA operation were conducted in accordance with an approved aerial shooting/ungulate control plan (State of Hawaiʻi 2016). Over 725 animals were removed from the forest reserve and native plant species (canopy and understory) started to naturally regenerate almost immediately. Thousands of native koa trees germinated from the soil seed bank and are now over ten feet tall. To augment forest recovery 90,770 native plants were grown in local nurseries and planted into the forest reserve (Table 18 and Figure 47).

Figure 46. Planting koa

With much of the planting within the fenced area completed, current management activities include weed and ungulate control and supplemental outplanting to compensate for mortality. LHWRP staff has also completed ungulate, invasive plant, and rare

Figure 47. Native Reforestation in Kahikinui FR



plant surveys across the watershed partnership and they are currently implementing a regional invasive species control plan that they drafted in 2015.

Figure 48. Deschampsia nubigena outplanted with fertilizer

Trials are also being done to re-vegetate hardpan soil erosion scars. Tree and shrub seedlings planted into these scars did not thrive, most likely due to the lack of topsoil. In an attempt to rehabilitate the soil, an endemic alpine hairgrass (*Deschampsia nubigena*) was planted. If the grass is able to establish, over time it will increase organic matter and soil moisture. Hopefully the soil will improve and canopy species such as koa can be established. Fertilizer application, based on soil analysis results, seem to significantly improve grass outplanting success.

Table 18: Summary of Kahikinui FR outplanting records

Species	Common name	# outplanted
Acacia koa	koa	47,053
Argyroxiphium sandwicense subsp. *macrocephalum*	ʻāhinahina	59
Capparis sandwichiana	maiapilo	600
Cheirodendron trigynum	ʻōlapa	436
Coprosma ochracea	pilo	1,152
Deschamsia nubigena		1,578
Dianella sandwichensis	ʻukiʻuki	100
Dodonaea viscosa	ʻaʻaliʻi	21,501
Metrosideros polymorpha	ʻōhiʻa	5,933
Myrsine lessertiana	kōlea	600
Osteomeles anthyllidifolia	ʻūlei	536
Pisonia brunoniana	pāpala kēpau	42
Rubus hawaiensis	ʻākala	204
Santalum freycinetianum	ʻiliahi	340
Sophora chysophylla	māmane	6,326
Pipturus albidus	māmaki	3,710
Wikstroemia uva-ursi	ʻākia	600
	Total	90,770

ʻŌpeʻapeʻa management

Kahikinui FR serves as a conservation area to offset take of endangered bats and birds resulting from the wind energy industry in Hawaiʻi. In accordance with their Habitat Conservation Plan, Kaheawa Wind Power II contributed funding to DOFAW for the fencing and management of the

forest reserve and for monitoring of bat activity for the purpose of quantifying the net benefit of mitigation. Data from baseline monitoring in Kahikinui FR has been included in section 3.6.1 of this plan. Subsequent monitoring efforts should occur at years 5, 10, 15, and 20 after the start of habitat restoration activities, and should consist of 3-month continual sampling efforts in the same three months of each sampling year.

Endangered seabird protection

Monitoring and protection of the endangered ‘ua‘u is being done by MNSRP. Information from their native seabird distribution and monitoring efforts are included in section 3.6.1 of this plan. To monitor seabird predators, MNSRP has five permanent tracking tunnel transects and 6 baited cat stations in upper Kahikinui. Predator monitoring in 2014-2015 provided baseline data following completion of the ungulate excluding fence in June 2014. The first follow-up survey was completed in 2017, and surveys are now performed twice annually to detect predators at the end of the winter and summer seasons (Table 19). Thus far predator detections in Kahikinui FR are low. In addition to established trap locations, opportunistic control of predators occasionally takes place during other field activities. MNSRP predator control efforts are summarized in Table 20.

Table 19. Summary of MNSRP predator tracking in Kahikinui State Forest Reserve

Predator	Winter				Spring		Summer			Fall	
(# sites)	2015	2017	2019	2020	2014	2017	2014	2017	2019	2014	2017
Rat (100)	2	1	1	4	0	5	2	6	6	3	4
Mongoose (30)	0	0	0	0	0	0	0	0	0	1	0
Cat (7)	0	2	2	0	1	0	1	1	0	0	1

Table 20. Summary of MNSRP predator control in Kahikinui State Forest Reserve

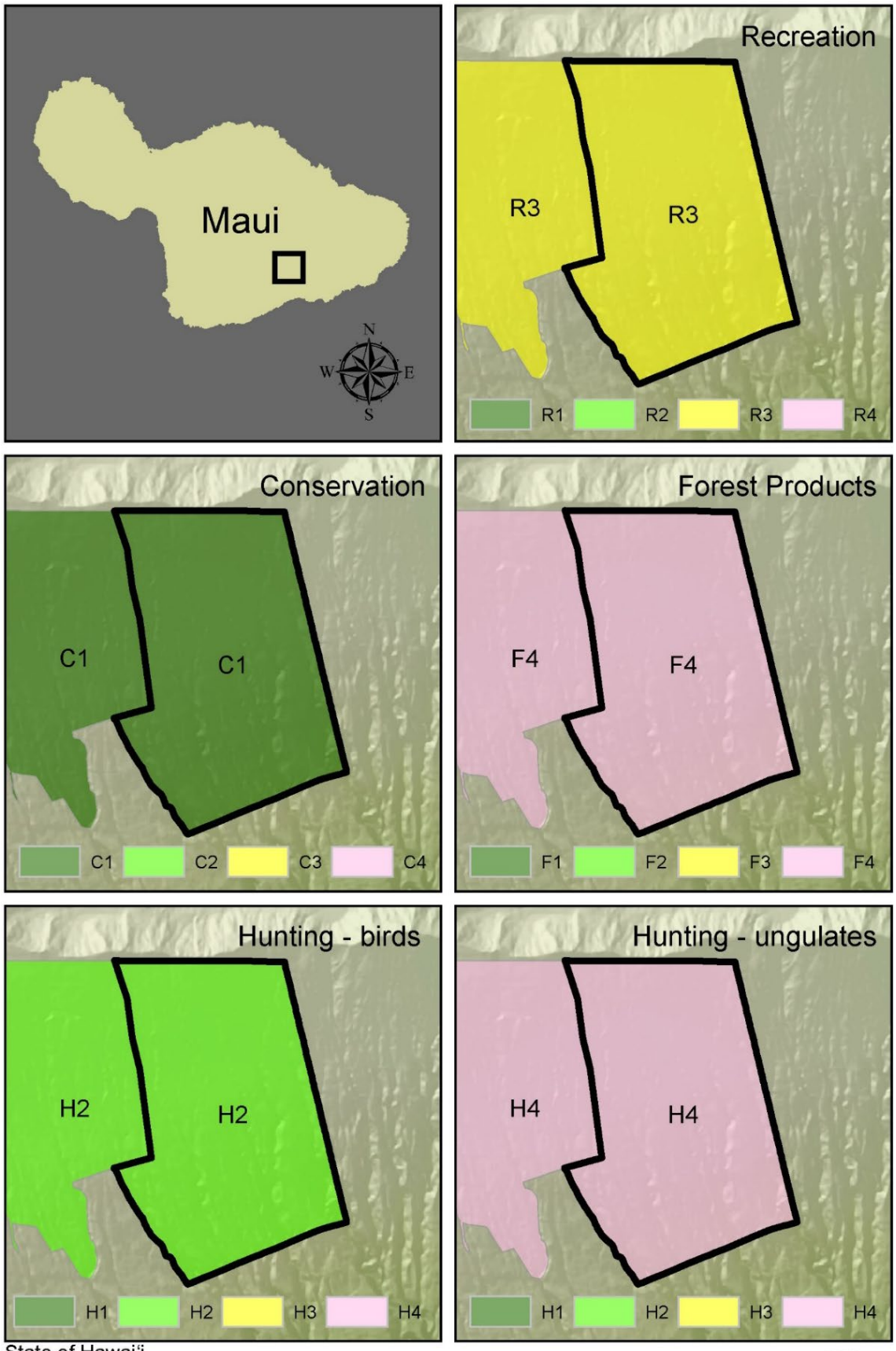
Trap type	Number of locations	Date established	Kills
Belisle	3	Oct. 2015	5 rats, 1 mongoose
DOC250	1	June 2016	2 rat
A24	2	Feb. 2016	11 rats

5.3 Management Priorities, Objectives and Goals

5.3.1 DOFAW Management Guidelines

DOFAW has developed a set of draft management guidelines and associated maps to assist in evaluating and balancing human activities and resource management objectives on lands under DOFAW jurisdiction. The purpose of the guidelines is to provide administrative policy direction and prioritize resource management activities based on the integrity of existing natural resources and social needs in four principal classifications: Conservation Resources, Forest Products Management, Recreation Management and Hunting Management. Detailed definitions of these classifications and their associated management strategies can be found in Appendix F.

Figure 49. Kahikinui FR DOFAW Management Guidelines



State of Hawai'i
Department of Land and Natural Resources
Division of Forestry and Wildlife
(808) 587-0166
May 2020

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Forest Products Management Guideline

DOFAW's Management Guidelines separate forest products management into four classifications: Large Scale Commercial (F-1), Small Scale Commercial (F-2), Personal Use (F-3), and Restricted (F-4). Kahikinui FR is designated F-4 or Restricted, where natural resource protection is the highest priority. Any forest product utilization activities allowed are minimally disruptive, or focused on improving forest and watershed health, native ecosystems, and other conservation efforts. Harvesting of timber will only be considered if such activities improves other priority resource outcomes. Permits for harvesting of non-timber forest products will be considered on a case by case basis for research and education, improving forest science and health, watershed protection, traditional and customary practices, and conservation efforts.

Hunting Management Guideline

DOFAW's Management Guidelines separate hunting management into four classifications: Active Hunting Management (H-1), Moderate Hunting Management (H-2), Low Intensity Hunting Management (H-3), and No Hunting Management (H-4). Due to the difference in environmental impacts of game bird versus ungulates, they were given separate hunting classifications.

Kahikinui FR is classified as H-4 for ungulates due to the area being unsuitable for open public hunting due to environmental sensitivity and the lack of legal public access. Goats are the most abundant species in this region and with the lack of easy public access the population is not being controlled to levels that are needed. The makai portion of Kahikinui FR that is not protected by ungulate proof fencing is experiencing high levels of grazing pressure. Large areas are devoid of vegetation and soil erosion is occurring during large rainfall events. Past efforts to increase public hunting access to this area have not been successful. To halt the environmental degradation that is occurring, plans to build more ungulate proof fencing are being considered. Public hunting opportunity for ungulates is not a priority for this area at this time.

Conversely, the forest reserve is classified as H-2 for game birds. While the lack of public access is still an issue, game birds are less damaging to the environment. DOFAW is still pursuing an agreement with DHHL to allow public access through land under their jurisdiction. If access is secured, the area could be opened for game bird hunting for those willing to make the long walk from Kahua cabin.

Recreation Management Guideline

DOFAW's Management Guidelines separate recreation management into four classifications: R-1 (High Recreation Management), R-2 (Medium Recreation Management), R-3 (Low Recreation Management), and R-4 (Restricted Access). The entire Kahikinui FR is classified as R-3, where outdoor recreation is of low intensity. Trails will likely receive limited use due to remoteness, and will require levels of maintenance relative to its usage. Public access and recreation is contingent on securing an access agreement through DHHL lands.

An environmental assessment completed in 2012, for the Kahikinui Koa Forest Protection and Restoration project also included the installation of a system of access trails and cabins

throughout Kahikinui FR. Exact locations of the proposed trails and cabins have not been determined, however the general plan was to distribute infrastructure throughout the parcel to allow public access to State lands (Figure 50). Proposed trails are aligned north-south along prominent and steep ridge tops and contour west-east across the deeply dissected terrain. Six ridgetop cabins were also proposed to support forest management and for overnight public use. This proposed action has not been implemented due to the lack of legal public access across neighboring properties to this landlocked forest reserve but could be considered if an access agreement is negotiated.

Conservation Resource Guideline

DOFAW's Management Guidelines separate conservation resources into four classifications: C-1 (High Conservation Resources), C-2 (Medium Conservation Resources), C-3 (Low Conservation Resources), and C-4 (Little to No Conservations Resources). The entire Kahikinui FR is classified as C-1, because it is an important restoration area for T&E native forest bird and bat habitat. There is also a high level of recovery potential as current forest restoration efforts have been highly successful. Management activities in C-1 areas include animal exclusion fencing, predator control, weed control, outplanting of native vegetation and reintroduction of native wildlife.

5.3.2 Management Priorities

Broad management priorities for each forest reserve were derived from the mandates that regulate DOFAW activities, including the Draft Management Guidelines and Administrative Rules, as well as input from district staff. These management priorities were divided into eight categories (listed below) and are used to guide management activities within the forest reserve.

- Watershed Values – Maintain or increase quantity and or quality of aquifer recharge and soils erosion control.
- Native Ecosystems – Landscape level protection of native ecosystems.
- Resource Protection – Protect forest ecosystems from wildfire, insects, and disease.
- Invasive Species Control - Monitor and control incipient and established invasive plants and animals that negatively impact ecosystems.
- Threatened and Endangered (T&E) Species Management – Protection of federally and state listed, rare plants and animals.
- Access, Trails, and other Public Uses – Non-income generating uses, such as recreation, cultural activities, personal gathering, educational or research activities, and events among others.
- Game Animal Management – Management of public hunting areas and game animals.
- Commercial Activity – Sustainable income generating activities such as timber, ecotourism, etc.

Figure 50. Proposed Trails and Cabins from project EA (DOFAW 2012)

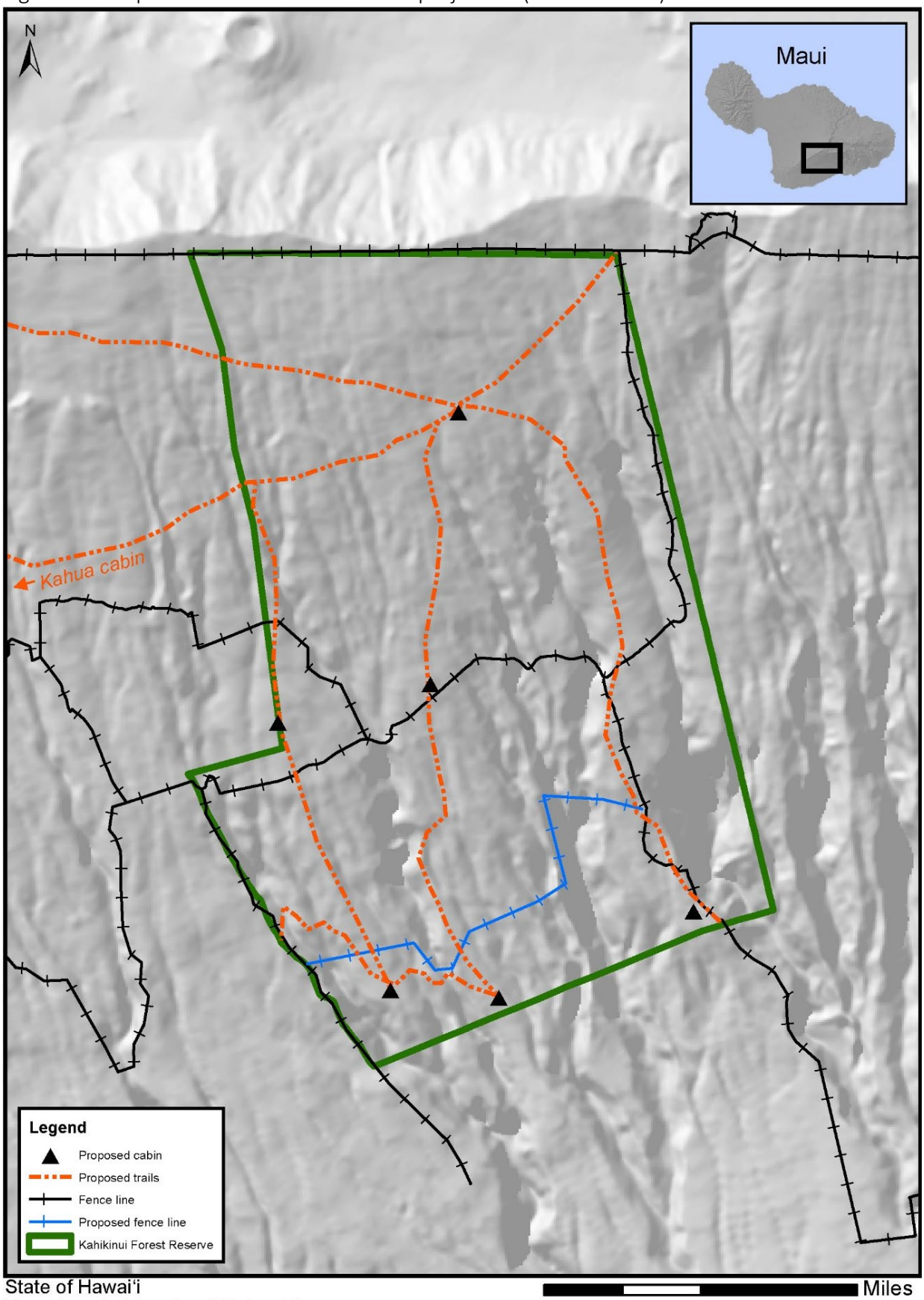

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Figure 51. Aerial view of koa reforestation in Kahikinui FR

Based on the natural and cultural resources and public use opportunities of the reserve, each category has been ranked on a qualitative scale of 1 to 8 with 1 as higher priority and 8 as lower priority. Table 21 lists the qualitative rankings of the management priority for Kahikinui FR.

Table 21. Kahikinui State Forest Reserve associated management priority categories

Forest Reserve	Resource Protection	Watershed Values	Invasive Species Control	T&E Species Mgmt.	Native Ecosystems	Game Animal Mgmt.	Commercial Activity	Access, Trails, and other Public Uses
Kahikinui	3	1	5	4	2	7	8	6

5.3.3 Management Objectives

Expanding on the management priority categories defined above, general management actions, along with tactical goals, action items, and estimated cost associated with these actions for the management of Kahikinui FR are presented in Table 22.

Table 22. Management of Kahikinui FR

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
Watershed Values	Increase land holdings protected under the Forest Reserve System	Support healthy forests through land acquisition and forest restoration Secure public access across neighboring state leased properties.	Initiate discussions with parcel lessees to acquire parcels for possible Forest Reserve designation or secure access route to existing FR lands. TMK: (2) 1-8-001:005 (2) 1-8-001:003 (2) 1-9-001:001 (2) 1-8-001:004	Staff & mgmt. costs; market value

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
	Reduce the threat and impact of erosion on reserve resources	Maintain forest cover on watershed lands to provide high quality water for communities of Maui	Re-establishment of appropriate vegetative cover	$75K/year + staff costs
		Exclude cattle from FR	Maintain fences to comply with HRS Chapter 183	$10K
			Conduct staff control operations for non-game mammal species. Locate and remove cattle with owner's assistance.	Staff & mgmt. costs only
		Control all other ungulate populations at levels consistent with watershed protection needs	Continue to monitor and control ungulate population inside existing fenced exclosures (ACETA).	$25K
			Update Maui District Kahikinui FR and Nakula NAR Aerial Shooting /Ungulate Control plan	Staff & mgmt. costs only
			Extend ungulate proof fencing and remove grazing animals to protect natural areas makai of the existing exclosure to halt environmental degradation caused by overgrazing. Assess strategic fence placement options to best enhance water quality.	$479K
		Post fire mitigation	Collect and store seed stock for various native plant species to be used for post-fire mitigation work	$15K/year
			Conduct post-fire mitigation such as seed scatter, aerial broadcast, weed control, soil conditioning and reforestation.	TBD

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Build fire-resilient native communities to stabilize soils following wildfires to prevent post-burn erosion.	$500k
	Monitor forest composition over time to determine landscape level needs	Determine permanent systematic monitoring protocol	Monitor established reforestation survivorship plots and photo points.	$15K/year
			Continue to assess forest monitoring effectiveness and needs. Establish new protocols as needed.	Staff & mgmt. costs only
	Collaboration	Maintain DOFAW's partner role in the LHWRP.	Improve communication and coordination between agencies	Staff & mgmt. costs only
			Establish regular communications, schedules, and protocols with WP	Staff & mgmt. costs only
			Participate in WP quarterly meetings	Staff & mgmt. costs only
			Annual renewal of LHWRP's Forest Reserve Special Use Permits	Staff & mgmt. costs only
	Climate Change Adaptation	Monitor latest publication and available information for climate change, vulnerability, modeling and adaptation.	Participate in climate change seminars, meeting and workshops.	Staff & mgmt. costs only
		Increase collaborative efforts to conserve streams and watersheds	Expand watershed conservation to lower elevations by enhancing watershed partnerships and seeking legislative changes at the state and local levels	Staff & mgmt. costs only
		Protect forests to increase recharge and water retention	Support heathy forests through land acquisition and forest restoration	TBD
Resource Protection	Fire presuppression and mitigation	Fire presuppression	Development of fire management plans	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Development of a CWPP plan	$26,000
			Scope sites for potential water storage tanks and dip tanks/reservoir	Staff & mgmt. costs only
			Install water storage and dip tanks for use during wildfire suppression activities	TBD
			Implement fuelbreak/firebreak installation and maintenance projects along state highway corridor (#377), around common ignition sites, and proposed access points and other potential high use areas.	$10K/year
			Explore feasibility of managed grazing and fuel treatments to along state highway and makai parcels to limit potential fire spread and severity	Staff & mgmt. costs only
		Public education and outreach	Participate in specific target outreach activities as appropriate based on fire preparedness levels.	Staff & mgmt. costs only
			Post Smokey Bear fire prevention signs at entrances/access point of Kahikinui FR during high fire preparedness level.	Staff & mgmt. costs only
	Monitor weather conditions	Install Remote Automated Weather Station (RAWS)	Seek out funds to purchase and install RAWS unit	$25K
			Annual maintenance of RAWS	$5K/year

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Use data to determine district fire preparedness levels	Implement fire preparedness level activities	Staff & mgmt. costs only
		Use data to monitor environmental conditions relating to forest health	Implement appropriate forest management activities	Staff & mgmt. costs only
	Forest Health	Forest health monitoring and implementation of forest management practices	Conduct monthly forest health surveys. Compose and submit annual survey report to Forest Health Coordinator.	Staff & mgmt. costs only
			Rapid response to mitigate forest health issue.	Staff & mgmt. costs only
		Rapid ʻŌhiʻa Death (ROD) Early Detection and Management	Collaborate with partners to secure essential technical information and understanding of the threat	Staff & mgmt. costs only
			Assist and collaborate with partners to secure new information on mode of transmission	Staff & mgmt. costs only
			Conduct aerial surveys and trail user information surveys for early detection quarterly, or as needed.	$10K/year
			Based on the results of the aerial survey, notify landowners and request access and or work with landowner to collect samples to test for ROD	TBD
			Document and report any sightings of dead or dying ʻōhiʻa trees in the field during routine operations	TBD
			Adopt sanitation procedures proven to be effective	$1K/year

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Implement biosecurity measures in the event that ROD is detected in Maui Nui, including rapid response to contain and eradicate	Staff & mgmt. costs only
			Include ROD sanitation and prevention procedures in all permits designated for Kahikinui FR	Staff & mgmt. costs only
		Increase public information and awareness for Rapid ʻŌhiʻa Death	Continue to participate in outreach activities targeting ROD	$5K/year + staff costs
	Cultural Resource Protection	Increase understanding of cultural resources in need of protection	Collect data from the community in order to better protect cultural resources	Staff & mgmt. costs only
		Increase biocultural landscape-based planning and management	Revise planning documents based on climate change data	Staff & mgmt. costs only
			Articulate the value of culturally significant habitats (especially for cultural resource improvement)	Staff & mgmt. costs only
		Prioritize and pair habitat restoration with cultural resource management	Restore culturally significant habitats from mauka to makai (e.g., loʻi, forests, beaches)	TBD
		Protect cultural practices (e.g., fishing, gathering, farming, fiber collection and processing)	Protect/create dedicated spaces for cultural practices	Staff & mgmt. costs only
Game Animal Management	Promote public hunting through Chapter 122, HAR and implement game bird management actions as provided in the PR Game Management Plan (2016)	Provide hunter access	Acquire land and/or easements. Work with lease holders of State land for access. Work with DHHL, through Haleakalā National Park to access through the upper portions of DHHL land.	$15K staff cost

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Review existing long term strategic goals set by the DOFAW Management Guidelines	Evaluate every five years	Staff & mgmt. costs only
		Public education	Continue hunter education program, other public outreach as required	$2K staff cost and materials
		Regulate hunting as per Chapter 122, HAR	Manage bird hunting seasons.	Staff & mgmt. costs only
			Sustain game bird populations: construct, maintain, and inspect game bird water units (below fenced units only)	$5000/year
T&E Species Management	Protection and recovery of listed rare plants and animals	Implement management and recovery of T&E species consistent with management guidelines and applicable recovery and management plans	PEPP staff and state botanists to conduct botanical survey.	Staff & mgmt. costs only
			Conduct surveys and monitoring efforts to obtain baseline data that will be used to help determine specific areas and to protect species of interest	Staff & mgmt. costs only
		Cooperate with PEP, USFWS and other rare plant agencies to prioritize rare plant species protection	Build fence and maintain exclosures around wild populations of rare plants. Outplant T&E species into exclosures. Conduct predator and ungulate control as needed.	$10K each
		With assistance from MFBRP, MNSRP, SEP, USFWS and other agencies prioritize endangered wildlife species protection	Build and maintain exclosures around wild populations of rare animal species. Conduct predator and ungulate control as needed.	$10K each

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Continue ongoing monitoring, surveys for presence, location, and population estimates of rare birds including seabirds (Hawaiian petrel) and nēnē	$10K/year
			Acoustic monitoring of ʻŌpeʻapeʻa at years 5, 10, 15, and 20 after the start of habitat restoration activities.	$70K/cycle
			Inspect and maintain existing fence exclosure twice per year or as needed. Conduct predator and ungulate control as needed.	$5K and Staff & mgmt. cost.
			Devise and implement predator control strategy. Install predator control traps (A24) maintain and monitor	$10K/year
		Assisted colonization to restore rare species	Identify and prioritize suitable habitat for release of rare species. Incorporate climate change scenarios into the decision making process.	Staff & mgmt. costs only
			Protect and prepare habitat for rare species introduction by increasing habitat quality and reducing threats (e.g., predators, invasive species, human disturbance)	$20k/year
			Release rare species into suitable habitat and monitor survival, dispersal, reproductive success, abundance, and genetic diversity	$20k/year
Native Ecosystems	Determine landscape level needs	Native ecosystem restoration.	Common native outplanting	$10K/acre

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Actively restore high-priority sites inside the fence, considering surrogate species that may be tolerant of future climate conditions	$10k/year
			Identify a good existing seed bank and allow for natural regeneration of native vegetation	$10k/year
	Re-evaluate and revise DOFAW's 2001 Draft Management Guidelines Vegetation Resource classifications (not included in this plan because update was not yet completed).	Consult with USFWS, TNC, HDOA, EMWP, LHWRP, and other agencies	Work with other agencies and institutions to identify research projects that would address native species management needs specific to FRs	Staff & mgmt. costs only
		Modify boundaries for vegetation classes in updated Management Guidelines	Participate in DOFAW's planning meetings to update Management Guidelines	Staff & mgmt. costs only
	Ungulate control	Remove ungulates from remote, inaccessible areas; unit areas located within ungulate proof fences designated for zero tolerance	Ground control and aerial control work as needed	TBD
	Climate change adaptation	Anticipate and facilitate habitat migration	Conduct a cost-benefit analysis for a range of management alternatives based on climate change vulnerability assessments and prioritization processes	Staff & mgmt. costs only
			Use common garden experiments (outplanting along elevational/moisture gradient) to identify species applicability under changing climatic conditions.	TBD

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Prioritize the planting of native species that thrive in a wide variety of conditions (e.g., generalists, resilient native/endemic species)	Staff & mgmt. costs only
			Outplant native species to create habitat and facilitate biome shift.	$100k/ year
			Monitor abundance of native and invasive species as temperature rises and precipitation changes.	Staff & mgmt. costs only
			Map transitional areas between different habitats (ie. mesic to dry) to identify and prioritize protection for areas that may transition to a drier habitat.	$10k/year
		Improve silvicultural practices for priority species	Improve seed storage capacity, seed propagation methods, and silvicultural planting methods (i.e. seed collection, composition, spacing)	$10k/year
			Consider climate projections in the timing and seasonality of planting to promote natural recruitment	Staff & mgmt. costs only
	Monitoring	Survey and monitor native species richness and diversity to establish baseline and track long-term trends.	Establish animal surveys using ground and aerial methods.	$10K/year
Invasive Species Control	Reduce the impact of invasive species/noxious weeds on the Forest Reserve and surrounding areas	Continue to work with cooperating agencies, including MISC, TNC, NRCS, HDOA, UH-CTAHR, EMWP, LHWRP, USFWS, and other cooperators	Invasive species technician and support staff to work with cooperators to monitor and control invasive species in the FR	$125K/ year
			Improve data sharing within and between agencies	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Prioritize invasive plant removal, focusing on areas with high diversity or rare species	Staff & mgmt. costs only
		Support biological control efforts in FR and adjacent lands	Support applied research for potential biocontrol agents, including labor and helicopter time	TBD
		Conduct research to support adaptive policies and technology that increase landscape-level protection and restoration	Research and develop new/improved methods of small predator control	Staff & mgmt. costs only
			Research and develop new/improved methods of weed control	Staff & mgmt. costs only
		Create "weed free" buffer corridor between Kula FR/Kahikinui FR (Papaanui Tract) and leeward Haleakalā watershed area (DHHL and Haleakalā National Park)	Conduct aerial and ground surveys	$20K/year
			Conduct aerial and ground control work to remove invasive species from area and prevent further spread to leeward Haleakalā	$50K/year
	Manage incipient and established invasive plants and animals	Invasive species monitoring and control	Collaborate and support partner research and invasive species control	$50K/year
			Manual, chemical and mechanical control.	$50K/year
			Write a comprehensive weed plan	$5K
	Biosecurity	Prevent introduction of invasive insects, plants, and animals, new diseases and pathogens by increasing biosecurity controls	Implement quarantines, intraisland policies, optional vs. mandatory restrictions.	Staff & mgmt. costs only
Access, Trails, and other Public Uses	Secure public access to the FR	Create, maintain and update (as needed) historical access agreements with adjacent landowners. Create new access as needed.	Meet with DHHL and neighboring land owners and lease holders to formalize agreement as appropriate for Kahikinui FR access	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
	Increase public information and awareness	Install informational signage	Sign installation as needed	$10K/year + staff costs
	Infrastructure management and construction	Create and maintain trails, cabins and other trail infrastructure in accordance to NAH program standards and plans, as proposed in the Kahikinui Forest Restoration EA	Update permits and get BLNR approval. Determine trails and cabin location. Construct features.	$600K
			Identify cabin locations and complete necessary documents for construction	Staff & mgmt. costs only
			Develop, maintain and repair trails, shelters and parking areas.	TBD
			Conduct risk assessment for all trails to determine mitigation needs	
			Provide public with covered rest area for day and extended overnight trips	
		Increase enforcement of Forest Reserve Rules and applicable HAR to protect DOFAW infrastructure.	Secure additional funding for additional night time survey and patrol.	$30K/year
		Climate change adaptation	Adjust the timing of actions (e.g. open/close dates, road or trail closures, food storage orders, special use permits) to accommodate changing climate conditions	Staff & mgmt. costs only
Commercial Activity	Generate income from suitable commercial activities in the Forest Reserve to supplement funding of natural resource management activities	Determine future income possibilities of low-impact sustainable activities including but not limited to commercial tour permits, collection and commercial harvest permits and film industry.	Determine protocol to manage fee collection	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Explore ecosystem services revenue streams	Carbon sequestration: Certified carbon offset market. Certification of Kahikinui FR reforestation projects under a Voluntary Carbon Standard.	$250K

5.4 Overall Measures of Success:

Measures of success for individual forest reserve management plans can be derived from the State of Hawai'i annual variance reports. Initial measures of success that may be applicable to Kahikinui include:

- Acres of invasive plants controlled
- Number of invasive animals removed
- Acres of fire protection area
- Miles of fence maintained
- Acres of native forest restored
- Number of native plants planted
- Survivorship of outplantings
- Number of rare, threatened, or endangered plant/animal species protected
- Number of cultural resources protected
- Number of volunteer service projects
- Metric tons of carbon sequestered
- Revenue generated from sale of carbon offset credits
- Amount of funds leveraged through competitive grant writing

6. FUTURE RECOMMENDATIONS

6.1 Desired Outcome for the Forest Reserves:

- Protection and enhancement of watershed quality and quantity.
- Continued maintenance of existing ungulate proof fencing and forest restoration areas.
- Extend ungulate proof fencing and restorations efforts downslope to revegetate and decrease soil erosion.
- Stable to increasing populations of threatened and endangered species.
- Healthy native ecosystems.
- Protection of cultural resources.
- Negotiate cooperative agreements with neighboring landowners to secure management and public access in perpetuity.
- Sustainable harvest level of game birds.

- Development of alternative revenue opportunities to support the management needs of the forest reserve.

6.2 Future Recommendations

- Continue to pursue land acquisitions to increase area for watershed protection, natural resource conservation and public hunting.
- Long term funding sources are needed to support fire mitigation projects such as the installation of water/dip tanks to support aerial fire suppression; fuel mitigation along access corridors; and the development of landscape fuel reduction projects.
- Develop alternative funding opportunities that support forest management and sustainable use, such as carbon offset credits or other ecosystem services markets.
- Enhance district forestry program capacity of personnel and equipment resources to ensure successful implementation of management plans.
- Re-assess feasibility of proposed network of trails and cabins outlined in the 2012 environmental assessment.
- Develop and implement spatially explicit management plans for endangered species recovery efforts in the Forest Reserve.
- Develop and implement monitoring methods to establish a baseline and track trends of species richness and diversity.

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8. APPENDICES

Appendix A: NRCS SSURGO Soil Map Unit Descriptions
Appendix B: Botanical and Faunal Survey Kahikinui Forest Reserve, Maui
Appendix C: State of Hawai‘i Wildlife Action Plan Species Profiles
Appendix D: Invasive Plant Species Profiles
Appendix E: Hawaiian Islands Climate Vulnerability and Adaptation Synthesis (pp. 46-65)
Appendix F: DOFAW Management Guideline Classification Definitions

Island of Maui, Hawaii

rVS—Very stony land

Map Unit Setting

National map unit symbol: hqcx
Elevation: 0 to 13,000 feet
Mean annual precipitation: 10 to 150 inches
Mean annual air temperature: 39 to 73 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

Very stony land and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Very Stony Land

Setting

Landform position (two-dimensional): Summit
Landform position (three-dimensional): Mountaintop
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Aa lava and volcanic ash

Typical profile

H1 - 0 to 10 inches: extremely stony very fine sandy loam
H2 - 10 to 60 inches: cobbles

Properties and qualities

Slope: 7 to 30 percent
Depth to restrictive feature: 40 to 60 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 15, Oct 3, 2017

Island of Maui, Hawaii

PZVE—Puu Pa very stony silt loam, 7 to 40 percent slopes

Map Unit Setting

National map unit symbol: hqb8
Elevation: 1,000 to 2,500 feet
Mean annual precipitation: 15 to 35 inches
Mean annual air temperature: 68 to 72 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

Puu pa, very stony, and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Puu Pa, Very Stony

Setting

Landform: Mountain slopes
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Volcanic ash

Typical profile

H1 - 0 to 6 inches: very stony silt loam
H2 - 6 to 40 inches: very stony silt loam
H3 - 40 to 50 inches: cobbles

Properties and qualities

Slope: 7 to 40 percent
Percent of area covered with surface fragments: 1.3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 15, Oct 3, 2017

Island of Maui, Hawaii

rRO—Rock outcrop

Map Unit Setting

National map unit symbol: hqcr
Elevation: 0 to 10,000 feet
Mean annual precipitation: 10 to 175 inches
Mean annual air temperature: 45 to 75 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

Rock outcrop: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rock Outcrop

Typical profile

H1 - 0 to 60 inches: bedrock

Properties and qualities

Slope: 5 to 99 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Capacity of the most limiting layer to transmit water (Ksat): Low to moderately low (0.00 to 0.06 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s
Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 15, Oct 3, 2017

BOTANICAL AND FAUNAL SURVEY
KAHIKINUI FOREST RESERVE, MAUI

Prepared By:
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Prepared For:
DIVISION OF FORESTRY AND WILDLIFE
DEPARTMENT OF LAND AND NATURAL RESOURCES

2018

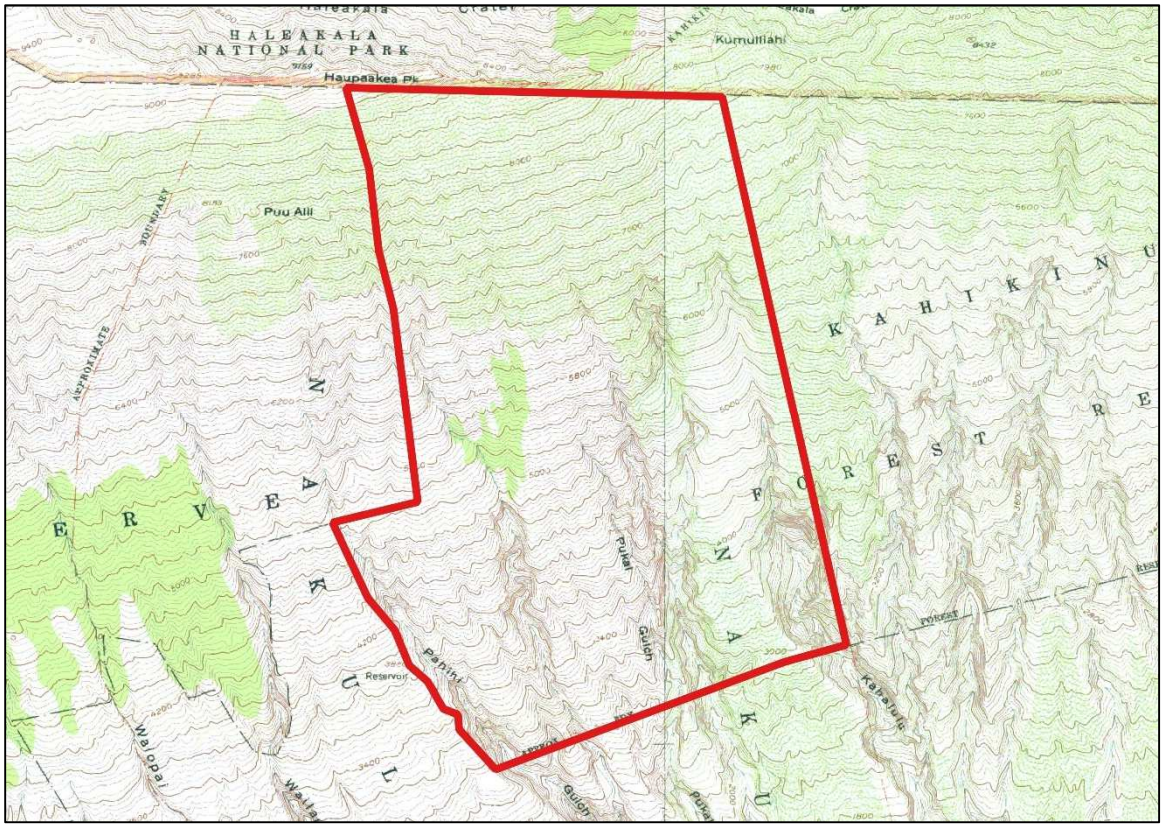
BOTANICAL AND FAUNAL SURVEY
KAHIKINUI FOREST RESERVE, MAUI

INTRODUCTION

The Kahikinui Forest Reserve encompasses about 2,200 acres, part of TMK 180010060000. The project area is on the south slope of East Maui. Haleakala National Park Crater District marks the mauka (upslope) boundary, Nakula Natural Area Reserve, leased State property, and Haleakala Ranch are to the west, leased State property is on the makai (downslope) boundary, and Haleakala National Park Nuu Section is to the east. The goal of this survey was to inventory the flora and fauna in the area, to provide current information to be included in a management plan for the reserve.

SITE DESCRIPTION

The project area is the Kahikinui Forest Reserve. The land is steep. In many places, too steep to readily access. Much of the lower elevations of the reserve are unvegetated. In areas that have plants, vegetation is dominated by grassland and remnant native forest and shrubland. There are many gullies that dissect the land. In the lower elevations of the reserve, these gullies converge to form large gulches. The project elevation ranges from 2,500 to 9,000 feet above sea level. Annual rainfall averages 45-55 inches. Annual air temperature averages 45-65 degrees Fahrenheit.



Project area, Kahikinui Forest Reserve, Maui.

BIOLOGICAL HISTORY

The original vegetation on the site would have ranged form a diverse dryland forest in the lower elevations, through mesic forest at the middle elevations, to subalpine shrubland at the highest elevations.

Typical dry forest canopy species would have included halapepe (*Chrysodracon auwahiensis*) and olopua (*Nestegis sandwicensis*). Mesic forest areas would have been dominated by koa (*Acacia koa*) and ohia (*Metrosideros polymorpha*) trees. Pukiawe (*Leptecophylla tameiameiae*) and mamane (*Sophora chrysophylla*) would likely have been prevalent in the subalpine region.

After the arrival of humans, a series of forces including fire, agriculture, forestry, and introduced plants, animals, and diseases transformed the site to predominantly non-native vegetation in the lowest reaches, grading to more native dominated vegetation in the highest elevations. Given the remote location and rugged terrain, the land has not seen many uses over the years, mostly ranching, hunting, and hiking.

SURVEY OBJECTIVE

The main objectives of the survey were to:

- Document what plant (terrestrial vascular flora) and animal (birds, bats, mammals, insects) species occur in the reserve or may likely occur in the existing habitat.

- Write up findings in a report that includes checklists of species, along with images and discussion of some of the more conspicuous and noteworthy elements of the flora and fauna in the reserve.

Typical cloudy/foggy conditions that occur over much of Kahikinui Forest Reserve.

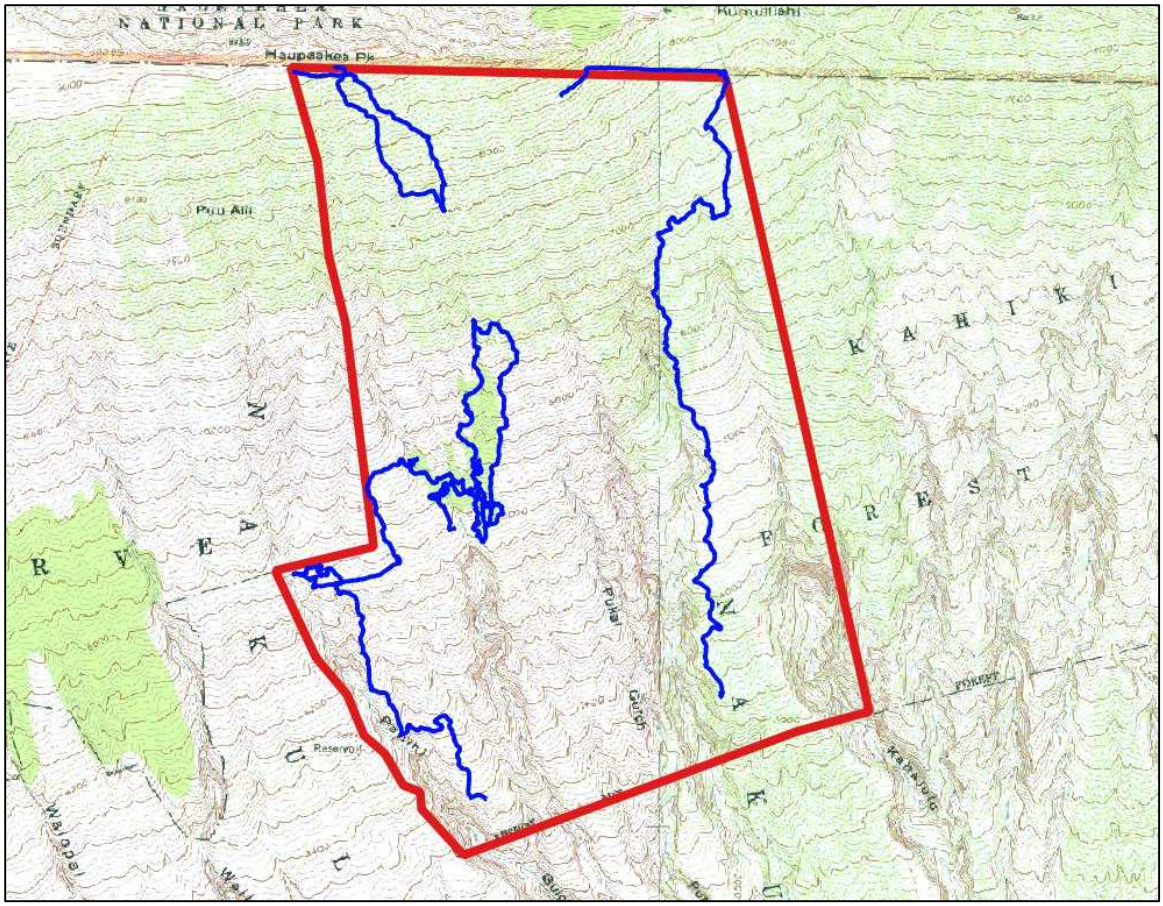
BOTANICAL SURVEY

SURVEY METHODS

A walk-through botanical survey method was used over representative areas of the reserve. Extra emphasis was placed on areas with high diversity, such as moist steep gullies with tree canopies and other pockets of remnant native plants. Binoculars were used to survey areas too steep to survey on foot. Notes were made on plant species, distribution and abundance.

The reserve was surveyed in February and March of 2018.

Taking notes on flora and fauna, Kahikinui Forest Reserve.



Area surveyed (blue lines).

Surveying vegetation in Kahikinui Forest Reserve.

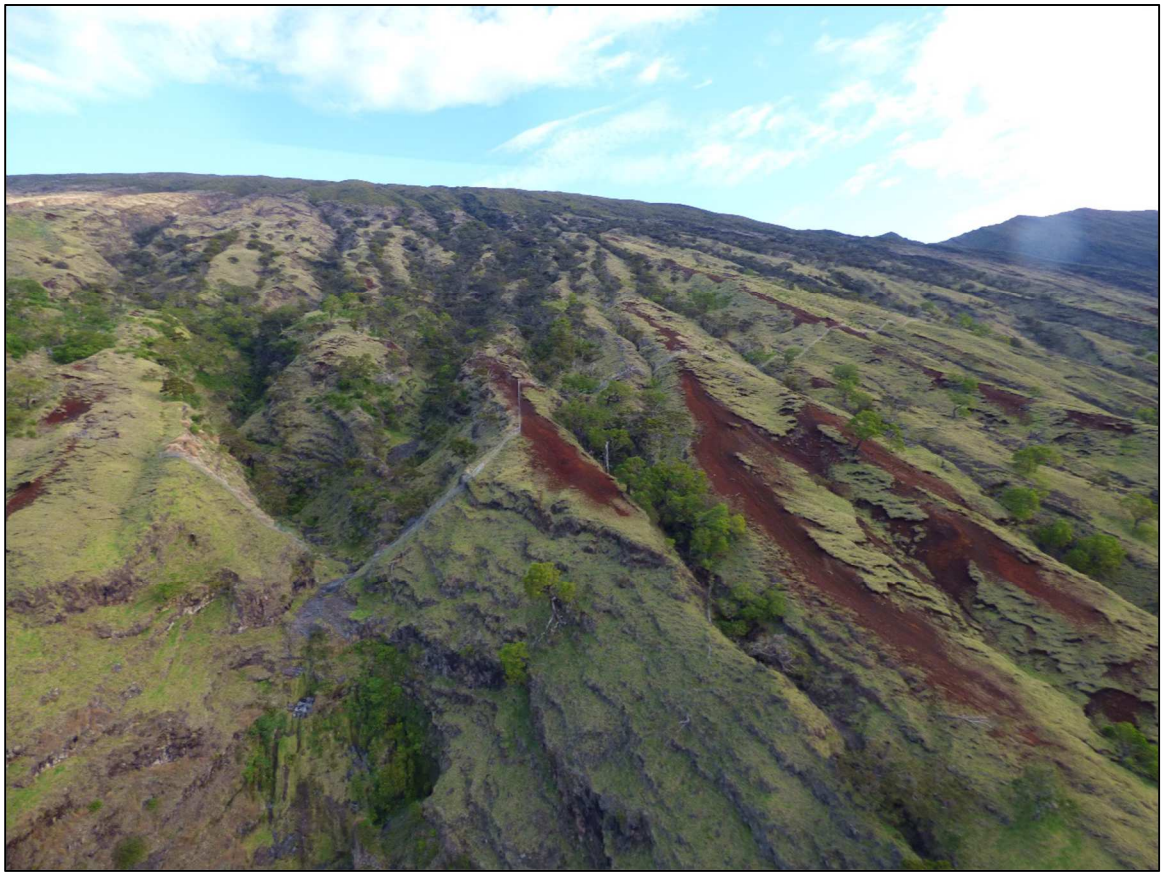
DESCRIPTION OF VEGETATION

There is a range of vegetation types within the Kahikinui Forest Reserve.

Dry Forest & Grassland: The lowest elevations, from 2,500-5,000 ft. are below the fenceline. These areas are heavily impacted by goats and pigs, and are vegetated with mostly non-native grasses, herbs, and shrubs, along with a few remnant native dry forest shrubs and trees. The area contains steep gulches and numerous erosion scars of bare dirt.

Mesic Forest & Grassland: A fenceline runs across the reserve at about the 5,000 ft. elevation. Areas above the fenceline have more vegetation, have recently been released from ungulate pressure, and are quickly regenerating. From 4,500-6,500 ft. tall ohia dominates in gullies, and the ridges are mostly native and non-native grasses. In this section, from 4,500-5,500 ft. koa is dominant in some areas. This koa zone is currently the area of highest plant diversity and the wettest part of the reserve.

Subalpine Shrubland: Above 6,500 ft. ohia trees transition to pukiawe and other subalpine shrubs, grasses, and ferns. At the top of the reserve, at 9,000 ft., the climate becomes drier and colder and the vegetation becomes sparse and short. Most of the vegetation in this zone is native.



Core of remnant forest in Kahikinui Forest Reserve. Area from ~4,500-7,500 ft. visible.

PUKIAWE SHRUBLAND (6,500-9,000 ft.)

Pukiawe (*Leptecophylla tameiameiae*) and ohelo (*Vaccinium reticulatum*) dominate the highest elevations of the subalpine section of the reserve.

The highest elevations of the Kahikinui Forest Reserve, 6,500-9,000 ft. are dominated by a pukiawe (*Leptecophylla tameiameiae*) shrubland. This area is colder and drier than the forested areas in the mid-elevations. It's also generally above the inversion layer, resulting in higher solar radiation. Most of the vegetation in this zone is native.

The upper reaches of the pukiawe shrubland have sparse and short vegetation. As one descends in elevation, the vegetation becomes taller. Eventually ohia (*Metrosideros polymorpha*) trees appear in gullies and the pukiawe starts to become less prevalent. At around 6,500 ft., the top of the inversion layer, a transition takes place from the pukiawe shrubland to ohia forest.

Small ohelo shrubs (*Vaccinium reticulatum*) are abundant in the highest elevations of the pukiawe shrubland. Other native shrubs in this area include pilo (*Coprosma montana*), aalii (*Dodonaea viscosa*), kukaenene (*Coprosma ernodeoides*), ulei (*Osteomeles anthyllidifolia*), kupaoa (*Dubautia menziesii*) and mamane (*Sophora chrysophylla*).

The Haleakala Silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) is found in the upper most reaches of the pukiawe shrubland, as is the native pamakani or Haleakala tetramolopium (*Tetramolopium humile* subsp. *haleakalae*).

Non-native herbs and low growing plants in the pukiawe shrubland include fireweed (*Senecio madagascariensis*), bull thistle (*Cirsium vulgare*), hairy horseweed (*Conyza bonariensis*), pamakani (*Ageratina riparia*, *A. adenophora*), hairy cat's ear (*Hypochoeris radicata*), scarlet pimpernel (*Anagalis arvensis*), and gamochaeta (*Gamochaeta* sp.).

Native grasses are predominantly hairgrass (*Deschampsia nubigena*), bentgrass (*Agrostis sandwicensis*), and pili uka (*Trisetum glomeratum*). Native sedges (*Carex wahuensis* and *C. macloviana*) and wood rush (*Luzula hawaiiensis*) are also present.

Non-native grasses include Sweet vernal grass (*Anthoxanthum odoratum*), Yorkshire fog (*Holcus lanatus*), rat tail fescue (*Festuca myuros*), and Tasmanian wallaby grass (*Rytidosperma semiannulare*).

Native ferns in the upper portion were mostly kalamoho (*Pellaea ternifolia*), maidenhair spleenwort (*Asplenium trichomanes* subsp. *densum*), and kilau or bracken fern (*Pteridium aquilinum* subsp. *decompositum*). In the lower ohia gulches additional native ferns included amau (*Sadleria cyatheoides*), polystichum (*Polystichum haleakalense*) and laukahi (*Dryopteris wallichiana*).

Non-native ferns present include golden fern (*Pityrogramma austroamericana*) and rough maidenhair fern (*Adiantum hispidulum*).

All of these species have been under browsing pressure from goats for quite some time. Now that the area has been fenced and ungulates removed, it is anticipated the vegetation will begin recovering, as has happened in nearby Haleakala National Park.

Pukiawe (*Leptecophylla tameiameiae*) is the dominant plant within the subalpine shrubland zone.

Pilo (*Coprosma montana*) is not common anywhere in the reserve, being restricted to areas that received the least ungulate browsing.

Hairgrass (*Deschampsia nubigena*) clumps among kilau or bracken fern (*Pteridium aquilinum* subsp. *decompositum*) and a mat-forming kukaenene (*Coprosma ernodeoides*).

Haleakala silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) reside in the subalpine zone of the reserve. Now that the area is fenced, this species may increase in abundance.

In the middle of the pukiawe shrubland the vegetation gets taller and pukiawe dominates.

Near the bottom of the shrubland ohia trees line gulches and native shrubs become less abundant.

MESIC OHIA FOREST & GRASSLAND (5,500-6,500 ft.)

Transition zone between the mauka extent of ohia forest and the makai edge of pukiawe shrubland.

From about 4,800-6,500 ft. elevation, tall ohia (*Metrosideros polymorpha*) dominates in gullies, and the ridges and understory are mostly covered in grasses. The ohia trees begin to show up in the pukiawe shrubland, as high as 7,600 ft. At around 6,500 ft., at the top of the inversion layer, there is an abrupt change as pukiawe quickly becomes less common and ohia begins to dominate. The ohia continues to be the most common tree in the forested areas to about 4,800 ft. At about 5,500 ft., koa becomes prevalent. Areas below 5,000 ft. are not fenced, and there are much less ohia and other trees below the fence.

Red, orange, and yellow ohia flowers blooming in the Kahikinui Forest Reserve.

The mesic ohia forest and grassland is typified by steep gullies filled with tall ohia trees with a grass understory, and nearby grassy ridges.

Virtually all the trees in this zone are ohia. Both the furry (var. *incana*) and glabrous (var. var. *glaberrima*) leaved forms of ohia are present. The only other species encountered in this zone that achieves tree form is kolea (*Myrsine lessertiana*). A few tall kolea were occasionally found in the middle of the stone gullies.

Mamane (*Sophora chrysophylla*) was observed in limited numbers, but never achieved tree status. A favorite of goats, perhaps it will become more common now that ungulates have been removed.

Native shrubs in this zone are mostly pukiawe (*Leptecophylla tameiameiae*) and ohelo (*Vaccinium reticulatum*), but also include pilo (*Coprosma montana*), kupaoa (*Dubautia platyphylla*), and aalii (*Dodonaea viscosa*).

Also found in low numbers are alaala wai nui (*Peperomia cookiana*) and opelu (*Lobelia hypoleuca*), generally in moist areas on steep cliffs and rock bands.

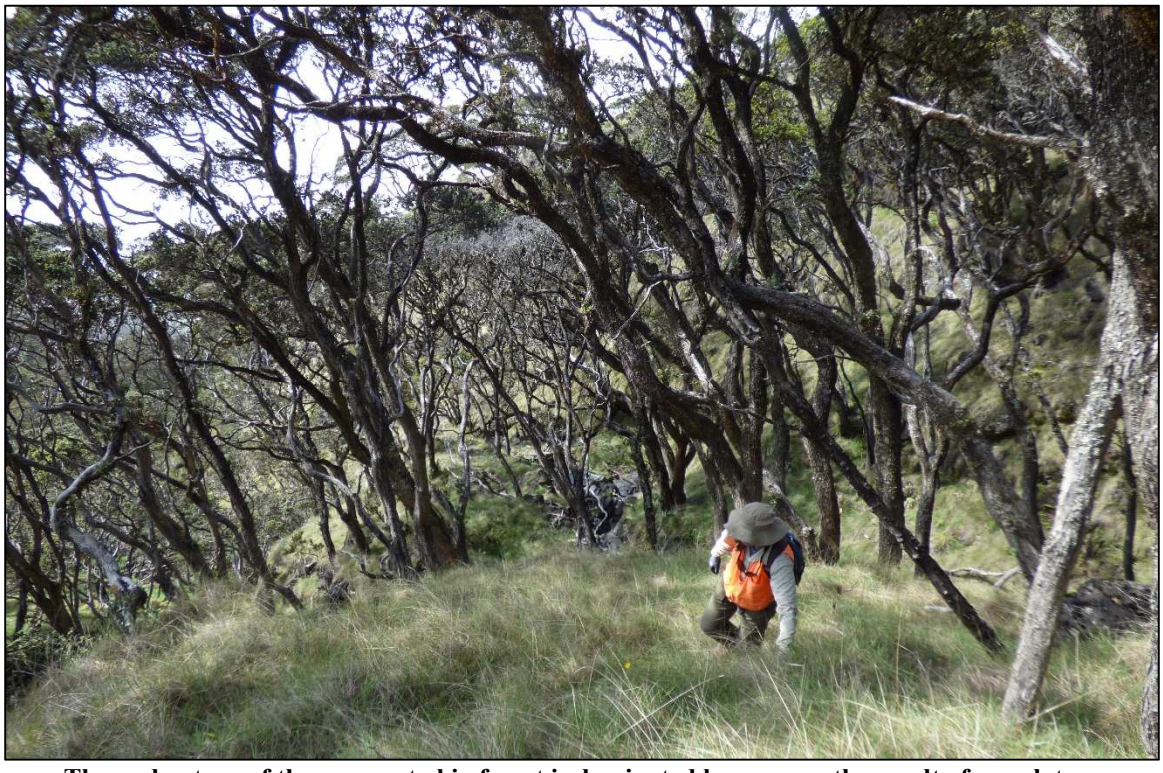
Non-native shrubs and herbs include pamakani (*Ageratina riparia* and *A. adenophora*) and hairy cat's ear (*Hypochoeris radicata*).

Native hair grass (*Deschampsia nubigena*) is dominant in the ohia understory and over many of the ridges. Non-native grasses in this zone include sweet vernal grass (*Anthoxanthum odoratum*) and Yorkshire fog (*Holcus lanatus*), Tasmanian wallaby grass (*Rytidosperma semiannulare*), and violet crab grass (*Digitaria violascens*).

The common native ferns in this zone include bracken fern (*Pteridium aquilinum* subsp. *decompositum*), found virtually anywhere, and makue (*Elaphoglossum paleaceum*) and amau (*Sadleria cyatheoides*) on rock bands in the moist, steep gulches.

Ohia leaf duff. Kahikinui Forest Reserve.

In some areas there is a closed ohia canopy. In most areas of the reserve it is somewhat open.



The understory of the remnant ohia forest is dominated by grasses, the result of ungulates.

Most of the less common native plants are restricted to moist cliff habitat within steep gullies.

The ridges between the steep gullies are dry, open and dominated by grasses.

Kolea (*Myrsine lessertiana*), one of the only other tree species in the ohia forest zone.

Opelu (*Lobelia hypoleuca*) is occasionally found hanging off moist cliffs.

***Elaphoglossum paleaceum* is common under the ohia canopy, growing on rock cliffs.**

MESIC KOA/OHIA FOREST & GRASSLAND (4,500-5,500 ft.)

Upper extent of koa forest, at about 5,500 ft. elevation. Recently planted koa in foreground. Belt of remnant koa forest in distance.

From about 4,500-5,500 ft. koa becomes dominant in some areas. This is currently the zone of highest plant diversity and the wettest part of the reserve, receiving thick fog/clouds on most days. The area has recently been fenced and the plants have been released from ungulate pressure. Many areas of koa and other plants are quickly regenerating. Additionally, a significant planting effort has been undertaken.

Koa flower buds and leaves.

In the mesic koa/ohia forest and grassland zone, ohia is again dominant in gullies, but increasingly shares dominance with koa (*Acacia koa*). Koa is regenerating from root suckers and plantings, after the area was fenced and ungulates removed.

The understory of the forested areas is mostly grass, with some diversity in the steepest, rockiest, and moistest areas. Nearby ridges are predominantly grasses with regenerating and planted koa trees. The eastern part of the reserve has very few remaining old koa trees, but the area has been recently planted with young koa trees on the ridges.

A few large kolea trees (*Myrsine lessertiana*) were occasionally observed. As was one kawau (*Ilex anomala*), below the fence. Mamane (*Sophora chrysophylla*) is present, but was a bit more shrub than tree like.

Non-native tree poppy (*Bocconia frutescens*) is present in moist gulches on the western edge of the reserve and in Pukai Gulch. *Bocconia* is established in Wailaulau Gulch in nearby Nakula NAR and is possibly spreading from there into Kahikinui Forest Reserve.

Shrubs in the mesic koa-ohia forest zone include pilo (*Coprosma montana* and *C. foliosa*), kupaoa (*Dubautia platyphylla* and *D. plantaginea*), mamaki (*Pipturus albidus*), hinahina (*Artemisia mauiensis*), lysimachia (*Lysimachia remyi*), manono (*Kadua centranthoides*), and opelu (*Lobelia hypoleuca*). Most of these are on steep gulch walls.

Common non-native shrubs and herbs in this area include pamakani (*A. riparia* and *A. adenophora*) and thimbleberry (*Rubus rosifolius*), which occur in patches over much of the area. Also somewhat ubiquitous are Spanish needle (*Bidens pilosa*), lythrum (*Lythrum maritimum*), and cranesbill (*Geranium homeanum*).

Native ferns include amau (*Sadleria cyatheoides* and *C. pallida*), polystichum (*Polystichum haleakalense*), pakahakaha (*Lepisorus thunbergiana*), kaapeape (*Cyrtomium caryotideum*), and palapalai (*Microlepia strigosa* var. *mauiensis*).

Common non-native ferns in the area are deparia (*Deparia petersenii*) and christella (*Cyclosorus parasiticus*), which are abundant in most gullied areas. Australian tree fern (*Sphaeropteris cooperi*) is just starting to take hold in the reserve.

Native hair grass (*Deschampsia nubigena*) is common in this zone. Non-native grasses in this zone include molasses grass (*Melinis minutiflora*), Yorkshire fog (*Holcus lanatus*), (*Andropogon virginicus*), and smut grass (*Sporobolus indicus*).

Native sedges (*Carex wahuensis* and *C. macloviana*) are scattered throughout, as is the native rush (*Luzula hawaiensis*).

The koa/ohia forest zone climatically extends below the fenceline at 5,000 ft. elevation. However, with high number of ungulates in that area, there is very little understory left and the canopy trees are less numerous, in decline, and not reproducing.

Natural regeneration of koa trees after fencing and ungulate removal.

Koa is increasing significantly above the fence, with koa regenerating across the landscape.

One of the richer gullies within the reserve. A number of plant species occur here that were not encountered elsewhere in the reserve, almost all of which were hanging off steep cliffs.

The same relatively rich gully from above. Many of the gulches in this and other areas were too steep to fully survey up close. We used binoculars to see what we could. This same cliffy terrain also minimized the goat browsing, which is likely why there are remnant native plants there today.

Manono (*Kadua centranthoides*). Only one plant of this species was encountered.

A few small patches of Alaala wai nui (*Peperomia cookiana*) are growing out of seeps in rock bands.

Hinahina (*Artemisia mauiensis*) occurs in a few steep cliff sites. Plants that were possibly *A. mauiensis* var. *diffusa* or *A. australis* were observed in a steep gully, but were not inspected up close.

A few patches of *Cyrtomium caryotideum* were encountered in moist sections of cliffs.

Amau (*Sadleria cyatheoides*) is common in many of the moist gully areas.

Ae (*Polypodium pellucidum*) was occasionally observed growing out of cliff faces.

A closed canopy forest is quickly returning to the koa/ohia forest zone above the fenceline.

Below the fenceline, ungulate pressure continues to convert the koa/ohia forest to an open grassland.

DRY FOREST & GRASSLAND (2,500-4,500 ft.)

One of two remnant halapepe trees (*Chrysodracon auwahiensis*) in the dry forest portion.

The lowest elevations of the Kahikinui Forest Reserve, from 2,500-4,500 ft. are below the fenceline. These areas are heavily impacted by goats and pigs, and are vegetated with mostly non-native grasses, herbs, and shrubs, along with a few remnant native dry forest shrubs and trees. The area contains steep gulches, many of which are mostly inaccessible, erosion scars, and vast areas of bare dirt.

Halapepe leaves.

When talking about dry forest and grassland in the Kahikinui Forest Reserve, we're referring more to what was here and what would climatically return if ungulates were removed from the area. Given the high numbers of goats and pigs in the area, most of the dry forest and grassland zone in the reserve is currently grassland or bare dirt.

The few native trees left in the area include scattered ohia and koa, about a dozen olopua (*Nestegis sandwicensis*), two halapepe (*Chrysodracon auwahiensis*), and a lone lama (*Diospyros sandwicensis*) hanging above a steep cliff.

There are also very few non-native trees in this zone. Some Chinaberry (*Melia azedarach*) and Christmas berry (*Schinus terebinthifolius*) trees occur on ridge tops and gulch walls at the lowest elevations. A few kukui nut (*Aleurites moluccana*) are in the bottom of steep gulches at the lowest elevations of the reserve. And a lone silky oak (*Grevillea robusta*) stands tall on a ridge near Pukai Gulch.

A broad band of the lowest reaches of the reserve are dominated by lantana (*Lantana camara*), with an occasional comb hyptis (*Hyptis pectinata*), prickly pear cactus (*Opuntia ficus-indica*), and tree tobacco (*Nicotiana glauca*).

The only native shrubs observed in this zone are aalii (*Dodonaea viscosa*) clinging to cliff faces, and akia (*Wikstroemia monticola*) which was scattered about in the lantana shrubland. The native ephemeral vine anunu (*Sicyos pachycarpus*) had recently germinated and was growing in the lantana thickets.

Non-native herbs and vines present are telegraph weed (*Heterotheca grandiflora*), fireweed (*Senecio madagascariensis*), beggarstick (*Bidens alba* var. *radiata*), chenopodium (*Dysphania carinata*), maile honohono (*Ageratum conyzoides*), and white passion vine (*Passiflora subpeltata*).

Kikuyu (*Cenchrus clandestinus*) and smut grass (*Sporobolus indicus*) dominate grass covered areas of this zone, along with Henry's crab grass (*Digitaria ciliaris*).

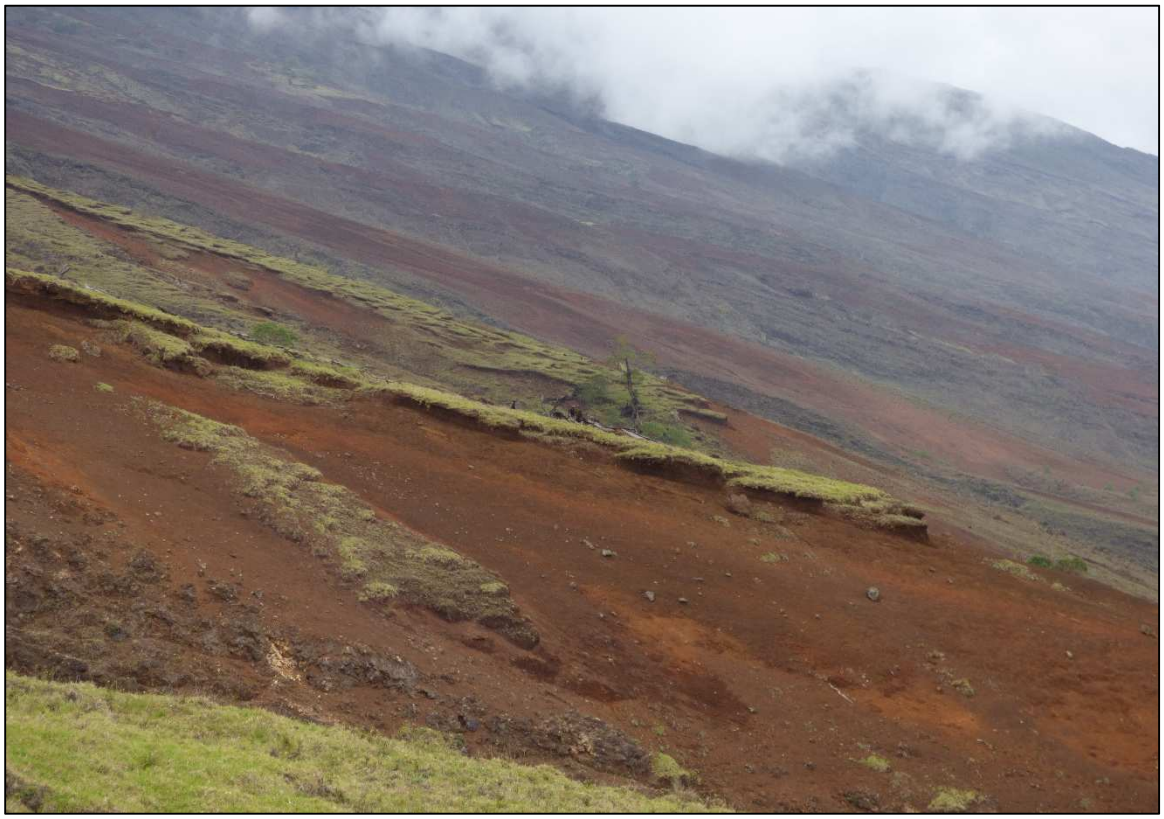
In many areas there is no vegetation, just vast areas of bare dirt and stone, presumably the result of overgrazing by feral ungulates.

Native anunu vine (*Sicyos pachycarpus*) in lantana thicket at bottom of reserve.

Two of about a dozen remnant olopua (*Nestegis sandwicensis*) trees in the dry forest and grassland section of the reserve. Similar areas elsewhere have been referred to as "olopua graveyards".

Olopua (*Nestegis sandwicensis*) is usually one of the last dry forest trees to disappear from an area. It is still present in the reserve, as a few old large dying trees. But there is no regeneration occurring.

Lantana shrubland with Christmasberry (*Schinus terebinthifolius*) tree in lowest reaches of reserve.



Severely eroded lower part of the reserve with bare soil, from about 3,000-5,000 ft. elevation.

The eastern part of the reserve has vast unvegetated areas of nothing but dirt and stones.

Vegetation remnants showing the large amounts of soil that have been lost to erosion.

INCIPIENT WEEDS

There are surprisingly few aggressive weed species in the Kahikinui Forest Reserve. A few notable species that are invasive elsewhere, yet were found to currently be in low numbers within the reserve are tree poppy (*Bocconia frutescens*), Australian tree fern (*Sphaeropteris cooperi*), and silky oak (*Grevillea robusta*).

Australian tree fern and tree poppy have small populations in the lower part of the koa/ohia belt, especially in gullies. One silky oak tree was observed on a ridge in the dry forest section. Further surveys would likely result in additional locations. These species will also likely continue to arrive in the reserve from nearby areas.

Tree poppy (*Bocconia*) is an aggressive invader of dry forest to mesic areas. It is well established over much of the South Slope, including the steep gullies of nearby Wailaulau Gulch in Nakula NAR.

Australian tree fern has windblown spores and is able to colonize remote moist locations.

PLANT PATHOGENS

Native and non-native pathogens were observed in the Kahikinui Forest Reserve. What appears to be the native koa gall rust (*Atelocauda digitata*) was in multiple locations, showing the characteristic brown powdery fungal spore masses on leaves and deformed branch tips. Slight damage to ohia leaves from what appeared to be non-native ohia rust (*Puccinia psidii*) was observed, some of which showed yellow fungal spore masses.

Rapid ohia death (*Ceratocystis* spp.) is killing vast areas of ohia trees on the Big Island, with locations as close to Kahikinui as the Kohala Mountains. Thankfully no signs of rapid ohia death were observed. If rapid ohia death were to arrive to the reserve, the main hope would be that some of the ohia strains in the area would show resistance.

Some koa leaves were yellowing in a pattern we hadn't seen before. The cause of the chlorotic koa leaves is unknown, perhaps a nutrient deficiency, sucking insect, or pathogen. This damage is not widespread in the reserve. If the damage from this or other plant disorders was found to be increasing in distribution or severity, additional research may be warranted to determine the cause.

Rust on koa leaf, possibly gall rust (*Atelocauda digitata*).

Possible ohia rust (*Puccinia psidii*) on ohia leaf.

Chlorotic koa leaf from unknown cause, perhaps a nutrient deficiency, sucking insect, or pathogen.

RESTORATION

The Kahikinui Forest Reserve has been heavily impacted by ungulates and other forces over the years. A recent increase in efforts to protect and restore the forests in the area through fencing and planting is showing tremendous progress and success. As the native plants return, so too will the native animals that rely on them.

Plants found in the reserve only in plantings included iliahi (*Santalum haleakalae* var. *haleakalae*) and pilo (*Coprosma ochracea*).

Despite the difficult terrain, fencing and removal of ungulates is working well to stimulate natural regeneration of koa and other native plants.

Along with fencing, a lot of planting is occurring. The plantings are doing well, adding diversity to the area and stimulating regeneration of the forest.

PLANT SPECIES LIST

Following is a checklist of all vascular plant species inventoried during field studies.

For each species, the following information is provided:

- Family, Scientific, and Common names.

- Bio-geographical status / nativity:
  - Endemic = Native to Hawaii; not naturally occurring anywhere else in the world.
  - Indigenous = Native to Hawaii and also to one or more other geographic area(s).
  - Non-native = Brought to Hawaii intentionally or accidentally by humans.

- Abundance of each species within the project area:
  - Dominant = Forming a major part of the vegetation within the project area.
  - Common = Widely scattered throughout the area or locally abundant within a portion of it.
  - Occasional = Scattered sparsely throughout the area or occurring in a few small patches.
  - Rare = Only a few isolated individuals within the project area.

Glabrous (var. *glaberrima*) and furry (var. *incana*) forms of ohia at Kahikinui Forest Reserve.

PLANT SPECIES LIST

Family	Scientific Name	Common Name	Nativity	Abundance
Fabaceae	*Acacia koa*	Koa	Endemic	Dominant
Pteridaceae	*Adiantum hispidulum*	Rough maidenhair	Non-native	Common
Pteridaceae	*Adiantum raddianum*	maidenhair fern	Non-native	Occasional
Asteraceae	*Ageratina adenophora*	Maui pamakani	Non-native	Common
Asteraceae	*Ageratina riparia*	Hamakua pamakani	Non-native	Occasional
Asteraceae	*Ageratum conyzoides*	Billygoat weed	Non-native	Occasional
Poaceae	*Agrostis sandwicensis*	Bentgrass	Endemic	Occasional
Euphorbiaceae	*Aleurites moluccana*	Kukui nut	Non-native	Rare
Thelypteridaceae	*Amauropelta globulifera*	Palapalai a Kamapuaa	Endemic	Rare
Primulaceae	*Anagallis arvensis*	Scarlet pimpernel	Non-native	Occasional
Poaceae	*Andropogon virginicus*	Broomsedge	Non-native	Occasional
Poaceae	*Anthoxanthum odoratum*	Sweet vernal grass	Non-native	Occasional
Caryophyllaceae	*Arenaria serpyllifolia*	Thyme-leaved sandwort	Non-native	Occasional
Asteraceae	*Argyroxiphium sandwicense* subsp. *macrocephalum*	Ahinahina, Haleakala Silversword	Endemic	Rare
Asteraceae	*Artemisia mauiensis*	Hinahina	Endemic	Rare
Apocynaceae	*Asclepias curassavica*	Butterfly weed	Non-native	Rare
Apocynaceae	*Asclepias physocarpa*	Balloon plant	Non-native	Occasional
Aspleniaceae	*Asplenium adiantum-nigrum*	Iwaiwa	Endemic	Occasional
Aspleniaceae	*Asplenium trichomanes* subsp. *densum*	Maidenhair spleenwort	Endemic	Occasional
Poaceae	*Axonopus fissifolius*	Narrow-leaved carpetgrass	Non-native	Occasional
Asteraceae	*Bidens alba var. radiata*	Beggartick	Non-native	Occasional
Asteraceae	*Bidens pilosa*	Spanish needle	Non-native	Occasional
Blechnaceae	*Blechnum appendiculatum*	Blechnum	Non-native	Occasional
Papaveraceae	*Bocconia frutescens*	Tree poppy	Non-native	Rare
Cyperaceae	*Carex macloviana*	Carex	Indigenous	Occasional
Cyperaceae	*Carex wahuensis*	Carex	Endemic	Common
Cyperaceae	*Carex meyenii*	Meyen's sedge	Endemic	Occasional
Poaceae	*Cenchrus clandestinus*	Kikuyu grass	Non-native	Common
Asteraceae	*Centaurium erythraea* subsp. *erythraea*	Bitter herb	Non-native	Occasional
Caryophyllaceae	*Cerastium fontanum subsp. vulgare*	Mouse-ear chickweed	Non-native	Rare
Araliaceae	*Cheirodendron trigynum*	Olapa	Endemic	Rare
Asparagaceae	*Chrysodracon auwahiensis*	Halapepe	Endemic	Rare
Asteraceae	*Cirsium vulgare*	Bull thistle	Non-native	Occasional
Asteraceae	*Conyza bonariensis*	Hairy horseweed	Non-native	Common
Asteraceae	*Conyza canadensis* var. *pusilla*	Horseweed	Non-native	Occasional
Rubiaceae	*Coprosma ernodeoides*	Kukaenene	Endemic	Occasional

Family	Scientific Name	Common Name	Nativity	Abundance
Rubiaceae	*Coprosma montana*	Pilo	Endemic	Occasional
Rubiaceae	*Coprosma ochracea*	Pilo	Endemic	Rare
Thelypteridaceae	*Cyclosorus parasiticus*	Parasitic maiden fern	Non-native	Common
Thelypteridaceae	*Cyclosorus sandwicensis*	Hoio kula	Endemic	Occasional
Poaceae	*Cynodon dactylon*	Bermuda grass	Non-native	Rare
Dryopteridaceae	*Cyrtomium caryotideum*	Kaapeape	Indigenous	Rare
Athyriaceae	*Deparia petersenii*	Deparia	Introduced	Common
Poaceae	*Deschampsia nubigena*	Hairgrass	Endemic	Dominant
Xanthorrhoeaceae	*Dianella sandwicensis*	Ukiuki	Endemic	Rare
Gleicheniaceae	*Dicranopteris linearis*	Uluhe	Indigenous	Rare
Poaceae	*Digitaria ciliaris*	Henry's crab grass	Non-native	Occasional
Poaceae	*Digitaria violascens*	Violet crab grass	Introduced	Rare
Ebenaceae	*Diospyros sandwicensis*	Lama	Endemic	Rare
Sapindaceae	*Dodonaea viscosa*	Aalii	Indigenous	Occasional
Dryopteridaceae	*Dryopteris glabra*	Kilau	Endemic	Rare
Dryopteridaceae	*Dryopteris wallichiana*	Laukahi	Indigenous	Occasional
Asteraceae	*Dubautia menziesii*	Kupaoa	Endemic	Occasional
Asteraceae	*Dubautia plantaginea* subsp. *plantaginea*	Kupaoa	Endemic	Occasional
Asteraceae	*Dubautia platyphylla*	Kupaoa	Endemic	Occasional
Amaranthaceae	*Dysphania carinata*	Chenopodium	Non-native	Occasional
Dryopteridaceae	*Elaphoglossum paleaceum*	Makue	Indigenous	Common
Poaceae	*Eragrostis brownii*	Sheepgrass	Non-native	Occasional
Euphorbiaceae	*Euphorbia hirta*	Hairy spurge	Non-native	Rare
Poaceae	*Festuca myuros*	Rat tail fescue	Non-native	Occasional
Asteraceae	*Galinsoga parviflora*	Gallant soldier	Non-native	Rare
Asteraceae	*Gamochaeta sp.*	Gamochaeta	Non-native	Occasional
Geraniaceae	*Geranium homeanum*	Cranesbill	Non-native	Occasional
Proteaceae	*Grevillea robusta*	Silky oak	Non-native	Rare
Asteraceae	*Heterotheca grandiflora*	Telegraph weed	Non-native	Occasional
Poaceae	*Holcus lanatus*	Yorkshire fog	Non-native	Common
Asteraceae	*Hypochoeris radicata*	Hairy cat's ear	Non-native	Occasional
Lamiaceae	*Hyptis pectinata*	Comb hyptis	Non-native	Common
Aquifoliaceae	*Ilex anomala*	Kawau	Indigenous	Rare
Fabaceae	*Indigofera suffruticosa*	Upright indigo	Non-native	Rare
Rubiaceae	*Kadua centranthoides*	Manono	Endemic	Rare
Santalaceae	*Korthalsella complanata*	Hulumoa	Indigenous	Rare
Cyperaceae	*Kyllinga brevifolia*	Green kyllinga	Non-native	Occasional
Poaceae	*Lachnagrostis filiformis*	Heupueo	Indigenous	Rare
Verbenaceae	*Lantana camara*	Lantana	Non-native	Common
Polypodiaceae	*Lepisorus thunbergianus*	Pakahakaha	Indigenous	Rare
Ericaceae	*Leptecophylla tameiameiae*	Pukiawe	Indigenous	Dominant

Family	Scientific Name	Common Name	Nativity	Abundance
Campanulaceae	*Lobelia hypoleuca*	Opelu	Endemic	Occasional
Juncaceae	*Luzula hawaiiensis*	Wood rush	Endemic	Occasional
Primulaceae	*Lysimachia remyi*	Lysimachia	Endemic	Occasional
Lythraceae	*Lythrum maritimum*	Lythrum	Non-native	Common
Thelypteridaceae	*Macrothelypteris torresiana*	Mariana maiden fern	Non-native	Rare
Meliaceae	*Melia azedarach*	Chinaberry	Non-native	Occasional
Poaceae	*Melinis repens*	Natal red top	Non-native	Occasional
Poaceae	*Melinis minutiflora*	Molasses grass	Non-native	Occasional
Myrtaceae	*Metrosideros polymorpha* var. *glaberrima*	Ohia	Endemic	Dominant
Myrtaceae	*Metrosideros polymorpha* var. *incana*	Ohia	Endemic	Dominant
Dennstaedtiaceae	*Microlepia strigosa* var. *mauiensis*	Hairy palapalai	Endemic	Rare
Primulaceae	*Myrsine lessertiana*	Kolea lau nui	Endemic	Occasional
Lomariopsidaceae	*Nephrolepis brownii*	Asian sword fern	Non-native	Common
Oleaceae	*Nestegis sandwicensis*	Olopua	Endemic	Rare
Solanaceae	*Nicotiana glauca*	Tree tobacco	Non-native	Occasional
Lindsaeaceae	*Odontosorius chinensis*	Palaa	Indigenous	Common
Primulaceae	*Oenothera stricta* subsp. *stricta*	Evening primrose	Non-native	Occasional
Cactaceae	*Opuntia ficus-indica*	Prickly pear cactus	Non-native	Occasional
Rosaceae	*Osteomeles anthyllidifolia*	Ulei	Indigenous	Occasional
Oxalidaceae	*Oxalis corniculata*	Yellow wood sorrel	Non-native	Occasional
Poaceae	*Paspalum dilatatum*	Dallis grass	Non-native	Occasional
Passifloraceae	*Passiflora subpeltata*	White passion vine	Non-native	Occasional
Pteridaceae	*Pellaea ternifolia*	Kalamoho	Indigenous	Common
Piperaceae	*Peperomia cookiana*	Alaala wai nui	Endemic	Occasional
Caryophyllaceae	*Petrorhagia velutina*	Childing pink	Non-native	Rare
Solanaceae	*Physalis peruviana*	Poha	Non-native	Rare
Urticaceae	*Pipturus albidus*	Mamaki	Endemic	Rare
Pteridaceae	*Pityrogramma austroamericana*	Golden fern	Non-native	Common
Plantaginaceae	*Plantago lanceolata*	Narrow-leaved plantain	Non-native	Occasional
Asteraceae	*Pluchea carolinensis*	Sourbush	Non-native	Occasional
Caryophyllaceae	*Polycarpon tetraphyllum*	Polycarpon	Non-native	Occasional
Polypodiaceae	*Polypodium pellucidum*	Ae	Endemic	Rare
Poaceae	*Polypogon interruptus*	Ditch polypogon	Non-native	Occasional
Dryopteridaceae	*Polystichum haleakalense*	Polystichum	Endemic	Common
Lamiaceae	*Prunella vulgaris*	Selfheal	Non-native	Occasional
Psilotaceae	*Psilotum nudum*	Moa	Indigenous	Occasional
Hypolepidaceae	*Pteridium aquilinum* subsp. *decompositum*	Kilau, bracken fern	Indigenous	Common
Pteridaceae	*Pteris cretica*	Cretan brake	Indigenous	Common

Family	Scientific Name	Common Name	Nativity	Abundance
Rubiaceae	*Richardia brasiliensis*	Richardia	Non-native	Occasional
Rosaceae	*Rubus rosifolius*	Thimble berry	Non-native	Common
Poaceae	*Rytidosperma semiannulare*	Tasmanian wallaby grass	Non-native	Occasional
Blechnaceae	*Sadleria cyatheoides*	Amau	Endemic	Common
Blechnaceae	*Sadleria pallida*	Amau	Endemic	Occasional
Santalaceae	*Santalum haleakalae* var. *haleakalae*	Iliahi	Endemic	Rare
Anacardiaceae	*Schinus terebinthifolius*	Christmasberry	Non-native	Rare
Asteraceae	*Senecio madagascariensis*	Fireweed	Non-native	Common
Asteraceae	*Senecio sylvaticus*	Wood groundsel	Non-native	Occasional
Rubiaceae	*Sherardia arvensis*	Blue fieldmadder	Non-native	Rare
Cucurbitaceae	*Sicyos pachycarpus*	Anunu	Endemic	Rare
Malvaceae	*Sida rhombifolia*	Cuban jute	Non-native	Rare
Asteraceae	*Sonchus asper*	Prickly sow thistle	Non-native	Rare
Asteraceae	*Sonchus oleraceus*	Sow thistle	Non-native	Occasional
Fabaceae	*Sophora chrysophylla*	Mamane	Endemic	Occasional
Orchidaceae	*Spathoglottis plicata*	Philippine ground orchid	Non-native	Rare
Rubiaceae	*Spermacoce exilis*	Spermacoce	Non-native	Rare
Cyatheaceae	*Sphaeropteris cooperi*	Australian tree fern	Non-native	Rare
Poaceae	*Sporobolus indicus*	Smut grass	Non-native	Common
Asteraceae	*Taraxacum officinale*	Common dandelion	Non-native	Occasional
Asteraceae	*Tetramolopium humile* subsp. *haleakalae*	Pamakani, Haleakala tetramolopium	Endemic	Occasional
Melastomataceae	*Tibouchina herbacea*	Cane tibouchina	Non-native	Rare
Fabaceae	*Trifolium repens*	White clover	Non-native	Rare
Poaceae	*Trisetum glomeratum*	Pili uka	Endemic	Occasional
Ericaceae	*Vaccinium reticulatum*	Ohelo	Endemic	Common
Fabaceae	*Vicia sativa* subsp. *nigra*	Vetch	Non-native	Occasional
Campanulaceae	*Wahlenbergia marginata*	Southern rockbell	Non-native	Occasional
Thymelaeaceae	*Wikstroemia monticola*	Akia	Endemic	Occasional

Typical Kahikinui Forest Reserve view at about 5,000 ft. elevation. If ungulates continue to be excluded from this area, this grassland will likely return to koa forest in the not too distant future.

FAUNAL SURVEY

SURVEY METHODS

A walk-through survey method was conducted in conjunction with the botanical survey. Field observations were made with the aid of binoculars and by listening to vocalizations. A series of five minute point counts were made across various habitats.

Notes were made on species, abundance, activities and location as well as observations of trails, tracks, scat and signs of feeding. Conspicuous insects were noted.

Information on Hawaiian Hoary Bats (*Lasiurus cinereus semotus*) was gleaned from a recent bat study in the Kahikinui Forest Reserve by Todd et al. 2016.

The reserve was surveyed in February and March of 2018.

Looking and listening for wildlife during five minute point count on rim of Pahihi Gulch.

BATS

Native Hawaiian Hoary Bats (*Lasiurus cinereus semotus*) are present over all of East Maui. Some of their highest numbers occur in forested sections of the mid-elevations.

United States Geological Survey (USGS) researchers installed and maintained a series of bat detectors in the Kahikinui Forest Reserve and nearby Nakula NAR during 2012-2014.

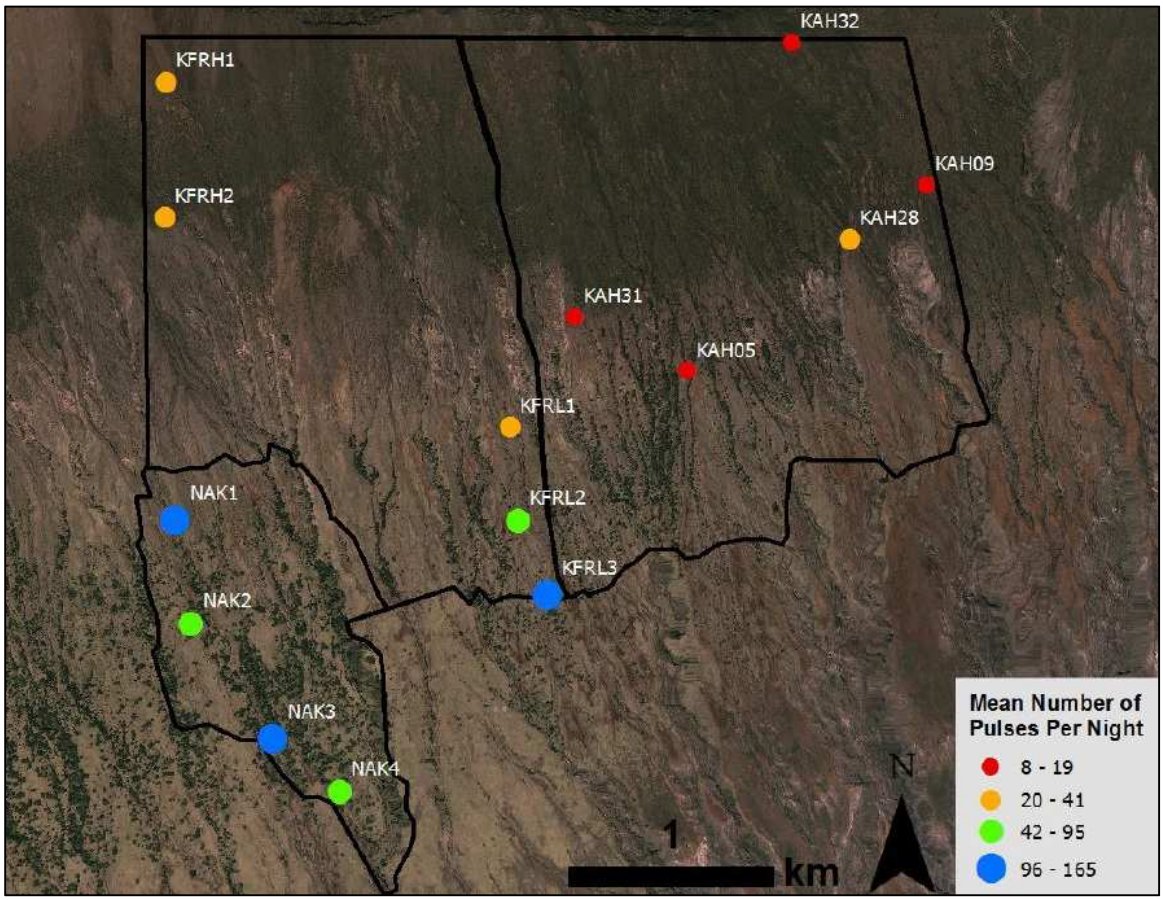
Results of the USGS detector work show bats are regularly flying over the reserve at night, being detected about half of the nights, especially in the koa/ohia forest sections.

USGS bat detector stations. Note also regrowth of forest from 2012-2014. (From Todd et al. 2016).

Hawaiian Hoary Bat, Olinda, Maui.

Detection of pulses was on the low side over much of the reserve, ranging from 8 pulses per night at one of the higher elevation stations in open shrubland, to a more active 130 pulses per night in a mid-elevation koa/ohia forest section of the reserve. On average, there were 37 pulses detected/night/detector in the reserve.

USGS results for adjacent Nakula NAR are similar, with bats detected over the entire area, and more detections in lower elevation forested areas.



Mean number of bat pulses detected per night. (From Todd et al. 2016).

Station	Pulses/Night	Buzzes/Night	% Detection/Night
KAH31	8	0.4	45%
KAH05	13	0.5	50%
KAH09	15	1.18	56%
KAH32	19	0	36%
KAH28	37	1.46	69%
KFRL3	130	3.6	59%
Average	**37**	**1.19**	**53%**

Summary of Kahikinui Forest Reserve bat detector data (From Todd et al. 2016).

NON-NATIVE MAMMALS

The Kahikinui Forest Reserve has numerous feral goats (*Capra hircus*) and pigs (*Sus scrofa*). Axis deer (*Axis axis*) and cows (*Bos taurus*) possibly occur within the reserve, but were not observed. Previous damage by goats and pigs is evident over most of the reserve. However, with a new ungulate fence installed, the only recent damage is now mostly below the fence at about 5,000 ft., in a rarely visited area open to public hunting.

At the highest elevations, only old scat, bones, browsing, and erosion scars are evident. As one approaches the fence at 5,000 ft. elevation, a strong smell of ungulate scat and urine wafts up the mountain, and goat cries are heard. Below the fence, there is very little woody vegetation, and the ground is heavily disturbed by ungulates. There are numerous goats and some pigs from the fence at 5,000 ft. to the bottom of the reserve near 3,000 ft.

Other mammals likely to utilize this property, but which were not observed or heard include rats (*Rattus* spp.), mice (*Mus domesticus*), cats (*Felis domesticus*), dogs (*Canis lupus familiaris*), and mongooses (*Herpestes javanicus*).

Young goats of varying color. Goats are abundant below the fence.

Part of a family of pigs. We didn't see too many pigs, but digging is common below the fence.

Goat herd near Kahalulu Gulch. Though the area is open to public hunting, access issues limit the actual hunting occurring, resulting in some of the highest densities of feral goats on the island.

Goats in a pig dug area of an unfenced portion of the koa/ohia forest.

Ungulate accelerated erosion around an ohia tree, with a newly installed ungulate fence below it.

Severe ungulate erosion has left nothing but dirt over vast areas of the lower reaches of the reserve. Increased hunting access may help bring the number of animals down to a more balanced level.

Fencing is the solution for keeping ungulates in hunting areas and out of restoration areas.

Recently built ungulate fence allowing hunting on one side and recovery of native forest on the other.

BIRDS

Apapane (*Himatione sanguinea*) is the most common bird species in the reserve. They were observed and heard over almost the entire range of ohia forest, from 4,000-7,600 ft. elevation. They are absent only in the highest elevations of the pukiawe shrubland and in the lower elevation grassland and bare dirt areas of the reserve.

Maui Amakihi (*Chlorodrepanis virens* var. *wilsoni*) is the second most abundant bird species in the reserve. As with Apapane, Amakihi were observed and heard in virtually all the forested areas of the reserve, and are mostly absent elsewhere.

A pair of Hawaiian Geese or Nene (*Branta sandvicensis*) were heard and observed flying over the reserve multiple times, between 4,000 and 7,000 ft. elevation. They were also observed loafing and foraging near a grassy camp and LZ at 6,100 ft. elevation. These two Nene seemed to be regulars in the area. It is not known if they were banded or not.

A Hawaiian Owl or Pueo (*Asio flammeus sandwichensis*) was observed multiple times at a transition zone between forested and grassland areas at about 5,000 ft. A pair of White-tailed Tropic birds (*Phaethon lepturus*) were circling and calling around the large gulches between 3,000-5,000 ft. They nest in similar terrain elsewhere in Hawaii.

Non-native passerines encountered included Red-billed Leiothrix (*Leiothrix lutea*), Japanese Bush-warbler (*Cettia diphone*), Japanese White-eye (*Zosterops japonicus*), House Finch (*Haemorhous mexicanus*), Common Myna (*Acridotheres tristis*), Scaly-breasted Munia (*Lonchura punctulata*), Northern Mockingbird (*Mimus polyglottos*), and Eurasian Skylark (*Alauda arvensis*).

Game birds heard or seen were Ring-necked Pheasant (*Phasianus colchicus*), Gray Francolin (*Francolinus pondicerianus*), Black Francolin (*Francolinus francolinus*), and Chukar (*Alectoris chukar*). The reserve is a bird hunting unit, allowing seasonal public hunting for game birds. However, access issues limit the actual hunting occurring.

Apapane calling in ohia canopy.

Hawaiian Petrels (*Pterodroma sandwichensis*) nest in burrows dug in the ground in the higher elevations of the subalpine shrubland of the Kahikinui Forest Reserve. As of 2017, there were eight Hawaiian Petrel burrows located within the reserve. We came across what is likely the ninth known burrow, in the northeast corner of the reserve. It was at the base of a lava flow on the side of a small knoll. A small white feather was visible in the entrance, and the burrow reeked of seabird guano.

Seabird monitoring and predator control has begun in the subalpine region of the reserve by Maui Nui Seabird Recovery Project, with the goal of increasing the seabird populations within the reserve. Band-rumped Storm-Petrel (*Oceanodroma castro*) and Newell's Shearwaters (*Puffinus newelli*) have not been recorded from the reserve, but may be able to utilize the habitat, especially as the area is further protected and restored.

The Maui Forest Bird Recovery Project is monitoring forest birds and restoring forest in nearby Nakula NAR, which is a planned release site for the Maui parrotbill or kiwikiu (*Pseudonestor xanthophrys*). Native forest birds released in Nakula would likely make their way over to the Kahikinui Forest Reserve.

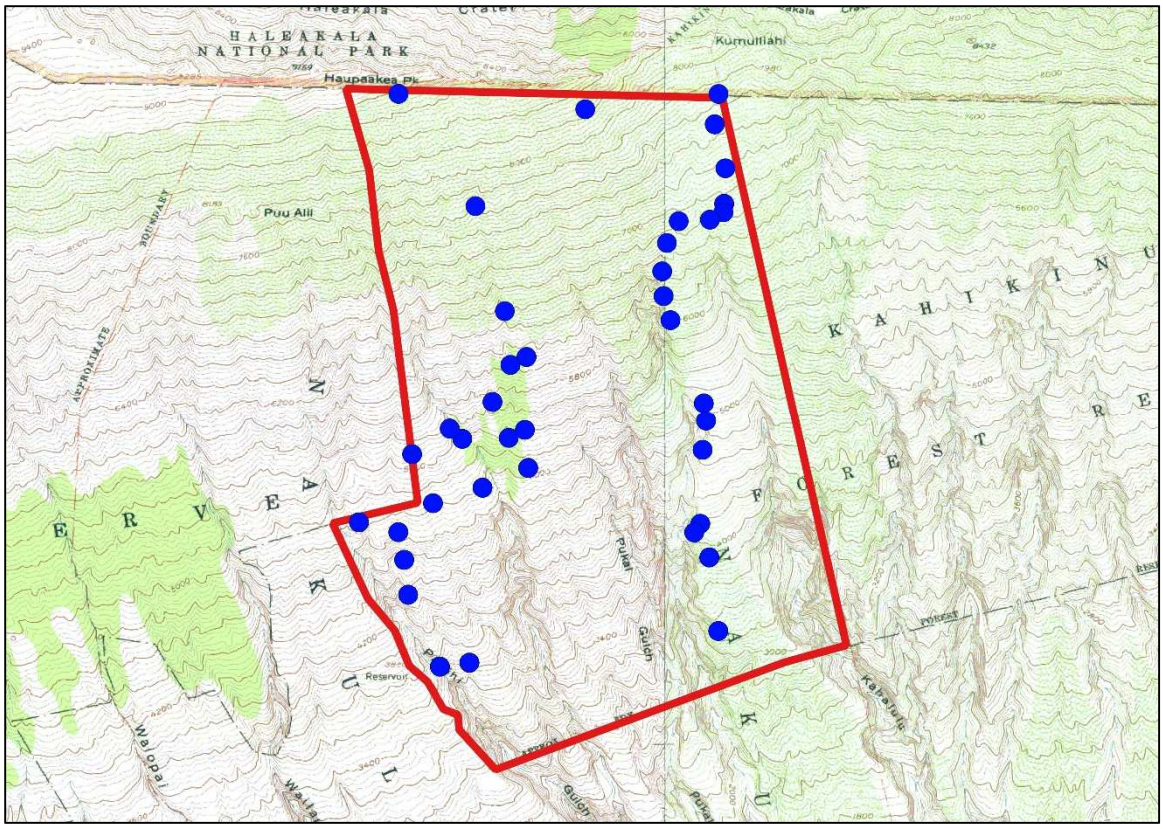
Birds reported from Nakula NAR, and not encountered during this survey, but possibly occurring in the Kahikinui Forest Reserve include the native Iwa or Great Frigatebird (*Fregata minor*) and Kolea or Pacific Golden-Plover (*Pluvialis fulva*).

Non-native birds not encountered, but possibly occurring in the reserve include California Quail (*Callipepla californica*), Northern Cardinal (*Cardinalis cardinalis*) Rock Pigeon, (*Columba livia*), African Silverbill (*Euodice cantans*), Chinese Hwamei (*Garrulax canorus*), Barn Owl (*Tyto alba*), and Mourning Dove (*Zenaida macroura*).

Nene loafing and foraging in open grassy area.

BIRD POINT COUNTS

A series of five minute point counts were done across a range of habitat types and elevations. All birds observed or heard for an unlimited distance were recorded.



Bird point count locations.

Looking and listening for birds during point count on rim of Pukai Gulch. Two White-tailed Tropicbirds were flying in arcs and occasionally calling over this large gulch. They nest in similar terrain elsewhere in Hawaii.

Elevation (ft.)	Apapane	Maui Amakihi	Eurasian Skylark	Ring-necked Pheasant	Chukar	Hawaiian Goose	Japanese Bush Warbler	Japanese White-eye	Gray Francolin	Short-eared Owl	White-tailed Tropicbird	Common Myna	Northern Mockingbird	Red-billed Leiothrix	House Finch	Scaly-breasted Munia	Black Francolin
8800					2								1				
8320					2												
7765				2													
7650	3																
7560				2	1								1				
7220	1																
6980	1			3	3												
6945	3																
6915	3				2												
6870	7				4												
6770	4																
6570	6			1													
6450	6																
6340	6	3	1	1													
6200	10	1				2											
6110	3	1															
6100	8	5				1											
5750	6	4															
5600	5	2															
5550	5	3					1										
5550	5	2		1													
5410	3	2				2											
5300	6	3															
5245	1		1														
5200	4	4	1	1		2	1			1		1					
5120	6	4		1			1			1							
5120	4	2															
5120	6	3		1			1	2						2			
5075	3	3	1			2											
4950	3	2					1										
4855	5	10	2	1		2											
4730	1	1	2	1				1									
4450		2	2		1		1	1									
4260			1								1						
4195			2				1		1								
3940			1				1				2	2					
3800		2	2			2		2	1								
3750		1	1		12	2			1						30	6	
3390			1	2	7												1

Bird point count results sorted by elevation and abundance.

BIRD SPECIES LIST

Following is a checklist of the bird species inventoried during the field work. For each species the following information is provided:

- Common & Scientific name

- Bio-geographical status / nativity:
  - Endemic = Native to Hawaii; not naturally occurring anywhere else in the world.
  - Indigenous = Native to Hawaii and also to one or more other geographic area(s).
  - Non-native = Brought to Hawaii intentionally or accidentally by humans.

- Abundance of each species within the project area:
  - Abundant = Many flocks or individuals seen throughout area at all times of day.
  - Common = A few flocks or well scattered individuals throughout the area.
  - Uncommon = Only one flock or several individuals seen within the project area.
  - Rare = only one or two seen within the project area.

Common name	**Scientific name**	**Nativity**	**Abundance**
Apapane	*Himatione sanguinea*	Endemic	Abundant
Black Francolin	*Francolinus francolinus*	Non-native	Rare
Chukar	*Alectoris chukar*	Non-native	Occasional
Common Myna	*Acridotheres tristis*	Non-native	Rare
Eurasian Skylark	*Alauda arvensis*	Non-native	Common
Gray Francolin	*Francolinus pondicerianus*	Non-native	Rare
Hawaiian Goose	*Branta sandvicensis*	Non-native	Common
Hawaiian Owl	*Asio flammeus sandwichensis*	Endemic	Rare
Hawaiian Petrel	*Pterodroma sandwichensis*	Endemic	Rare
House Finch	*Haemorhous mexicanus*	Non-native	Rare
Japanese Bush-warbler	*Cettia diphone*	Non-native	Common
Japanese White-eye	*Zosterops japonicus*	Non-native	Occasional
Maui Amakihi	*Chlorodrepanis virens wilsoni*	Endemic	Abundant
Northern Mockingbird	*Mimus polyglottos*	Non-native	Rare
Red-billed Leiothrix	*Leiothrix lutea*	Non-native	Rare
Ring-necked Pheasant	*Phasianus colchicus*	Non-native	Common
Scaly-breasted Munia	*Lonchura punctulata*	Non-native	Rare
White-tailed Tropicbird	*Phaethon lepturus*	Indigenous	Rare

Maui Amakihi visiting ohia flowers.

INSECTS

A complete inventory of the insects was beyond the scope of this survey. Conspicuous insects were noted and special effort was made to look for insects of conservation concern. Very little survey work has been done on insects in the Kahikinui Forest Reserve, and there is still much to be discovered, including new undescribed species. Some of the more conspicuous and noteworthy insects we came across are noted below.

YELLOW-FACED BEES

Native yellow-faced bees (*Hylaeus* spp.) (Hymenoptera: Colletidae) are abundant in the subalpine shrubland of the reserve, especially near pukiawe plants in bloom. These black bees with yellow face markings are important pollinators of the Haleakala Silversword and other plants. Once common across all Hawaii, subalpine East Maui is now one of the only places they can still be found in large numbers.

Yellow-faced bee (*Hylaeus nivicola*). Important pollinator of native plants such as silverswords.

ECTEMNIUS WASPS

In one of the most degraded sections of the reserve, near the makai boundary, there are native *Ectemnius* wasps (Hymenoptera: Sphecidae). These predatory wasps prey on flies (Diptera), with which they provision nest cells for their young. There are historical reports of *Ectemnius* wasps awaiting the arrival of flies to a freshly killed deer. There are lots of ungulates in this area. Additionally, they have been recorded preying on the introduced lantana gall-forming fly (*Eutreta xanthochaeta*), which is also common in this part of the reserve, along with the lantana it feeds on.

Native predatory *Ectemnius* sp. wasp waiting for flies in the lowest reaches of the reserve.

KOA BUTTERFLY

A native koa butterfly (*Udara blackburni*) (Lepidoptera: Lycaenidae) was observed flitting about and sipping nectar from fireweed (*Senecio madagascariensis*) near the makai edge of the koa forest. The larvae of this species feed on koa and aalii. As koa and aalii become more common, so too should this native butterfly.

Koa butterfly (*Udara blackburni*) sipping nectar from fireweed.

OMIODES MOTHS

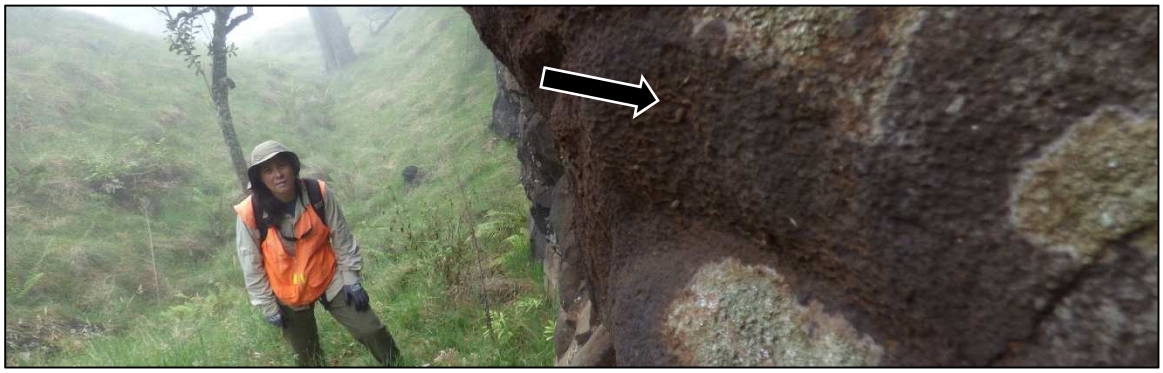
Native Hawaiian leaf roller moths (*Omiodes continuatalis*) (Lepidoptera: Crambidae) were observed multiple times in the Kikuyu grass (*Cenchrus clandestinus*) zone of the reserve. This native moth was once widespread across the state, but has since declined in distribution, and in 1980 was listed as extinct. Subsequent surveys "rediscovered" the species on Hawaii island and Maui-Nui. Though not recently found on Oahu or Kauai, this species is currently locally abundant in a few select places, including much of mid-elevation East Maui. The larvae of this moth are able to utilize both native and non-native grasses as host plants, allowing it to survive in a wide range of areas.

Hawaiian leaf roller moth (*Omiodes continuatalis*) resting on pamakani in the Kikuyu grass zone.

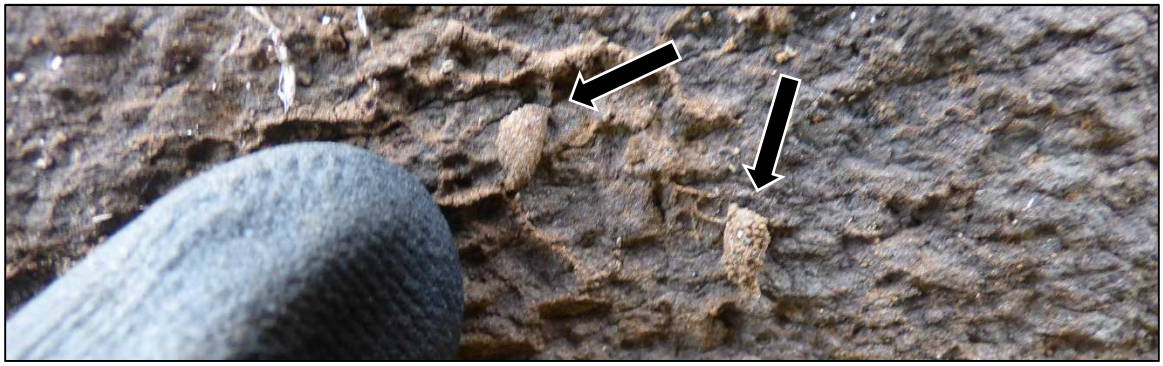
HYPOSMOCOMA MOTHS

Able to survive in some of the least hospitable areas of Hawaii, native fancy-cased moths (*Hyposmocoma* spp.) (Lepidoptera: Cosmopterigidae) are abundant over much of Kahikinui. Most prevalent to our eyes were the "burrito" shaped larvae/pupae that were common in sheltered areas on large stones and cliff faces across the entire reserve. We also came across a few larvae with cases of the "cigar/carnivorous" types.

The burrito larvae create a sleeping bag type structure they stick bits of mud and lichen to while they crawl around and graze on lichen and fungi. Larvae pupate in the cases they make. Adults emerge as small moths. The carnivorous *Hyposmocoma* possibly eats snails or other *Hyposmocoma* larvae. Some of these could be new undescribed native species.



***Hyposmocoma* spp. habitat in sheltered areas on stones and cliff faces.**



***Hyposmocoma* sp. "burrito" shaped larvae/pupae adorned with bits of soil.**

***Hyposmocoma* sp. "cigar/carnivorous" larva / caterpillar sticking its head out of the case.**

BLACKBURN'S SPHINX MOTH

The Blackburn's sphinx moth (*Manduca blackburni*) (Lepidoptera: Sphingidae) is an endangered native moth that often feeds on the non-native tree tobacco (*Nicotiana glauca*). A few large patches of tree tobacco were observed around 3,700 ft. at the top of the lantana shrubland on the east side of the reserve. The plants were searched for evidence of Blackburn's sphinx moth.

No eggs, larvae, frass, feeding damage or adults of the Blackburn's sphinx moth were observed. The only insect feeding damage on tree tobacco appeared to be from Fuller's rose weevils (*Naupactus godmani*). The tree tobacco plants also appeared to be grazed on and damaged by goats. And the plants had what appeared to possibly be a virus that was discoloring and distorting the leaves a bit. The only other Solanaceae encountered was poha (*Physalis peruviana*), which also had no evidence of Blackburn's sphinx moth.

Though Blackburn's sphinx moths were not encountered, there are host plants in the reserve that could support them, and it is probable they are in the reserve at times.

Blackburn's sphinx moth larva on tree tobacco (*Nicotiana glauca*) at Puu o Kali, Maui.

Tree tobacco (*Nicotiana glauca*) in Kahikinui Forest Reserve.

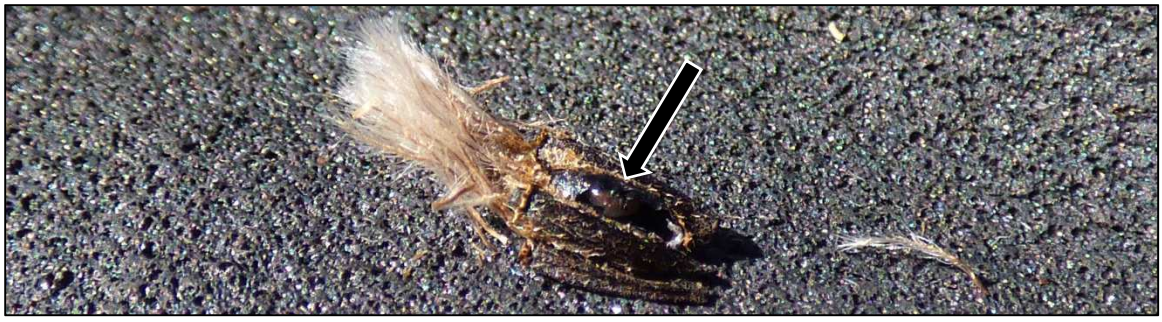
NATIVE TEPHRITID FLIES

Once common over much of Hawaii, native tephritid or fruit flies (Diptera:Tephritidae) have now become restricted to the least disturbed habitats of Hawaii. Subalpine East Maui is one of the last significant refugia for these flies. Though less diverse than it once was, the Kahikinui Forest Reserve still contains multiple species of native tephritid flies.

Most abundant is *Trupanea cratericola*, which lays eggs on flowers of kupaoa (*Dubautia* spp.) and Haleakala silverswords. The larvae eat the seeds and pupate within them. *T. limpidapex* lays eggs in the shoot tips of *Dubautia*. Pupal cases and characteristic damage to *Dubautia* from both of these species was observed in the subalpine shrubland.

Though no adults or pupae were observed, *T. artemisae* is likely utilizing the flowers of *Artemisia mauiensis* within the reserve. Additionally, *T. crassipes*, which utilizes the flowers and seeds of the non-native Spanish needle (*Bidens pilosa*) may episodically become abundant in the area.

Trupanea cratericola **resting on vegetation in subalpine region.**



Trupanea cratericola **pupa in seeds of** ***Dubautia menziesii*****.**

Trupanea limpidapex **pupa with emergence hole in shoot tip of** ***Dubautia menziesii*****.**

NON-NATIVE TEPHRITID FLIES

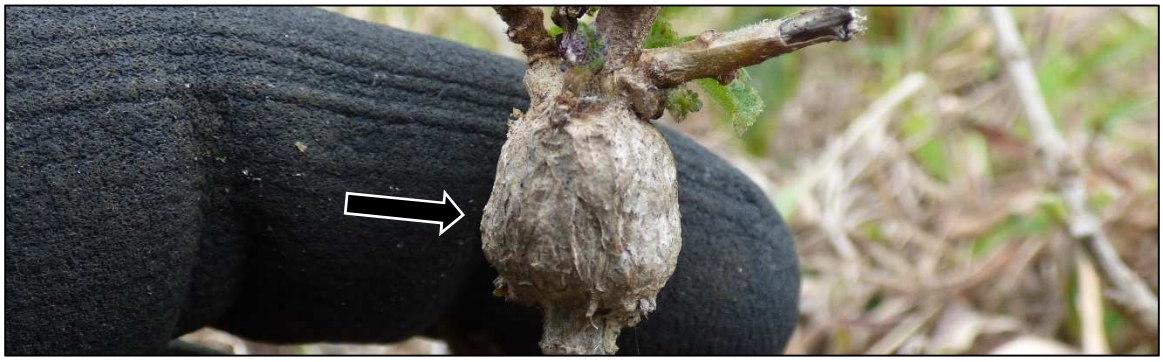
A number of non-native tephritid flies (Diptera: Tephritidae) have been introduced to Hawaii for biocontrol of weeds. Below are a few present within the reserve.

When pamakani became a serious pest in agriculture and forestry in Hawaii, the gall forming tephritid flies, *Procecidochares utilis* and *P. alani* were imported. Within a few years of introduction, they dramatically reduced populations of pamakani.

Eutreta xanthochaeta was introduced in 1902 for biocontrol of lantana, also by creating galls. However, it is generally not considered significant for control of lantana.

Pupa of stem galler (*Procecidochares utilis*) in Maui pamakani (*Ageratina adenophora*).

Gall and exit holes of stem galler (*Procecidochares alani*) in Hamakua pamakani (*Ageratina riparia*).



Lantana stem-galler (*Eutreta xanthochaeta*) in lantana.

ANTS

Hawaii has no native ants (Hymenoptera: Formicidae). Just two species, the big-headed ant (*Pheidole megacephala*) and *Cardiocondyla kagetsuchi* were encountered within the reserve. Big-headed ants are more likely to be found in lowland areas, below 4,000 ft.

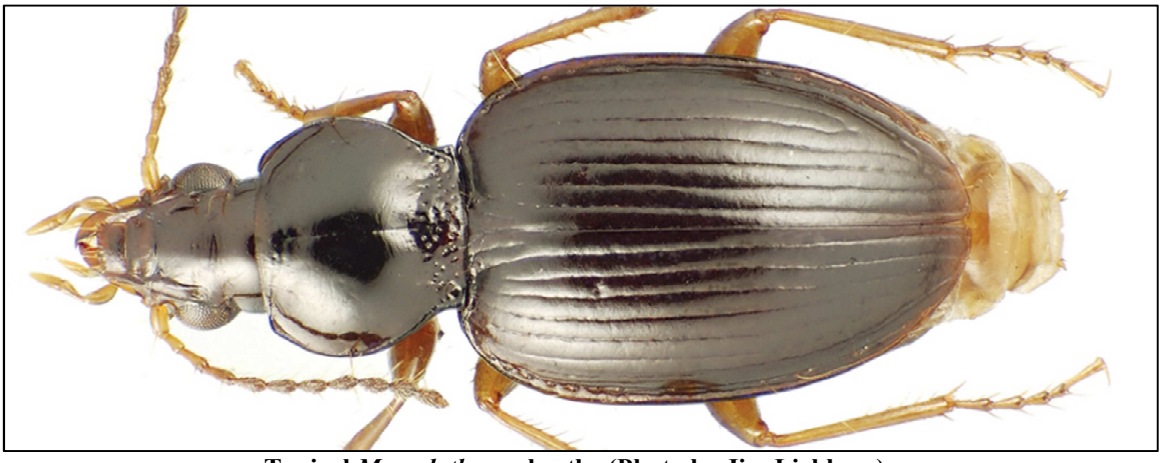
Detailed ant surveys including baiting were not done for this project and more ant species likely exist within the reserve. An ant survey of part of the reserve in 2008 found one additional species, *Hypoponera opaciceps*.

Argentine ants (*Linepethima humile*), a highly invasive species which would be more likely to be found in higher elevations of the reserve, above 4,000 ft., were not encountered. This bodes well for native insects, which can be heavily impacted by ants.

***Cardiocondyla kagetsuchi* in subalpine shrubland of Kahikinui Forest Reserve.**

GROUND BEETLES

Native *Mecyclothorax* beetles (Coleoptera: Carabidae) are known to be negatively impacted by the presence of aggressive ants such as the Argentine ant. Though not encountered during this survey, a single specimen of *Mecyclothorax krushelnyckyi* was collected from leaf litter in the subalpine shrubland during 2008 ant surveys.



Typical *Mecyclothorax* beetle. (Photo by Jim Liebherr)

OHIA PSYLLIDS

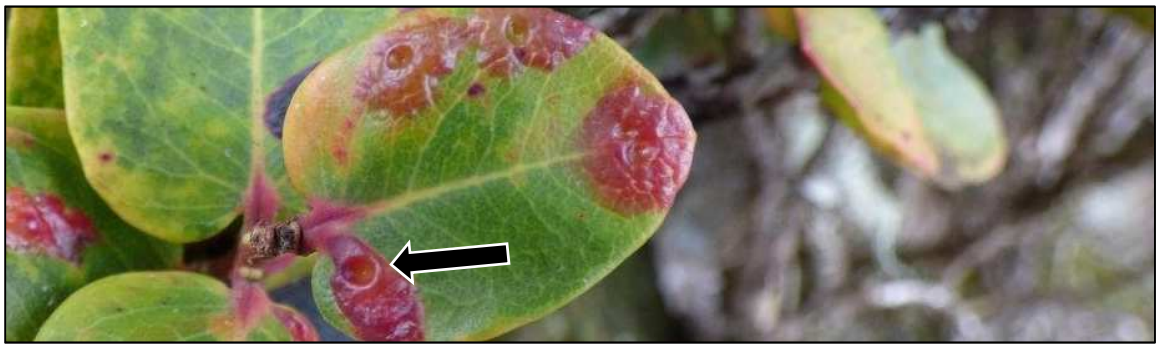
Many ohia trees have galls on their leaves created by native psyllids or jumping plant lice (*Pariaconus* spp.) (Hemiptera: Psyllidae). There are at least three types of galls created by multiple native ohia psyllid species in the reserve.

The "closed gall" psyllids create galls that look like little bumps on the leaves of ohia. This species is found in all but the highest elevation ohia trees.

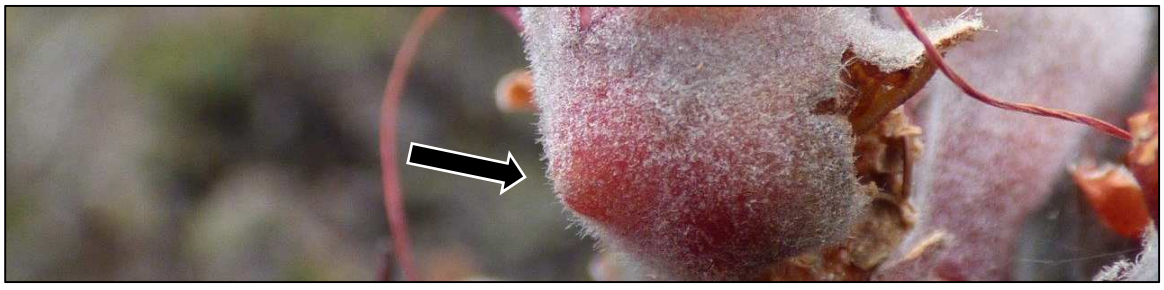
"Pit gall" psyllids create pits in the leaves, and were only encountered in the subalpine shrubland. The immatures of this species were previously unknown before this survey.

There are two species of "stem/flower bud gallers", which make galls in the stems and flower buds of ohia. They are present over the entire range of ohia in Kahikinui.

"Closed galls" on ohia leaves created by native psyllids (*Pariaconus* sp. nr. *montgomeri*).



"Pit galls" created on ohia by native psyllids (*Pariaconus* sp. nr. *gibbosus*)



"Stem/flower bud gall" created on ohia by native psyllids (*Pariaconus* spp. nr. *kupua* & *mauiensis*).

PLANTHOPPERS

Native planthoppers (*Nesosydne* sp.) (Hemiptera: Delphacidae) are present within the Kahikinui Forest Reserve. The *Nesosydne* genus is an adaptive radiation of host-specialized Hawaiian planthoppers. It has been said that each species of native Hawaiian plant likely has its own species of *Nesosydne* that evolved to feed on it. The Haleakala silversword even has its own, *N. argyroxiphii.* As the native plants within the reserve become more abundant, so too will these native planthoppers.

***Nesosydne* sp. on *Dubautia menziesii*.**

SPIDERS

Spiders are present in small numbers over the entire reserve. Of note are the native wolf spiders (*Lycosa hawaiiensis*) (Araneae: Lycosidae), which hunt for prey in the subalpine shrubland. These spiders live under stones, and at times carry dozens of live young baby spiders on their backs. Other native spiders observed include predatory crab spiders (*Mecaphesa* sp.) (Araneae: Thomisidae) waiting in ohia flowers to ambush their prey.

Hawaiian wolf spider on silversword, Sliding Sands Trail, Haleakala National Park.

INSECT SPECIES LIST

Following is a checklist of the insect species inventoried during the field work. For each species the following information is provided:

- Oder, Family, Scientific & Common name

- Bio-geographical status / nativity:
  - Endemic = Native to Hawaii; not naturally occurring anywhere else in the world.
  - Indigenous = Native to Hawaii and also to one or more other geographic area(s).
  - Non-native = Brought to Hawaii intentionally or accidentally by humans.

Order	**Family**	**Scientific Name**	**Common Name**	**Nativity**
Araneae	Lycosidae	*Lycosa hawaiiensis*	Hawaiian wolf spider	Endemic
Araneae	Thomisidae	*Mecaphesa* sp.	Crab spider	Endemic
Coleoptera	Coccinellidae	*Coccinella septemnervia*	Seven-spot lady bird	Non-Native
Coleoptera	Coccinellidae	*Olla abdominalis*	Ash-grey lady bird	Non-Native
Coleoptera	Curculionidae	*Naupactus godmani*	Fuller's rose weevil	Non-Native
Coleoptera	Tenebrionidae	*Gonocephalum adpressiforme*	Gonocephalum	Non-Native
Diptera	Agromyzidae	*?*	Bidens pilosa leaf miner	Non-Native
Diptera	Muscidae	?	House fly	Non-Native
Diptera	Tephritidae	*Eutreta xanthochaeta*	Lantana stem galler	Non-Native
Diptera	Tephritidae	*Procecidochares alani*	Hamakua pamakani stem galler	Non-Native
Diptera	Tephritidae	*Procecidochares utilis*	Maui pamakani stem galler	Non-Native
Diptera	Tephritidae	*Trupanea cratericola*	Hawaiian fruit fly	Endemic
Diptera	Tephritidae	*Trupanea limpidapex*	Hawaiian fruit fly	Endemic
Diptera	Tipulidae	*?*	Crane flies	?
Hemiptera	Aphididae	*?*	Aphids	Non-Native
Hemiptera	Delphacidae	*Nesosydne* sp.	On Dubautia	Endemic
Hemiptera	Lygaeidae	*Nysius sp.*	On ohia	?
Hemiptera	Psyllidae	*Pariaconus* sp. nr. *gibbosus*	Ohia leaf pit gall psyllid	Endemic
Hemiptera	Psyllidae	*Pariaconus* sp. nr. *kupua*	Ohia stem/flower bud gall psyllid	Endemic
Hemiptera	Psyllidae	*Pariaconus* sp. nr. *mauiensis*	Ohia stem/flower bud gall psyllid	Endemic
Hemiptera	Psyllidae	*Pariaconus* sp. nr. *montgomeri*	Ohia leaf closed gall psyllid	Endemic
Hymenoptera	Apidae	*Apis mellifera*	Honey bee	Non-Native
Hymenoptera	Colletidae	*Hylaeus nivicola*	Yellow-faced bee	Endemic
Hymenoptera	Formicidae	*Cardiocondyla kagutsuchi*	Cardiocondyla ant	Non-Native

Order	Family	Scientific Name	Common Name	Nativity
Hymenoptera	Formicidae	*Pheidole megacephala*	Big-headed ant	Non-Native
Hymenoptera	Sphecidae	*Ectemnius* sp.	Ectemnius	Endemic
Hymenoptera	Vespidae	*Odynerus* sp.	Odynerus wasp	Endemic
Isopoda	?	*?*	Sow bugs	?
Lepidoptera	Cosmopterigidae	*Hyposmocoma* sp.	Fancy cased moths - "burrito" case type	Endemic
Lepidoptera	Cosmopterigidae	*Hyposmocoma* sp.	Fancy cased moths - "cigar/carnivorous"	Endemic
Lepidoptera	Crambidae	*Omiodes continuatalis*	Hawaiian grass leafroller	Endemic
Lepidoptera	Xyloryctidae	*Thyrocopa* sp.	Flightless moth	Endemic
Lepidoptera	Nymphalidae	*Vanessa cardui*	Painted lady butterfly	Non-Native
Lepidoptera	Pieridae	*Abaeis nicippe*	Sleepy orange butterfly	Non-Native
Lepidoptera	Pieridae	*Pieris rapae*	Cabbage butterfly	Non-Native
Lepidoptera	Lycaenidae	*Udara blackburni*	Koa butterfly	Endemic
Lepidoptera	Nymphalidae	*Danaus plexippus*	Monarch butterfly	Non-Native

Searching for native *Hyposmocoma* moths, some of which live on rocks and rock bands. Though we only surveyed the rims of these large gulches, the moths were abundant, and there are likely untold numbers of these cryptic native moths living on virtually all the rock bands visible.

MOLLUSKS

TORNATELLID SNAILS

Native tornatellid snails (*Tornatellides* sp.) (Gastropoda: Achatinellidae) were encountered on foliage. This genus of snails is found in a variety of habitats from the Northwestern Hawaiian Islands to the main Hawaiian Islands.

Unlike some other native snails, such as *Achatinella*, which are mostly restricted to the least disturbed native habitats, tornatellids are able to utilize habitat which has seen significant human induced disturbance and change.

Tornatellid snails are known to be eaten by the native *Hyposmocoma* moth, *H. molluscivora*, which captures the snail with silk and eats them alive.

Further surveys would undoubtedly turn up more mollusk species in the reserve. Like tornatellids, native amber snails (*Succinea* spp.) are able to utilize both native and non-native dominated habitat, and are likely in parts of the reserve.

Native tornatellid snail (*Tornatellides* sp.) on underside of fern.

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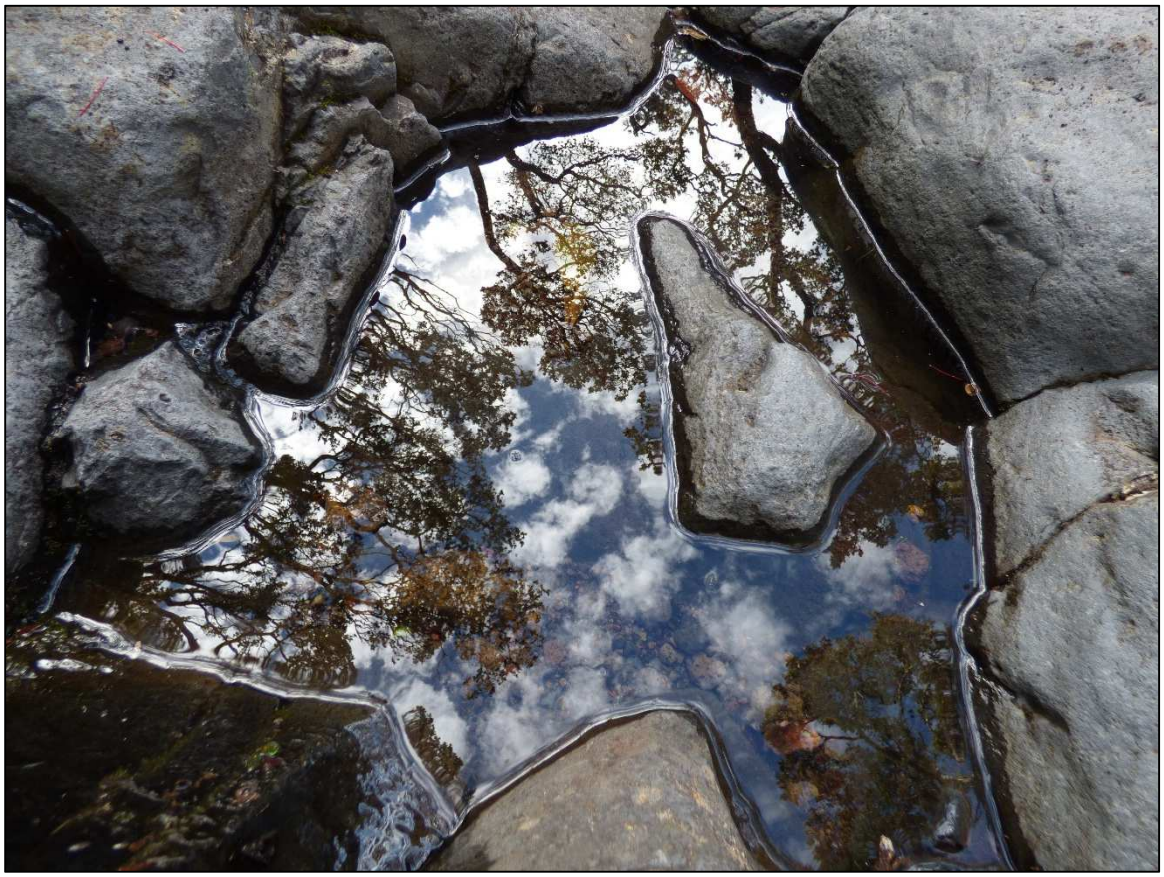

Ephemeral pool of water under a canopy of ohia trees in Kahikinui Forest Reserve.
"Hahai nō ka ua i ka ululāʻau" - The rain follows the forest.


Photo: Chris Eckart

Forest Birds

Hawai‘i ‘amakihi

Hemignathus virens

SPECIES STATUS:
State Listed Endangered on Lāna‘i
State Recognized as Endemic
NatureServe Heritage Rank G3—Vulnerable

SPECIES INFORMATION: The Hawai‘i ‘amakihi is a small, generalist Hawaiian honeycreeper (Family: Fringillidae). Until 1995, the Hawai‘i ‘amakihi, and the O‘ahu (*H. flavus*) and Kaua‘i ‘amakihi (*H. kauaiensis*) were considered a single species: the common ‘amakihi (*H. virens*). Plumage of all species is similar; males are yellow-green to olive with black lores. Females are generally similar, but duller. All have decurved bills. Plumage of males is bright yellow-green above, and there is some inter-island variation, especially among females. The Hawai‘i ‘amakihi is brighter and smaller than the Kaua‘i ‘amakihi. Hawai‘i ‘amakihi are generalized foragers that glean arthropods from the leaves, blossoms, twigs, branches, and less frequently from tree trunks, ferns, and shrubs. Feeds on nectar predominately from the flowers of ‘ōhi‘a (*Metrosideros polymorpha*), māmane (*Sophora chrysophylla*), and native lobelias (Campanulaceae), but also forages on flowers of a number of other native and non-native plants. They also eat fruit from native and non-native plants, but predominately from pilo (*Coprosma* spp.). Forages alone, in pairs, in family groups, or in mixed flocks. Courtship behavior is somewhat complex and includes courtship chases, advertising displays, and courtship feeding. Pairs remain together for successive breeding seasons. Pair selects nest site; female builds an open-cup nest and lays two or three eggs. Only females incubate eggs and brood nestlings. Males deliver food to females who then feed nestlings. Fledglings are dependent on parents for up to three months. The Hawai‘i ‘amakihi usually raise two broods in a season.

DISTRIBUTION: Occurs between 300 and 2,900 meters (1,000 – 9,500 feet) on Hawai‘i, Maui and Moloka‘i; not common below 500 meters (1,625 feet). Widely distributed on Hawai‘i and Maui. Original range likely included all forested regions of the above islands as well as those on Lāna‘i, where it was last seen in 1976.

ABUNDANCE: The Hawaiian Forest Bird Survey (1976-1983) estimated the population at 870,000 ± 5,612 (95% confidence interval) birds on the island of Hawai‘i, 44,000 ± 1,786 birds on east Maui, 3,000 ± 408 on west Maui, and 1,800 ± 357 birds on Moloka‘i. Populations on Hawai‘i and Maui are probably stable; the Moloka‘i population is probably declining.

LOCATION AND CONDITION OF KEY HABITAT: A range of habitats including native shrubland and dry, mesic, and wet forests in montane and subalpine communities. Densities are highest on the island of Hawai‘i in subalpine ‘ōhi‘a scrub in Ka‘ū, and in māmane/naio (*Sophora chrysophylla* and *Myoporum sandiwicense*) forests on Mauna Kea. ‘Amakihi also are common in koa (*Acacia koa*) reforestation areas at higher elevations. On Maui, they are common in subalpine dry communities dominated by ‘ōhi‘a, māmane, pūkiawe (*Styphelia tamieameiae*)

and ʻaʻaliʻi (*Dodonea viscosa*). They also occupy some non-native tree plantations on Maui, near areas where native vegetation persists. Habitat on Molokaʻi is restricted to the ʻōhiʻa forests of the eastern half of the island. The condition of this habitat varies considerably. Much of the species' current range is under State or federal jurisdiction.

THREATS: Although populations appear stable they are likely susceptible to the same factors that threaten other native Hawaiian forest birds, including loss and degradation of habitat, predation by introduced mammals, and disease.

CONSERVATION ACTIONS: Hawaiʻi ʻamakihi likely have benefited from management actions to conserve other endangered forest birds in the Hakalau Forest National Wildlife Refuge, Hawaiʻi Volcanoes National Park, and the ʻŌlaʻa/Kīlauea Watershed Partnership. These efforts include fencing, ungulate and small mammal control, forest restoration, habitat monitoring, and studies of disease and disease vectors. Future management specific to the Hawaiʻi ʻamakihi may include the following:

- Translocate captive-bred individuals to Lānaʻi and Kahoʻolawe.
- Conduct public education and outreach.
- Continue protection and management of wildlife sanctuaries and refuges.

MONITORING: Continue forest bird surveys and habitat monitoring.

RESEARCH PRIORITIES: Research priorities for most Hawaiian forest birds include improving methods for controlling rats (*Rattus* spp.) and feral cats (*Felis silvestris*) in native forests, determining the ecological requirements of *Culex* mosquitoes at mid- and high-elevation forests, and developing methods to control mosquito populations. Currently, the U.S. Geological Survey's Biological Resources Division is conducting genetic analyses to determine the species' phylogenetic status and examining the relationship between genetic diversity and disease resistance. Additional research priorities include the following:

- Quantify population structure, dispersal patterns, survivorship, nesting phenology and success, especially for Maui and Molokaʻi populations.
- Determine if competition with Japanese white-eyes (*Zosterops japonicus*) occurs, and if so, its effect on Hawaiʻi ʻamakihi populations.
- Conduct translocation experiments using Hawaiʻi ʻamakihi to help reestablish this and other Hawaiian honeycreeper populations.

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Photo: Eric Nishibayashi

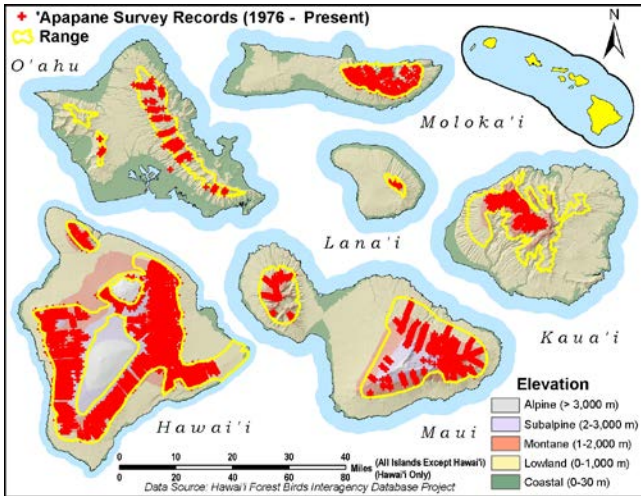
Forest Birds

ʻApapane

Himatione sanguinea

SPECIES STATUS:
State Recognized as Endemic
NatureServe Heritage Rank G3—Vulnerable
IUCN Red List Ranking— Least Concern

SPECIES INFORMATION: The ʻapapane is a small, crimson, primarily nectarivorous Hawaiian honeycreeper (Family: Fringillidae) and is an important ʻōhiʻa (*Metrosideros polymorpha*) pollinator. It is the most abundant and widely distributed Hawaiian honeycreeper, and is often seen flying above the canopy in search of patches of flowering ʻōhiʻa. Wide-ranging movements may facilitate disease transmission among native forest birds. ʻApapane often forage in conspecific flocks, likely to overwhelm ʻiʻiwi (*Vestiaria coccinea*) and ʻākohekohe (*Palmeria dolei*), which often defend flower-rich trees. Outside the breeding season, ʻapapane also join mixed-species flocks. They feed on insects, which they glean from outer foliage and twigs in the upper- and mid-canopy. Sexual chasing and courtship feeding often precede nest building, a task shared by both male and female. Pairs defend small territories around nests. Females incubate three eggs and brood young; males feed females away from the nest. Both parents feed nestlings, and fledglings may remain with their parents for up to four months.



DISTRIBUTION: Occurs in native forests above 1,250 meters (4,100 feet) on the islands of Hawaiʻi, Maui, and Kauaʻi. On Oʻahu, occurs in the Koʻolau Range from 300 meters (975 feet) to summit at 946 meters (3,075 feet), and are less common in the Waiʻanae Range above 600 meters (1,950 feet). Rare on Molokaʻi and Lānaʻi. Historically were common at low elevations on all islands with appropriate habitat.

ABUNDANCE: Based on Hawaiian Forest Bird Surveys (1976-1981): 1,080,000 ± 25,000 (95% confidence interval) birds on island of Hawaiʻi, 110,000 ± 9,000 on Maui (86% on Haleakalā), 39,000 ± 5,000 on Molokaʻi, 540 ± 213 on Lānaʻi, and 30,000 ± 1,500 on Kauaʻi (Oʻahu was not included in surveys). On Kauaʻi, populations declined after the 1992 hurricane but have significantly increased since, estimated at 64,972 ± 2,014 (SE) birds in 2000. Rare on Molokaʻi and Lānaʻi.

LOCATION AND CONDITION OF KEY HABITAT: Mesic and wet forests dominated by ʻōhiʻa and koa (*Acacia koa*), primarily at elevations greater than 1,250 meters (4,100 feet). The

primary reason for this limitation is the high density of cold-intolerant *Culex* mosquitoes, an important disease vector, below this elevation. Occupied habitats also contain kōlea (*Myrsine lessertiana*), naio (*Myoporum sandwicense*), and hapu'u tree ferns (*Cibotium* spp.). Māmane (*Sophora chrysophylla*) is common in high-elevation foraging habitat. Although much of the species' current range is under State or Federal jurisdiction, habitat protection and restoration efforts vary considerably.

THREATS: Although populations appear stable on the islands of Hawai'i, Maui, and Kaua'i, they are likely susceptible to the same factors that threaten other native Hawaiian forest birds including habitat loss and degradation, predation by introduced mammals, and disease. For 'apapane the following is of particular concern:

- Disease. Of Hawaii's native forest birds, 'apapane have the highest prevalence of avian malaria. Individuals infected with avian pox also are more likely to be infected with malaria. Foraging movements may increase their exposure to disease. 'Apapane breed in mid-elevation forests, which suggests some disease resistance.

CONSERVATION ACTIONS: 'Apapane likely benefited from actions to conserve other endangered forest birds on northeastern Haleakalā, Hakalau Forest National Wildlife Refuge, Hawai'i Volcanoes National Park, the 'Ōla'a/Kīlauea Watershed Partnership, and Alaka'i Wilderness Preserve and surrounding areas. These efforts include fencing, ungulate and small mammal control, forest restoration, habitat monitoring, and studies of disease and disease vectors. Future actions specific to the protection of 'apapane may include the following:

- Control mosquitos in degraded habitats.
- Conduct public education and outreach.
- Continue protection and management of wildlife sanctuaries and refuges.

MONITORING: Continue forest bird surveys and habitat monitoring on all islands.

RESEARCH PRIORITIES: Research priorities for most Hawaiian forest birds include improving methods for controlling rats and feral cats in native forests, determining ecological requirements of *Culex* mosquitoes at mid- and high-elevation forests, and developing methods to control mosquito populations. Research priorities specific to 'apapane include the following:

- Determine if disease-resistant individuals exist and if so, if resistance is passed to offspring. Disease-resistant birds could be used to found of new populations.
- Determine the role of 'apapane in disease transmission between high- and low-elevation habitats.
- Conduct life history studies to quantify the population structure, dispersal patterns, survivorship, nesting phenology, and success of this poorly known species.

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Photo: Eric VanderWerf

Koa'e kea or White-tailed Tropicbird

Phaethon lepturus

SPECIES STATUS:
State recognized as Indigenous
NatureServe Heritage Ranking G5 - Secure
North American Waterbird Conservation Plan – High concern
Regional Seabird Conservation Plan - USFWS 2005

SPECIES INFORMATION: The koa'e kea or white-tailed tropicbird is a showy, white seabird (Family: Phaethontidae), related to boobies and frigatebirds. Six koa'e kea (white-tailed tropicbird) subspecies are recognized; only one (*P. l. dorothea*) breeds in Hawai'i. Adult male and females are mostly white, although sometimes with pale pinkish wash, except for a narrow black eye patch, black streak on upper wings, and black on the leading edge of the outer primaries; both sexes have long, narrow, white central tail feathers. Large yellow-green bill; legs and feet are very small. Flight is characterized by rapid wing beats, interspersed with brief periods of gliding. Koa'e kea (white-tailed tropicbird) usually forage alone, but occasional with conspecifics, most often far from land; often will follow ships. Koa'e kea (white-tailed tropicbird) captures prey by plunge diving from 15 to 20 meters (50 – 65 feet) above the water. Diet is poorly known, but includes flyingfish and is likely similar to koa'e ula or red-tailed tropicbird (*P. rubricauda*). Koa'e kea (white-tailed tropicbird) breed in colonies and pairs remain together for years. At the beginning of the breeding season, pairs engage in complex aerial displays. Nests are placed in hard to reach locations on cliffs as well as in caves and tree hollows; nests have little if any material. In Hawai'i, breeding occurs March through October and a single egg is laid per season. Both parents incubate the egg, and brood and fed the chick. No post-fledging care is provided. Based on few data, age at first breeding is likely after fourth year; no data on longevity.

DISTRIBUTION: Koa'e kea (white-tailed tropicbird) breed on Midway Atoll and in the MHI at the following locations: Waimea Canyon, Kīlauea Point National Wildlife Refuge, and the Nā Pali Coast on Kaua'i; Pelekunu Valley, Waikolu, and windward sea cliffs on Moloka'i; Kaholo Pali, Maunalei Gulch, Hauola Gulch on Lāna'i ; Kīlauea Crater and windward coast on the island of Hawai'i, and the offshore islet Mokoli'i. A few pairs nest on southeastern O'ahu. Outside of Hawai'i, koa'e kea (white-tailed tropicbird) breed on oceanic islands throughout the Atlantic, Indian, and Pacific oceans as well as the Caribbean. Outside the breeding season, adults are solitary and pelagic, and their range is poorly known.

ABUNDANCE: In Hawai'i, population estimated at 1,800 breeding pairs with most occurring in the MHI. The worldwide population is estimated at less than 200,000 breeding pairs.

LOCATION AND CONDITION OF KEY HABITAT: Terrestrial: Koa'e kea (white-tailed tropicbird) breeds mainly on oceanic islands. Frequently nests in inaccessible crevices or ledges on cliff walls, outside of Hawai'i the species is known to nest in a variety of sites including caves, tree hollows, and in closed-canopy rain forests. **Marine:** Pelagic and nearshore.

THREATS:

- Introduced predators. Like all seabirds, adults and nests susceptible to predation by rats (*Rattus* spp.) and feral cats (*Felis silvestris*).

CONSERVATION ACTIONS: The following management goals are important to Pacific seabird conservation: maintain, protect, and enhance habitat; eradicate or control non-natives; minimize bycatch and other negative effects of fishing; improve the effectiveness of oil spill response efforts; identify contaminates and hazardous substances; and minimize the effects of powerlines, towers, wind turbines and lights (USFWS 2005). The goal of these management actions is not only to protect seabird populations and their breeding colonies, but also to re-establish former breeding colonies thereby reducing the risk of extinction. In addition to these efforts, future management specific to Hawaiian populations of koa'e kea (white-tailed tropicbird) should include the following:

- Eradication and control of introduced predators at current and potential breeding colonies.
- Continued protection and management of existing wildlife sanctuaries and refuges.

MONITORING: Continue surveys of population and distribution in known and likely habitats.

RESEARCH PRIORITIES: Most research priorities for seabirds are related to determining the most appropriate methods for achieving the above goals**.** Research priorities specific to koa'e kea (white-tailed tropicbird) include the following:

- Conduct long-term demographic studies to determine population trends, philopatry to nest colonies and nest sites, survival rates, and reproductive success.
- Develop survey protocol to assess population status and monitor trends.

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Photo: DOFAW

Migratory Birds

Kōlea
or Pacific Golden-Plover

Pluvialis fulva

SPECIES STATUS:
State recognized as Indigenous
U.S. Shorebird Conservation Plan - High concern

SPECIES INFORMATION: The kōlea or Pacific golden-plover is a moderately small yellow-and-buff mottled shorebird (Family: Charadriidae) which winters in the Main Hawaiian Islands (MHI) and breeds in Siberia and westernmost Alaska. Most adults arrive in Hawai'i in August, while juveniles arrive in October; spring departures begin in late April. Kōlea feed primarily on terrestrial insects such as cockroaches, moths, caterpillars, and earwigs, all of which they locate by sight. During the breeding season, they are also known to eat berries, leaves, and seeds. Kōlea show high site fidelity to wintering grounds and will chase intruders from their territories while foraging. Hawai'i is thought to support a large proportion of the world's wintering kōlea population.

DISTRIBUTION: Kōlea winter across the tropical Pacific, in upland and coastal areas from Hawai'i to Japan. In Hawai'i, kōlea are more common in NWHI year-round, but between August and May are also commonly seen on all of the MHI.

ABUNDANCE: Reliable estimates of the global kōlea population have not been made. One estimate of the east Asian population was 90,000, while the population of the MHI has been estimated at 74,000 individuals. In the late 1960s, the O'ahu population was estimated at about 15,000. From 1986 to 2004, the average number of kōlea in Hawai'i State waterbird surveys has been about 950 ± 170 (SE) individuals across MHI. Estimated wintering densities range from 0.22 to 44.7 birds per hectare in wild habitats such as forest trails and coastal mudflats. Densities in developed habitats in Hawai'i have been estimated as 1.4 birds per hectare on golf courses and 5.2 birds per hectare on lawns.

LOCATION AND CONDITION OF KEY HABITAT: The winter range of kōlea is extremely varied, including crop fields, pastures, coastal salt marshes, mudflats, beaches, mangroves, grassy areas at airports, cemeteries, athletic fields, parks, residential lawns, golf courses, roadsides, and clearings in heavily wooded areas. In Hawai'i, birds also use open stands of ironwood (*Casuarina* spp.) and small urban lawns and gardens in areas such as downtown Honolulu. Military bases and airports often provide important wintering grounds. Where suitable habitats (pastures, etc.) occur on mountain slopes, kōlea range to at least 2,500 meters (8,125 feet) elevation. Extensive land-clearing in Hawai'i, dating back to the Polynesian colonization, has probably improved wintering conditions by creating open habitat with plentiful insects.

THREATS: Hunting was a significant threat until 1941 when it was prohibited, and populations are thought to have rebounded since then. Effects of pesticide exposure on wintering grounds and along migratory routes are unknown, but on golf courses in Hawai'i, kōlea come into contact with herbicides and pesticides that may be harmful. Aircraft strikes at Līhu'e (Kaua'i) and Kahului (Maui) airports occur occasionally in the fall, apparently as naive juvenile birds attempt to establish foraging territories on airport grounds.

CONSERVATION ACTIONS: To protect the ability of wintering kōlea to survive while in Hawai'i and to return in good condition to breeding grounds in Alaska, current statewide and island-specific conservation actions should include:

- Protection of current habitat.

MONITORING: Continue surveys of population and distribution in known and likely habitats.

RESEARCH PRIORITIES: Kōlea studies remain fragmentary, probably because the species is neither endemic nor endangered. Research priorities should include the following:

- Increased study of all aspects of ecology and behavior of kōlea in Hawai'i, and comparative research on unstudied populations elsewhere.
- Evaluation of conditions on winter range habitats as related to expanding human activities (e.g., agriculture, reclamation, urbanization, pollution).
- Increased effort to make accurate population estimates, along with systematic monitoring wherever possible to facilitate the recognition of trends and potential problems.

References:

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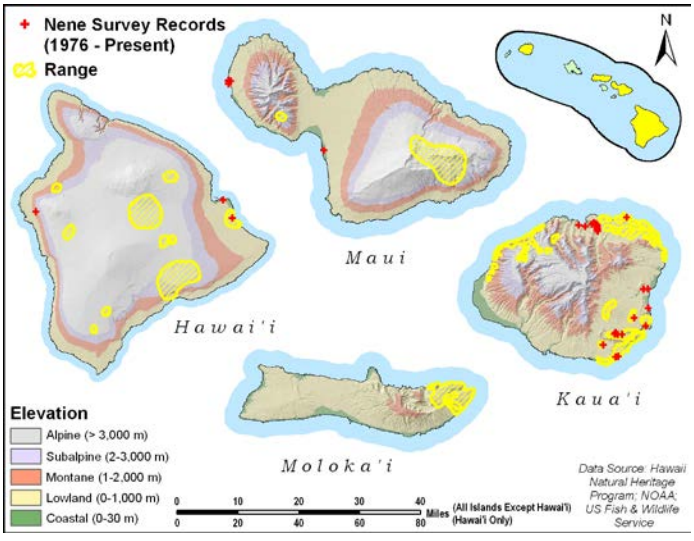
Photo: Jack Jeffery

Nēnē
or Hawaiian goose

Branta sandvicensis

SPECIES STATUS:
Federally Listed as Endangered
State Listed as Endangered
State Recognized as Endemic
NatureServe Heritage Rank G1 - Critically Imperiled
IUCN Red List Ranking - Vulnerable
Revised Recovery Plan for the Nēnē or Hawaiian Goose (*Branta sandvicensis*) – USFWS 2004

SPECIES INFORMATION: Historically, at least five species of geese (family: Anatidae) occurred in Hawai'i; today, only the nēnē, or Hawaiian goose, survives. Adults are mostly dark brown or sepia with a black face and crown, cream-colored cheeks, and a buff neck with black streaks. Females are smaller than males. Compared to other geese, nēnē are more terrestrial and have longer legs and less webbing between their toes, which likely facilitates walking on lava flows. Nēnē graze and browse on the leaves, seeds, flowers, and fruits of at least 50 native and nonnative grasses, sedges, composites, and shrubs. Diet varies by location and habitat, and they may require a diverse suite of food plants. Currently, several species of nonnative grass are important in mid- and high-elevation habitats. Nēnē facilitate seed dispersal and play an important role in influencing the species composition of early successional plant communities. Historically, flocks moved between high-elevation feeding habitats and lowland nesting areas. Pairs mate for life and engage in relatively simple courtship displays in which the male attacks or threatens potential competitors, runs back to his mate, and calls loudly. Nēnē have an extended breeding season, and nesting may occur in all months except May, June, and July, although the majority of birds nest between October and March, and most clutches are laid between October and December. Nests consist of a shallow scrape lined with plant material and down. Breeding pairs usually return to the previous year's nest site, typically in dense vegetation; when available, kīpuka may be preferred. Females lay two to five eggs, which hatch after 30 days. Young are precocial and not fed by their parents; however, they remain with their parents for up to a year.



DISTRIBUTION: Between sea level and 2,400 meters (7,800 feet) elevation on the island of Hawai'i, Maui, Kaua'i, and Moloka'i, and a single pair was reported on O'ahu in 2014. Historically, the

species was found on all Main Hawaiian Islands and was likely widespread.

ABUNDANCE: In 1951, the wild nēnē population was estimated at 30 individuals and information on historical abundance is limited. The current population is estimated at 2,450–2,550 birds, with 550 on the island of Hawai'i, 400 on Maui, 1,500 on Kaua'i, 80 on Moloka'i, and a single nesting pair reported on O'ahu in 2014. During 2005-2010, about 224 nēnē were removed from near the Kaua'i Airport and released at remote relocation sites on that island to reduce the risk of bird-aircraft strikes. Since 2011, the continued growth of the Kaua'i nēnē population prompted the removal of an additional 600 nēnē from the vicinity of the Kaua'i Airport and which were released into the wild on Hawai'i and Maui.

LOCATION AND CONDITION OF KEY HABITAT: Nēnē historically occurred in lowland dry forest, shrubland, grassland, and montane dry forest, and shrubland. Current habitat preferences are likely biased by the location of release sites of captive-bred birds. They currently use a wide variety of habitats including coastal dune vegetation and nonnative grasslands (e.g., golf courses, pastures, rural areas), sparsely vegetated low- and high-elevation lava flows, mid-elevation native and nonnative shrubland, early successional cinderfall, cinder deserts, native alpine grasslands and shrublands, and open native and nonnative alpine shrubland-woodland community interfaces. Nesting occurs in a variety of habitats, including beach strand, shrubland, grassland, and lava rock, and at a range of elevations. On the islands of Hawai'i and Maui, most nests are built under native vegetation, such as pūkiawe (*Styphelia tameiameiae*), 'a'ali'i (*Dondonaea viscose*), and 'ōhi'a (*Metrosideros polymorpha*). On Kaua'i, however, most nesting areas are dominated by nonnative species, and nēnē often nest under Christmas berry (*Schinus terebinthifolius*), shrub verbena (*Lantana camara*), and ironwood (*Casuarina* spp.). The condition of habitats occupied by nēnē varies considerably. Many of the areas used by the species are managed for conservation by the State of Hawai'i and the U.S. Fish and Wildlife Service (USFWS).

THREATS: Historical threats included habitat loss and degradation, hunting, and predation by rats (*Rattus* spp.), cats (*Felis silvestris*), dogs (*Canis familiaris*), and the small Indian mongoose (*Herpestes auropunctatus*). Current threats include predation by nonnative mammals; exposure to diseases that can be transmitted by introduced nonnative animals such as feral and domestic cats (e.g. toxoplasmosis); nutritional deficiencies due to paucity of quality habitat, exposure stress at high-elevation habitats; a lack of contiguous lowland habitat; human-caused disturbance and mortality (e.g., road mortality, disturbance by hikers, aircraft strikes, collisions with wind turbines); behavioral problems related to captive propagation; and inbreeding depression.

CONSERVATION ACTIONS: Past and current actions include captive propagation and release of captive-bred individuals into the wild, predator control, habitat enhancement, research and monitoring, private conservation efforts, formation of the Nēnē Recovery Action Group, and public education. Other actions specific to conservation of nēnē should include the following:

- Enhance and protect habitats used by nēnē, including foraging habitat, breeding grounds, and summer flocking areas.
- Increase predator control effort and effectiveness, including use of predator-proof fences. Increase efforts to detect and remove mongooses from Kaua'i.

- Significantly increase efforts to minimize negative human-nēnē interactions through public education and outreach focused on communities or areas where the number of nēnē are known to be increasing; continue to promote avoidance and minimization measures that will reduce the risk of collisions with vehicles , aircraft, and wind turbines.
- Develop a statewide long-range management plan for nēnē that includes all of the distinct populations and anticipates changes resulting from management actions and human interaction.
- Continue the nēnē population reintroduction efforts and establish additional populations only where risks can be minimized and habitat quality can support recovery.

MONITORING: Continue surveys to monitor abundance and distribution and annual productivity.

RESEARCH PRIORITIES:

- Standardize survey and monitoring protocols and develop a platform for data sharing.
- Conduct studies on diet and nutrition, particularly as it relates to forage quality of nonnative versus native vegetation, focusing on the needs of goslings and breeding females.
- Refine predator control and exclusion methods.
- Evaluate movement patterns and habitat use by nēnē.
- Evaluate and refine translocation and release methods that incorporates monitoring subsequent dispersal and movement patterns, survival, and reproduction.
- Investigate population genetics as a management tool to monitor the potential for inbreeding.

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Photo: USFWS

Terrestrial Mammal

ʻŌpeʻapeʻa or Hawaiian hoary bat

Lasiurus cinereus semotus

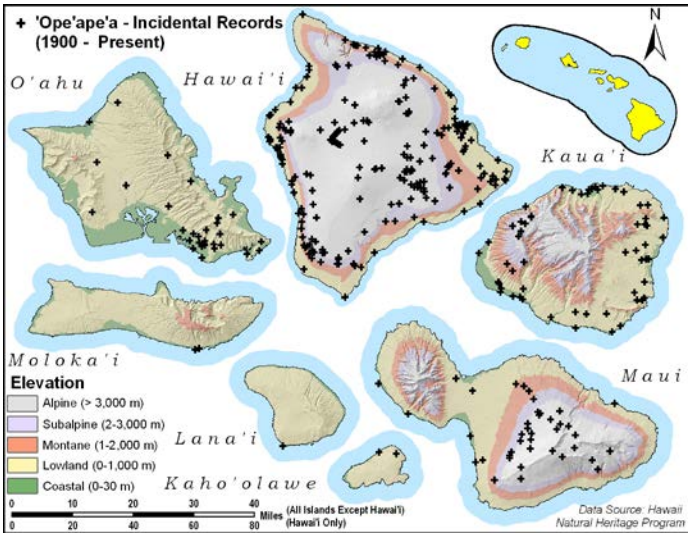
SPECIES STATUS:
Federally Listed as Endangered
State Listed as Endangered
State Recognized as Indigenous (at the Species Level and Endemic at the Subspecies Level)
NatureServe Heritage Rank G5/T2 – Species Secure/Subspecies Imperiled
Recovery Plan for the Hawaiian Hoary Bat – USFWS 1998

SPECIES INFORMATION: The ʻōpeʻapeʻa, or Hawaiian hoary bat (Family: Vespertilionidae), is Hawaiʻi's only native terrestrial mammal, although sub-fossil evidence indicates that at least one other bat species was native to the islands. Additionally, the hoary bat has dispersed to the Hawaiian Islands from the mainland at least twice, forming two different populations of Hawaiian hoary bats (Russell et al. 2015). The first emigrant arrived approximately ten thousand years ago, and the more recent emigrant arrived an estimated 600 years ago (Russell et al. 2015). Both sexes have a coat of brown and gray fur. Individual hairs of the coat are tipped or frosted with white; hence the name "hoary" which means frosted. The older population of hoary bats on the Hawaiian Islands is typically chestnut brown in color with less white "frosting" of the fur tips—it has largely lost the "frosted" appearance. The more recent population comprises individuals that are more hoary ("frosted"), similar to mainland hoary bats. Males and females have a wingspan of approximately one-third of a meter (1 foot), and females are typically larger than males. The Hawaiian name refers to a half taro leaf or canoe sail shape; these being somewhat similar to the shape of the bat.

Little research has been done on the ʻōpeʻapeʻa, and little is known about its habitat requirements or population status. Fewer than 30 accounts of roosting are known statewide, but these indicate that ʻōpeʻapeʻa roost in native and non-native vegetation from 1 to 9 meters (3 – 29 feet) above ground level; the species is rarely observed using lava tubes, cracks in rocks, or human-made structures for roosting. While roosting during the day, ʻōpeʻapeʻa are solitary, although mothers and pups roost together. They begin foraging either just before or after sunset depending on the time of year; altitude also may affect activity patterns. ʻŌpeʻapeʻa feed on a variety of native and non-native night-flying insects, including moths, beetles, crickets, mosquitoes, and termites; and similar to other insectivorous bats, prey is located using echolocation. Water courses and edges (e.g., coastlines and forest/pasture boundaries) appear to be important foraging areas; the species also is attracted to insects that congregate near lights. Breeding bats (e.g., lactating females) have been documented only on the islands of Hawaiʻi, Kauaʻi, and Oʻahu (Dave Johnston pers. obs.). Mating most likely occurs between September and December, and females usually give birth to twins during June. Mother bats likely stay

with their pups until they are six to seven weeks old. Little is known regarding dispersal or movements, but inter-island dispersal is possible.

DISTRIBUTION: The hoary bat is the most widely distributed bat in North America. In Hawai'i, 'ōpe'ape'a have been reported from all the Main Hawaiian Islands except for Ni'ihau, although specimen records exist only for Kaua'i, O'ahu, Maui, Moloka'i, and the island of Hawai'i. 'Ōpe'ape'a occur in a wide range of habitats across a wide elevation gradient. On the island of Hawai'i, bats are found primarily from sea level to 2,288 meters (7,500 feet) elevation, although they have been observed near the island's summits (above 3,963 meters or 13,000 feet). See "Location and Condition of Key Habitat," below, for distribution by seasons.



ABUNDANCE: Mostly unknown, although Pinzari et al. 2014 suggested that the population on the island of Hawai'i has been stable or is slightly increasing based on occupancy models from acoustic monitoring. Survey methods to count or estimate populations of solitary roosting bats have not been established. Although based on incomplete data, Kaua'i and the island of Hawai'i may support the largest populations.

LOCATION AND CONDITION OF KEY HABITAT: 'Ōpe'ape'a have been found roosting in 'ōhi'a (*Metrosideros polymorpha*), pu hala (*Pandanus tectorius*), coconut palms (*Cocos nucifera*), kukui (*Aleurites moluccana*), kiawe (*Proscopis pallida*), avocado (*Persea americana*), shower trees (*Cassie javanica*), pūkiawe (*Styphelia tameiameiae*), fern clumps, eucalyptus (*Eucalyptus* spp.), cook pine (*Araucaria columnaris*), and Norfolk Island pine (*Araucaria heterophylla*) stands. Recent work on the island of Hawai'i found that bat activity varied with season and altitude, and the greatest level of activity occurred at low elevations (below 1,280 meters or 4,200 feet) from April to December (Bonaccorso et al. 2015). Because warm temperatures are strongly associated with reproductive success in this and other bat species, it has been suggested that key breeding habitat is likely to occur at sites where the average July minimum temperature is above 11°C (52°F). If true, key breeding habitat on the island of Hawai'i would occur below 1,280 meters (4,200 feet) elevation (Bonaccorso et al. 2015). Because bats use both native and non-native habitat for foraging and roosting, the importance of non-native timber stands, particularly those at low elevations, should be determined. Breeding sites are known for Mānuka Natural Area Reserve and scattered areas along the Hāmākua Coast.

THREATS: Bats are affected by habitat loss, pesticides, collisions with structures, and roost disturbance. A reduction in tree cover (e.g., roost sites) might be the primary reason for the species' decline in Hawai'i. Pesticides also may have reduced populations. Bats are known to interact and sometimes collide with wind turbines. Lastly, bats of many species are affected by predation, so this may also be a problem for 'ōpe'ape'a.

CONSERVATION ACTIONS: The goals of conservation actions are to not only protect current populations and key breeding habitats, but also to establish additional populations thereby reducing the risk of extinction (U.S. Fish and Wildlife Service 1998). In addition to common statewide and island conservation actions, specific management directed toward ʻōpeʻapeʻa should include the following:

- Conserve known occupied habitat.
- Develop and implement conservation plans and strategies that guide the management and use of forests to reduce negative effects on known bat populations.
- Support Hawaiian hoary bat research.

MONITORING: Continue surveys of population and distribution in known and likely habitats and identify key limiting factors affecting the recovery of the species.

RESEARCH PRIORITIES: Given that little is known about ʻōpeʻapeʻa any research would contribute to the understanding of and ability to conserve this species. Research priorities for the ʻōpeʻapeʻa include the following:

- Develop standard survey and monitoring methods and procedures that will allow the accurate estimation of populations and changes in activity and/or occupancy.
- Conduct occupancy surveys of all the Main Hawaiian Islands to examine distribution and population trends.
- Identify key breeding and wintering sites.
- Better describe roost site characteristics and preferences.
- Increase efforts to track and monitor movements and behaviors.
- Determine the extent to which Hawaiian hoary bats use torpor.
- Better describe threats and important factors limiting recovery such as whether depredation by introduced animals or availability of prey represent constraints for populations.
- Continue to support the development of avoidance and minimization measures that can be effectively implemented to reduce collisions with wind turbines.
- Direct research findings toward the development of conservation and management actions that address the needs and deficiencies of the species and refine these approaches using an adaptive management approach.

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Photo: NRCS

Pueo or Hawaiian Short-eared Owl

Asio flammeus sandwichensis

SPECIES STATUS:
State listed as Endangered on O'ahu
State recognized as Endemic at the subspecies level
NatureServe Heritage Rank G5/T2 –
Species secure/Subspecies imperiled

SPECIES INFORMATION: The pueo, or Hawaiian short-eared owl, is an endemic subspecies of the nearly pandemic short-eared owl (*Asio flammeus*; Family: Strigidae). The species is thought to have colonized the Hawaiian Islands sometime after the arrival of Polynesians. Unlike most owls, pueo are active during the day (i.e., diurnal), and are commonly seen hovering or soaring over open areas. Like short-eared owls in continental environments, those in Hawai'i primarily consume small mammals. Their relatively recent establishment on Hawai'i may have been tied to the rats (*Rattus exulans*) that Polynesians brought to the islands. Little is known about the breeding biology of pueo, but nests have been found throughout the year. Males perform aerial displays known as a sky dancing display to prospective females. Nests are constructed by females and are comprised of simple scrapes in the ground lined with grasses and feather down. Females also perform all incubating and brooding. Males feed females and defend nests. Chicks hatch asynchronously and are fed by female with food delivered by male. Young may fledge from nest on foot before they are able to fly and depend on their parents for approximately two months.

DISTRIBUTION: Found on all the Main Hawaiian Islands from sea level to 2,450 meters (8,000 feet).

ABUNDANCE: Unknown. Because of relatively few detections, the Hawaiian Forest Bird Survey did not estimate the population size of the pueo. Pueo were widespread at the end of the 19th century, but are thought to be declining.

LOCATION AND CONDITION OF KEY HABITAT: Pueo occupy a variety of habitats, including wet and dry forests, but are most common in open habitats such as grasslands, shrublands, and montane parklands, including urban areas and those actively managed for conservation. Because of a lack of historical population data and the species' current, broad habitat use, key habitat variables are difficult to determine. Pueo occur in many areas that are managed by the Sate of Hawai'i or Federal agencies.

THREATS: Pueo are likely susceptible to the same factors that threaten other native Hawaiian birds, including: loss and degradation of habitat, predation by introduced mammals, and disease. However, their persistence in lowland, non-native and rangeland habitats suggests

that they may be less vulnerable to extinction than other native birds, especially because they may be resistant to avian malaria (*Plasmodium relictum*) and avian pox (*Poxvirus avium*). Despite this, for pueo populations, the following are of particular concern:

- "Sick owl syndrome". Mortality on Kaua'i has been attributed to this syndrome, which may be related to pesticide poisoning or food shortages.
- Predation. Because pueo nest on the ground, their eggs and young are vulnerable to predation by rats (*Rattus* spp.), cats (*Felis silvestris*), and the small Indian mongoose (*Herpestes auropunctatus*).
- Habitat loss. May be particularly important to O'ahu pueo populations.
- Contaminants or toxins. Because pueo are top predators, fat-soluble contaminants may accumulate in prey species; may be related to "sick owl syndrome" (see above).
- Human interaction. Hunting behavior and habitat use predispose pueo to vehicular collisions, which have been documented on Lāna'i and the island of Hawai'i.

CONSERVATION ACTIONS: Pueo likely have benefited from management activities designed to conserve other endangered birds. They also may benefit from game bird management; high densities of pueo occur on lands where game birds also are common. In addition to these efforts, future management specific to the pueo may include the following:

- Determine population trends, especially on islands where "sick owl syndrome" has been documented.
- Public outreach and education.
- Continue protection and management of wildlife sanctuaries and refuges.

MONITORING: Regular island-wide population surveys are necessary to determine population trends for this species. This information is needed to assess the efficacy of habitat management efforts.

RESEARCH PRIORITIES: Research priorities specific to pueo include the following:

- Analysis of population trends and changes in habitat occupancy, especially on O'ahu.
- Determine the cause of "sick owl syndrome" and its potential effect on populations.
- Quantify the number of vehicular collisions and determine the level of threat to populations.

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Photo: C. S. N. Bailey, NPS

ʻUaʻu or Hawaiian petrel

Pterodroma sandwichensis

SPECIES STATUS:
Federally Listed as Endangered
State Listed as Endangered
State Recognized as Indigenous
NatureServe Heritage Rank G2/T2 –
Species Globally Imperiled/Subspecies Locally Imperiled
IUCN Red List Ranking – Vulnerable
Regional Seabird Conservation Plan – USFWS 2005

SPECIES INFORMATION: The ʻuaʻu or Hawaiian petrel is a medium-sized, nocturnal gadfly petrel (Family: Procellariidae) endemic to Hawaiʻi. The name is derived from a commonly uttered call, heard at colonies. Adults are uniformly dark grayish black above forming a partial collar which contrasts with white throat, forehead, and cheeks; entirely white below except for black tail and leading and trailing edges of underwings. Owing to darkness of back color, the 'W-pattern' across back and upper surface of wings is not visible except in worm plumage. Bill black, and legs and feet mostly pink. Even during the breeding season, ʻuaʻu often feed thousands of kilometers from their breeding colonies, usually foraging within mixed-species feeding flocks over schools of predatory fishes. They feed by seizing prey while sitting on the water or by dipping prey while flapping just above the ocean surface. In Hawaiʻi, they feed primarily on squid, but also on fish, especially goatfish and lantern fish, and crustaceans. ʻUaʻu nest in colonies, form long-term pair bonds, and return to the same nest site year after year. Colonies are now typically in high-elevation, xeric habitats or wet, dense forests, although before the arrival of the Polynesians and their associated animals these birds nested in the lowlands, too. They nest in burrows, crevices, or cracks in lava tubes; nest chambers can be from 1 to 9 meters (3-30 feet) deep. Most eggs are laid in May and June and most birds fledge by December, although there are significant inter-island differences in breeding phenology; for example, the nesters that are earliest by more than a month reside at the summit of Haleakala Volcano. Both parents incubate the single egg, and brood and feed the chick. Birds first breed at five to six years of age.

DISTRIBUTION: Nests among the Main Hawaiian Islands (MHI) including Maui, Hawaiʻi, Kauaʻi, Lānaʻi, and possibly on Molokaʻi. Subfossil evidence indicates that prior to the arrival of Polynesians, ʻuaʻu was common throughout the MHI. At sea, they occur throughout the central tropical and subtropical Pacific Ocean.

ABUNDANCE: In the early 1990s the population was estimated at 19,000 individuals with a breeding population of 4,500 to 5,000 pairs, although inaccessible nesting locations make accurate counts difficult. Analysis of at-sea counts indicate broad consistency with the island-based estimates. More recently (1998-2011) the global population was estimated at 52,000 birds,

although due to differences in sampling methods it is unknown whether these higher numbers reflect a population increase or a difference in the proportion of the total population sampled. More than 1,800 individuals occur at Haleakalā National Park on Maui (a few hundred more nest in West Maui), around 150 pairs occur on Mauna Kea, Hawai'i; around 1,600 pairs occur on Kaua'i; several thousand birds occur on Lāna'i; and potentially around 50 pairs nest on Moloka'i.

LOCATION AND CONDITION OF KEY HABITAT: Nests in a variety of remote, inland habitats. On the islands of Hawai'i and Maui, colonies are located above 2,500 meters (8,200 feet) in xeric habitats with very sparse vegetation, with most nests in existing crevices in the lava. On Kaua'i and Lāna'i, and West Maui colonies occur in lower-elevation forests dominated by 'ōhi'a (*Metrosideros polymorpha*) often with a dense understory of uluhe fern (*Dicranopteris linearis*). At sea, they are pelagic and occur over the open ocean.

THREATS:

- Historical hunting. Nestlings were considered a delicacy by Polynesians, and were harvested from nest burrows, including artificial ones constructed by the Polynesians. Adults were netted as they returned to colonies, and smoky fires were sometimes lit along flight corridors to disorient and ground birds.
- Introduced predators. Adults and chicks are susceptible to depredation by dogs, pigs, rats, barn owls, feral cats, and the small Indian mongoose. The presence of these destructive introduced animals, the main force behind population decline, has relegated the species now to nest only in remote interior areas, at very high altitude, or on islands that are predator-free.
- Feral ungulates. Feral goats (*Capra hircus*), mouflon sheep (*Ovis musimon*), and potentially axis deer (*Axis axis*) trample burrows and degrade nesting habitat.
- Artificial lighting. Street and resort lights, especially in coastal areas, disorient fledglings, causing them to eventually fall to the ground exhausted or increasing their chance of colliding with artificial structures (i.e., fallout) such as powerlines. Once on the ground, fledglings are killed by cars, cats, and dogs, or die of starvation or dehydration.
- Collisions. Adults and fledglings are susceptible to mortality from collisions with obstacles such as communication towers, utility lines, fences, and wind farm structures while commuting between inland nest sites and the ocean at night.
- Colony locations. The remoteness of colonies, as well as the habitat in which they occur (e.g., steep terrain or dense forest), complicates predator and ungulate eradication or control.

CONSERVATION ACTIONS: Past actions directed at 'a'o (Newell's shearwater [*Puffinus auricularis*]) have often benefited 'ua'u populations. These actions include the rescue and rehabilitation of downed fledglings by the Save Our Shearwaters (SOS) program and efforts to shade and curtail resort and event lighting and streetlights. Current and future conservation efforts on Kaua'i to benefit should include efforts to reduce and shield lighting, control predators and invasive species at breeding colonies, conduct surveys to locate and characterize additional colonies, evaluate updated population estimates, and implement management actions appropriately. Actions being carried out in association with several Habitat Conservation Plans, along with State and federal recovery efforts are resulting in conservation benefits to 'ua'u on Maui, Lāna'i and Kaua'i; these include efforts to protect existing breeding populations and establish new colonies using predator-proof fencing, predator control,

ungulate control, social attraction, and translocation work plans. In addition to these efforts, future management actions specific to ʻuaʻu populations should include the following:

- Continue predator and ungulate control at colonies on Hawaiʻi, Maui, Lānaʻi, and Kauaʻi, and potentially at offshore islets that contain suitable nesting habitat.
- Locate additional breeding colonies on Lānaʻi, Hawaiʻi, Maui, and Kauaʻi and perform surveys on Molokaʻi, Lānaʻi, and Kahoʻolawe to assess ʻuaʻu presence on these islands.
- Continue to identify fallout areas and minimize effects of powerlines and artificial lights.
- Continue to support the SOS program, particularly public outreach about light attraction and fallout, the rescue and rehabilitation program, and the establishment of similar programs on other islands where appropriate.
- Re-establish/expand breeding colonies by identifying suitable candidate locations for social attraction and/or translocation, and continue to refine translocation protocols.

MONITORING: Continue at-sea and terrestrial surveys in known and likely habitats to evaluate the population size and status, and to locate unidentified breeding colonies. Monitor breeding incidence, breeding density, reproductive success, causes of mortality, population trends, return rates and effectiveness of management at breeding colonies. Assess the efficacy of predator control efforts.

RESEARCH PRIORITIES:

- Develop and implement standardized survey and monitoring protocols that can be used throughout Hawaiʻi to better estimate population parameters and changes.
- Expand and refine radar studies to monitor population trends, locate colonies, investigate behavior, determine geographic variability in threats, and evaluate the effectiveness of conservation measures.
- Conduct long-term demographic studies to evaluate reproductive success, breeding incidence, breeding density, colony boundaries, population trends, and survival rates.
- Develop, refine, and monitor the outcome of conservation actions and measures that are employed to avoid and minimize impacts from flight collision and other causes, and broaden adaptive management approaches.

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Cabinet-level direction on invasive species issues
Hawaii Invasive Species Council

PLUME POPPY (*Bocconia frutescens*)

Hawaii Pacific Weed Risk Assessment: None
Regulatory Status: Hawaii Noxious Weed List (HAR 68)
Prevention and Control Category: None

Description

- Shrub to small (20 ft) tall tree
- Native to Central and South America, introduced to Hawaii as an ornamental garden plant

Impacts

- Aggressive invader of dry forests. Forms dense stands that crowd out and compete with native plants, keeping them from growing
- Each plant can produce thousands of seeds that are particularly attractive to birds, which spread them long distances.
- Mechanical and chemical control of this species is difficult. Plants often resprout after control and persistence is required to completely control plume poppy.

Distribution

- Kauai: Not present. Please contact KISC if you see this plant on Kauai.
- Oahu: Present, but not an OISC target. Landowners are encouraged to control this pest.

- Maui: Serious invader in native dry and mesic forests of East Maui with dense infestations from Kula to Kahikinui. It is not believed to be controllable or eradicable on an island-wide basis. Landowners are asked to control where possible.
- Molokai: None known.
- Lanai: None known.
- Kahoolawe: None known.
- Big Island: Infestations in Wood Valley, Kau Forest Reserve, Honomalino and Manuka on the Big Island. BIISC has worked to control this plant in cooperation with landowners and community groups, but has no current funding to continue work. Please call 643-PEST if you see this plant, especially in the Honomalino area.

SILKY OAK (*Grevillea robusta*)

Hawaii Pacific Weed Risk Assessment: 8, High Risk
Regulatory Status: None
Prevention and Control Category: None

Description

- Common names: Silky oak, silk oak, silver oak
- Tall tree that grows up to 70f ft. in height.
- Young branches are hairy and rusty.
- Leaves simple, alternate, smooth, deeply and narrowly lobed, grows up to 1 ft. long. Lower surface of leaves rusty turning to whitish with margins curling under.
- Flower in clusters up to 7 inches long, orange to golden brown in color. Peak blooming occurs from May to June.
- Fruits are dry, dark capsules (follicles) with a long hair-like appendage at the end.

Silky oak flower and fruit

Impacts

- Silky oak was widely planted and is a prolific seeder.
- It is a pest in mesic pastures and forests.
- Pollen may trigger allergies.

Distribution

- Native to Australia.
- It was introduced to Hawai‘i around 1880 with over two million trees have been planted throughout Hawai‘i.
- Occurs on all major islands.
- Drought resistant but also does well in moist areas (60-80 in. rainfall).

Flowering silky oak

CHRISTMAS BERRY (*Schinus terebinthifolius*)

Hawaii Pacific Weed Risk Assessment: 19, High Risk
Regulatory Status: None
Prevention and Control Category: None

Description

- Common names: Brazilian peppertree, Christmasberry, wilelaiki.
- A local politician Willie Rice used to wear the berries on his hat, hence the name wilelaiki
- Small tree that grows up to 20 ft. in height, bark is dark and slightly rough.
- Leaves alternate, pinnately compound with 7 leaflets, each about 3 in. by 1.25 in. wide. Terminal leaflet is the largest.
- Flowers are in clusters, greenish white in color. Male and female trees separate.
- Fruits cluster, bright red “berries,” papery hull, single seed per fruit. Trees fruit in fall and winter hence the name “Christmasberry.”
- Seeds will not germinate while in fruit and will retain viability no more than nine months.

Impacts

- Grows densely in dry mesic pastures and forests.
- This plant is a prolific seeder and is spread by birds.
- Pollen can cause respiratory problems and the sap can cause rash.
- Seeds are known to kill deer and horses.

Distribution

- Native of Argentina, Brazil and Paraguay
- Widespread throughout Hawaii in mesic to dry areas.
- Also a serious problem in Florida and Australia.

FIREWEED (*Senecio madagascariensis*)

Hawaii Pacific Weed Risk Assessment: 23, High Risk.
Regulatory Status: Hawaii Noxious Weed List (HAR 68)
Prevention and Control Category: KISC Target Species. OISC Target Species. MoMISC Target Species.

Description

Fireweed is already widespread on the islands of Maui, Oahu, Lanai, and Hawaii, but can be prevented from invading Kauai. Fireweed is a daisy-like herb that grows up to 2' high. The stem is upright and slender with bright green leaves. The leaves are smooth, very narrow (only ¼" wide), have serrated edges, and they reach about 5" long. The small yellow flowers have 13 petals and are about the size of a nickel. The mature flowers turn into white thistle-like downy seed balls.

Impacts

Fireweed invades pastures, disturbed areas, and roadsides. It is very toxic to cattle, horses and other livestock. When ingested it causes illness, slow overall growth, liver-malfunction and even death in severe cases. In Australia, fireweed costs over $2 million per year in losses and control.

Distribution

Fireweed is native to Madagascar and South Africa. Fireweed was first discovered on the Big Island in the 1900's and is now too widespread for control there. This pest can also be found on Maui and Lanai. On Kauai, known infestations from hydro-mulched areas near Halfway Bridge and in Kalihiwai were controlled by KISC and HDOA. Kauai, Oahu, and Molokai continue to be monitored for new infestation areas. The preferred habitat for this weed is disturbed grasslands, abandoned pastures and roadsides. Fireweed grows on a wide range of soils in sub-humid to humid subtropical woodland.

Look-alike Species

Spanish needle (*Bidens pilosa*):Spanish needle is a widespread invasive herb on Kaua'i. It has tiny yellow flower clusters unlike fireweed's daisy-like flowers. Spanish needle also grows much taller; up to 6 feet. **THIS LOOK-ALIKE IS ALSO A PEST!**

Wedelia (*Sphagneticola trilobata*): Wedelia is another widespread invasive herb that is commonly planted as an ornamental groundcover. It can be distinguished from fireweed by its larger yellow flowers which grow 1-2″ wide. It also has a variable amount of pedals, unlike fireweed's constant 13. **THIS LOOK-ALIKE IS ALSO A PEST!**

AUSTRALIAN TREE FERN (*Sphaeopteris cooperi*)

Hawaii Pacific Weed Risk Assessment: 16, High Risk
Regulatory Status: None
Prevention and Control Category: MoMISC Target Species

Description

- Large tree fern up to 12 m (40ft) tall with large (up to 6m long) triangular leaves, lacy blades
- Scaly, brown stems fall off when dead, leaving oval scars
- White hairs on stalks (unlike native hapuu, which has red hairs)
- Trunk doesn't have the thick, soft fiber wrapping like the native hapuu
- Native to Australia, introduced to Hawaii as an ornamental

Impacts

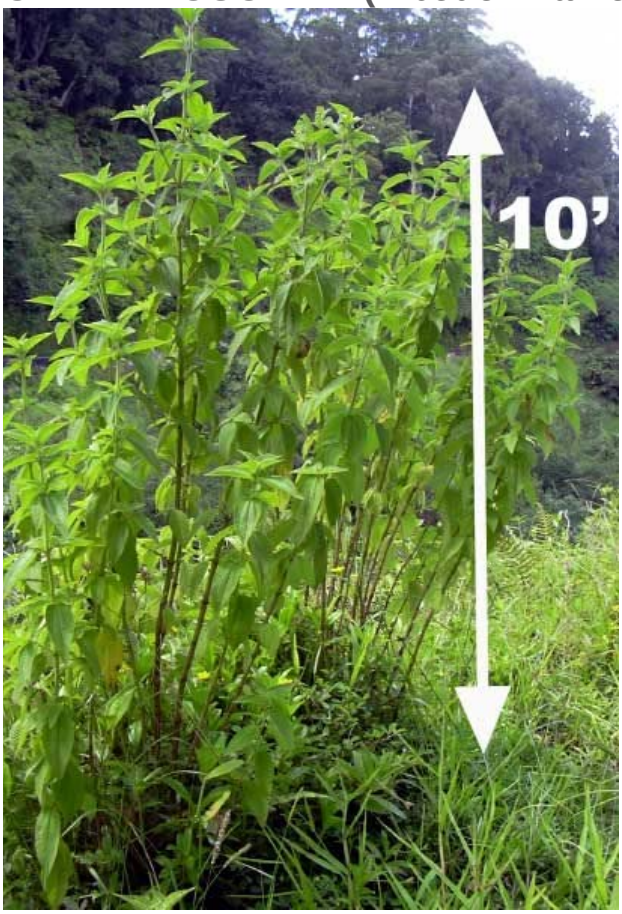
- Wind spread spores can travel over 12 km (7 miles) from parent plant, as seen when plants from Hana nurseries spread to Kipahulu Valley.
- Fast growing and aggressively outcompetes native plants in the forest understory
- Displaces native ferns, including the slower growing hapuu

Distribution

- Kauai: Spreading in native forests including Hanalei, Koloa, and Kokee. Landowners are asked to plant non-invasive alternates instead.
- Oahu: Spreading in the Koolau and Waianae mountains. Landowners are asked to plant non-invasive alternates instead.
- Maui: Widely cultivated and naturalized. Infesting Kipahulu Valley, Peahi, Haiku, and areas in West Maui.

- Molokai: No infestations known in the wild, although planted in landscaped areas at several residences. MoMISC is working to educate community members to remove these plants and select non-invasive alternates.
- Lanai: Presence/absence unknown
- Kahoolawe: None known.
- Big Island: Spreading from landscaped areas in Volcano, Laupahoehoe, Kona and other areas. Landowners are asked to plant non-invasive alternatives instead of non-native tree ferns.

CANE TIBOUCHINA (*Tibouchina herbacea*)



Hawai‘i-Pacific Weed Risk Assessment Score: 24 (*Visit http://www.hpwra.org for more information*)
Regulatory Status: Hawai‘i Noxious Weed List (HAR 68)
Prevention and Control Category: OISC Target Species

Report this species if seen on O‘ahu

REPORT INVASIVE SPECIES
643-PEST
643pest.org
CALL OR CLICK TO PROTECT HAWAII

Description

- This shrub is semi woody and can grow up to 9′ tall.
- The young stems are angled and hairy.
- The leaves are opposite, 3″ long by 1.4″ wide, hairy, and have 5-7 prominent veins.
- The flowers are pink and have 4 petals with bright yellow anthers.
- The fruit is cup-like and extremely small.

- The seeds are very small and numerous.

Impacts

- This plant is a prolific seeder and spread by birds.
- It forms dense stands in pastures and can also invade disturbed forest areas, displacing native species.

Distribution

- This shrub is native to southern Brazil, Uruguay, and Paraguay.
- Cane tibouchina has heavy infestations on Maui and Big Island.
- It occurs in the northern Koʻolau range on Oʻahu, as well as on Molokaʻi and Lānaʻi, and in Hilo, including lower Saddle Road on Hawai'i.
- This pest is not known to be on Kauaʻi. Please report any new sighting of this pest!

Look-alike Species

Glorybush (*Tibouchina urvilleana*): Also called princess flower, this is another Melastome species that can be very invasive. It has larger, purple flowers with five petals and can grow up to 12′ tall. The anthers of this plant are purple, unlike the yellow anthers of cane tibouchina. This plant can be seen in Kōkeʻe, naturalized along the roadside. This look-alike is also a pest.

Asian melastome (*Melastoma candidum, M. septemnervium*): This is a spreading shrub that forms tangled brush between 5′ to 15′ tall. Each flower usually contains five to six petals, averaging 1″ long. This plant is widespread across Kauaʻi. This look-alike is also a pest.

Pages 46 - 65 - Excerpt from:

Hawaiian Islands Climate Vulnerability and Adaptation Synthesis

2018

www.EcoAdapt.org

Citation
Gregg, R.M., editor. 2018. Hawaiian Islands Climate Vulnerability and Adaptation Synthesis. EcoAdapt, Bainbridge Island, WA.

For more information on this report and other products, please contact Rachel@EcoAdapt.org and visit http://bit.ly/HawaiiClimate.

Produced in cooperation with the Pacific Islands Climate Change Cooperative with funding from the U.S. Fish and Wildlife Service

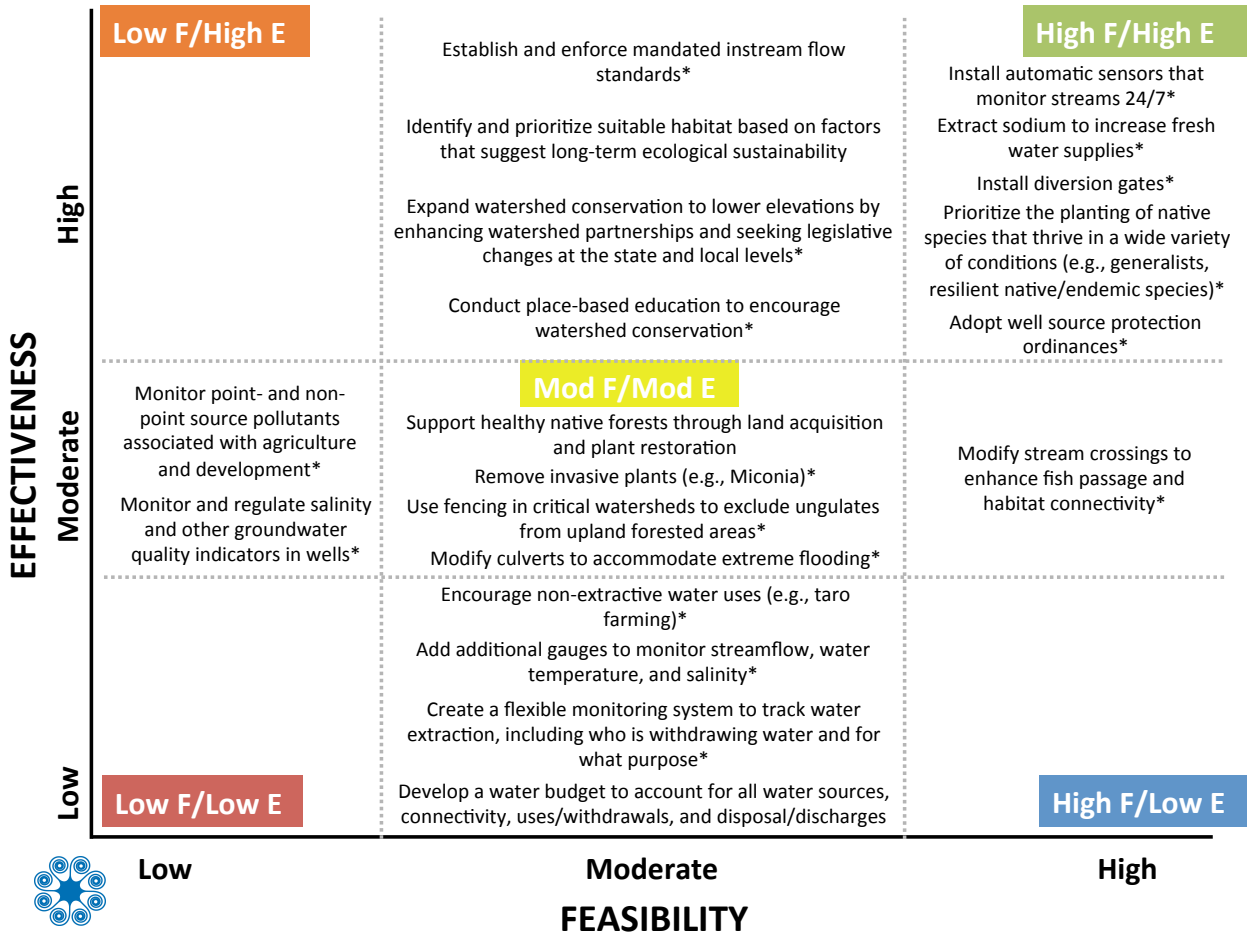


Figure 10. Maui Nui aquatic habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants. All other adaptation action evaluations are based on expert opinion.

Dry Forest

Dry forests and mesic lowland shrublands are typically found in low-elevation areas and on leeward slopes (up to 2,000 m [6,560 ft]), and receive the majority of their moisture from cloud/fog drip and intermittent rain. These habitat types are often associated with younger, shallow substrates comprised of cinder, ash, and lava flows. Dry forests also feature ephemeral streams and wetlands. These habitats are dominated by a variety of species, including lama, ʻōhiʻa, koa, wiliwili, ʻaʻaliʻi, olopua, ʻālaʻa, alaheʻe, ʻōlapa, lovegrass, and pili grass.

Vulnerability Assessment Results

Dry forest habitats were evaluated as having *moderate-high* vulnerability to climate change due to *moderate-high* sensitivity to climate and non-climate stressors, *moderate-high* exposure to projected future climate changes, and *low-moderate* adaptive capacity. Because dry forests are already limited by moisture, they are most sensitive to climatic factors that increase water stress, such as increased drought, warmer air and soil temperatures, reduced soil moisture, and changes in the timing of precipitation; these changes are likely to impact species recruitment, community composition, and forest distribution. Disturbance events (e.g., wildfire, floods, wind, insects, disease) may also damage

forest areas, reducing forest cover and canopy integrity and increasing vulnerability to invasion, while non-climate stressors, such as residential and commercial development, agriculture, and pollution, further reduce habitat extent, integrity, and continuity, limiting species dispersal and recruitment. Invasive species (e.g., ungulates, mammalian predators, trees/shrubs, flammable grasses, social insects, and pathogens/parasites) also impair dry forest recruitment and recovery by competing with and displacing vegetation, altering ecosystem processes (e.g., water infiltration, pollination), and/or causing direct plant damage or mortality.

Over 90% of historical dry forest area in Hawai‘i has already been lost, and the remaining area is highly fragmented and vulnerable to conversion to agriculture or other uses. Although dry forests are diverse and have high numbers of endemic species, many native species are endangered. Although intensive restoration efforts have led to the successful reestablishment of native species in some areas, degraded dry forests are largely unable to recover without active management.

Adaptation Planning Results

Table 11 presents a summary of possible adaptation strategies and actions for Maui Nui dry forest habitat, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 11 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 11. Summary of possible adaptation strategies and actions for Maui Nui dry forest habitat.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Manage invasive species	•! Expand the use of fencing in and remove invasive ungulates and plants from remnant native habitats and corridors between protected habitats
	Maintain and protect existing dry forest habitat	•! Improve biosecurity controls to prevent the introduction of invasive insects, pathogens, plants, and animals
	Improve fire prevention and response	•! Maintain fuel breaks below power lines and on road sides •! Use managed grazing and fuel treatments to limit potential fire spread and severity
Resilience *Near- to mid-term approach*	Maintain and restore existing dry forest habitat	•! Collect and propagate native seeds for revegetation in disturbed areas •! Consider climate projections in the timing and seasonality of planting to promote natural recruitment
	Improve resilience of key dry forest species/communities	•! Identify and prioritize existing dry forest biomes and create a strategy to expand protection and restoration •! Create a digital and physical genetic database to protect remaining species, using both in situ

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
		(outplanting) and ex situ (seed storage) methods •! Explore genetic engineering for increased resilience (e.g., drought tolerance)
Response *Long-term approach*	Improve resilience of key dry forest species/communities	•! Identify key species that are most adapted to future climate conditions
	Identify and promote climate-adapted species composition	•! Map transitional areas between dry and mesic habitat to identify and prioritize protection for areas of mesic habitat that may transition to dry habitat •! Use common garden experiments to outplant along elevational/moisture gradients and identify species applicability under changing conditions
	Use assisted colonization to restore rare species (e.g., corals, turtles, birds)	•! Identify and prioritize suitable habitat for release of rare species •! Protect and prepare habitat for rare species introduction by increasing habitat quality and reducing threats (e.g., predators, invasive species, human disturbance) •! Release rare species into suitable habitat and monitor survival, dispersal, reproductive success, abundance, and genetic diversity
Knowledge *Near- to long-term approach*	Increase knowledge to improve dry forest restoration	•! Identify gaps in cultural and technical knowledge to prioritize research needs •! Develop new technologies to increase survival and long-term restoration success (e.g., fog drip capture, irrigation, invasive species, biomimicry, nanobots)
Collaboration *Near- to long-term approach*	Increase capacity for dry forest restoration	•! Create a community workforce to implement restoration in historic dry forest and high-priority sites in a timely manner
	Raise public awareness and community support for dry forest protection	•! Conduct a comprehensive public media campaign to highlight the importance of dry forest habitats and what is at risk from climate change (e.g., culture, economy, ecosystem services) •! Engage community (i.e. cultural woodworkers, agricultural producers) in addressing knowledge gaps and restoration work •! Celebrate success to keep the community involved

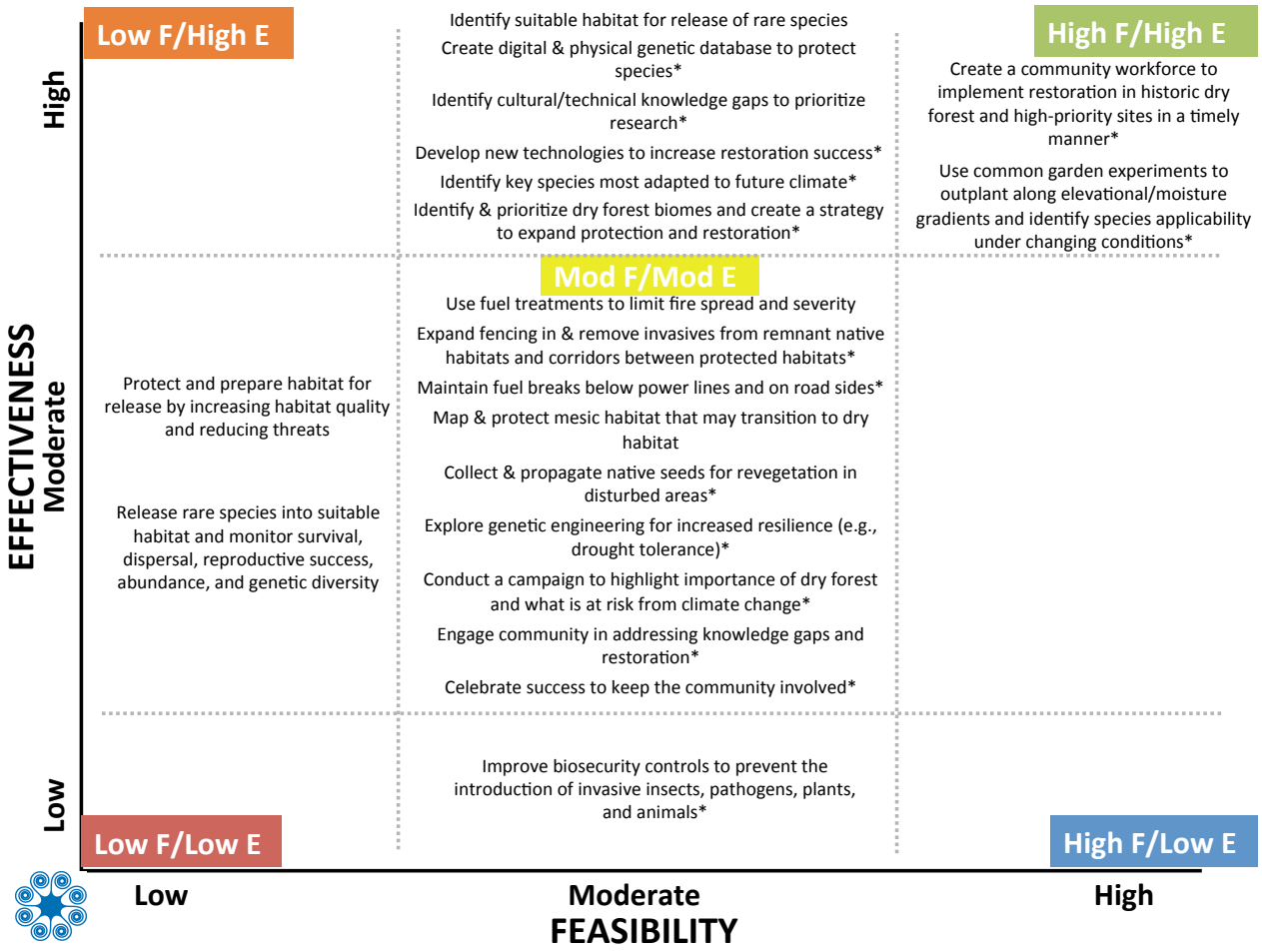


Figure 11. Maui Nui dry forest habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants. All other adaptation action evaluations are based on expert opinion.

Mesic and Wet Forest

Mesic and wet forest habitats are typically found on windward lowland areas and montane slopes up to elevations of 2,194 m (7,200 ft). These mesic/wet bands are created in areas that lie at or below the mean height of the TWI, and receive up to 7,620 mm (300 in) of rainfall per year. Mesic and wet forest habitat types range from mesic forests to tropical montane cloud forests, and are typically dominated by ʻōhiʻa and koa trees with dense understories comprised of shrubs, ferns, and sedges. Mesic and wet forest habitats can be found on east Maui from Makawao clockwise to Kipahulu and Kahikinui, and on the upland, windward slopes of west Maui. On Lānaʻi, mesic forest habitats are distributed on the windward slopes and extend down to the ocean. Kahoʻolawe lies in the rain shadow of Maui and does not contain mesic or wet forest habitat.

Vulnerability Assessment Results

Mesic and wet forest habitats were evaluated as having *moderate* vulnerability to climate change due to *moderate-high* sensitivity to climate and non-climate stressors, *moderate-high* exposure to projected future climate changes, and *moderate* adaptive capacity. Mesic and wet forests are sensitive to factors that alter moisture gradients, such as drought, precipitation amount and timing, storms, and air

temperature. Disturbance events, such as disease, wind, and insect outbreaks can damage large habitat areas, potentially allowing invasive plants to become established. Invasive ungulates, mammalian predators, trees/shrubs, flammable grasses, and pathogens/parasites are the primary non-climate stressors for mesic and wet forest types, and have led to the rapid decline of many native and endemic species over the past several hundred years. High-elevation wet forests remain relatively intact, but lowland areas and mesic forests experience development pressure and conversion to agriculture, ranching, or other uses. Forest species diversity and endemism is very high, and many species are able to recover rapidly from wildfire and other disturbances. Management and restoration efforts are likely to be relatively successful at alleviating the impacts of climate change, though public value and societal support for mesic and wet forest habitats is low.

Adaptation Planning Results

Table 12 presents a summary of possible adaptation strategies and actions for Maui Nui mesic and wet forest habitats, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 12 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 12. Summary of possible adaptation strategies and actions for Maui Nui mesic/wet forest habitat.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Manage invasive species	•! Expand fencing to lower elevations, focusing on incipient sites or most vulnerable areas throughout the forest •! Increase upfront investment in ungulate and mammalian predator removal through hunting/shooting and snares •! Remove invasive plants through biological, chemical, or mechanical treatments •! Prevent introduction of new insects and diseases by increasing biosecurity controls (e.g., quarantines, intra-island policies, optional vs. mandatory restrictions)
	Improve fire prevention and response	•! Prevent off-road vehicle and pedestrian activity in high recharge areas, sensitive watersheds, and core native habitats through education and access limits
Resilience *Near- to mid-term approach*	Maintain intact, native-dominated ecosystems	•! Outplant native species to create habitat and facilitate biome shifts •! Augment native habitat through outplanting and seeding of temperature- and drought-tolerant species in post-disturbance sites and buffer zones
	Maintain and restore water quality and quantity by controlling erosion and sedimentation	•! Plant species that control erosion (e.g., vetiver) •! Create and maintain check dams and retention basins to mechanically control erosion
Response	Facilitate transition of	•! Create test plots to determine where habitat may shift

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Long-term approach	species into new areas as climate regimes shift	along ecotone boundaries and identify potential unintended consequences •! Prioritize the planting of native species that thrive in a wide variety of conditions (e.g., generalists, resilient native/endemic species)
	Manage invasive species	•! Erect fences across biome and habitat borders to allow for potential habitat and species range shifts
Knowledge *Near- to long-term approach*	Develop more efficient technologies/tools for habitat restoration and invasive species control	•! Increase technical capacity and decrease regulations of invasive species removal (e.g., herbicide delivery) •! Develop biocontrol methods for invasive species •! Improve methods for native species propagation (all taxa) in high-quality core habitat
	Increase education and outreach to instill a community conservation ethic	•! Increase awareness of biocultural and ecosystem services
	Collect data on existing non-climate stressors	•! Monitor abundance of native and invasive forest species as temperature rises and precipitation changes
Collaboration *Near- to long-term approach*	Increase direct community restoration	•! Conduct place-based community education, organizing, management, and action focused on habitat restoration, cultural practices, and climate change impacts
	Create new/improve partnerships to increase capacity	•! Collaborate with universities to conduct research on invasive species management •! Improve data sharing within and between agencies

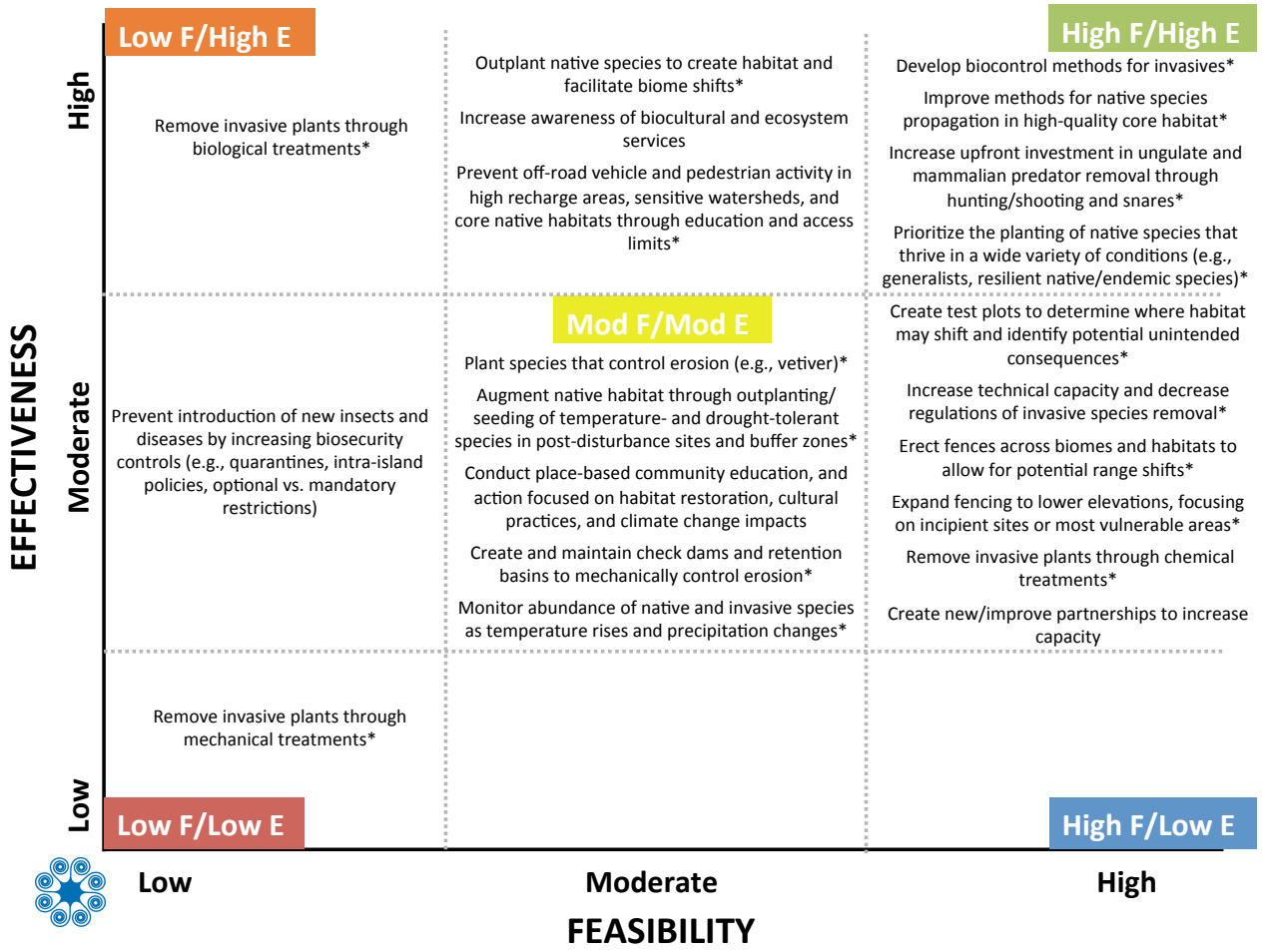


Figure 12. Maui Nui mesic and wet forest habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants. All other adaptation action evaluations are based on expert opinion.

Alpine/Subalpine

Alpine and subalpine habitats are found in high-elevation areas of Haleakalā on Maui. These habitats mostly lie above the mean height of the TWI, and are arid with very little precipitation or fog. Unlike many areas of the world, high-elevation vegetation is most likely limited by moisture rather than by temperature. Alpine communities are found above the tree line up to the summit of Haleakalā at 3,055 m (10,023 ft). Alpine habitats are dry and semi-barren, with sparse, highly specialized vegetation including the Haleakalā silversword. Subalpine communities lie between 2,000 and 3,000 m (6,560 to 10,000 ft) in elevation, and may consist of forests, shrublands, and grasslands. Dominant vegetation includes māmane, naio, and ʻōhiʻa trees; ʻōhelo, pūkiawe, and pilo shrubs; bracken fern; and alpine hairgrass. These communities are primarily found on windward east Maui, where subalpine shrublands transition into wet forest, and on leeward east Maui, where subalpine forests transition into remnant dry and mesic forest and and non-native habitats dominated by introduced forest and grassland species.

Vulnerability Assessment Results

Alpine and subalpine habitats in Maui were evaluated as having *moderate* vulnerability to climate change due to *moderate* sensitivity to climate and non-climate stressors, *moderate-high* exposure to projected future climate changes, and *low-moderate* adaptive capacity. Alpine and subalpine habitats are sensitive to factors that contribute to water stress, including changes in the amount and timing of precipitation, drought, air temperature, soil moisture, and changes in the frequency of the TWI. Disturbance events, such as wildfire, may allow invasive plants to become established, as native vegetation is slow to recover. Although non-climate stressors have a low impact on these habitats, invasive/problematic species and recreation can degrade habitats and alter native species composition. These habitat types are protected but very limited in extent, with little ability to shift upslope into higher-elevation areas. Although these habitats are highly valued, increasing water stress and the eventual loss of refugia may make it difficult for many endemic and highly specialized species to survive.

Adaptation Planning Results

Table 13 presents a summary of possible adaptation strategies and actions for Maui alpine and subalpine habitats, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 13 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 13. Summary of possible adaptation strategies and actions for Maui alpine/subalpine habitats.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Manage invasive species	•! Remove small mammals inside fences, as well as within a buffer around the fence •! Erect fencing to protect subalpine areas from feral ungulates •! Remove feral ungulates through aerial eradication, ground hunting, or snares •! Improve biosecurity controls to prevent the introduction of invasive insects, pathogens, plants, and animals
	Build fire-resilient native communities	•! Stabilize soils following wildfires to prevent post-burn erosion •! Increase fuel reduction efforts in common ignition sites and areas of high conservation value
Resilience *Near- to mid-term approach*	Manage invasive species	•! Prioritize invasive plant removal, focusing on areas with high diversity or rare species
	Maintain and augment native species populations	•! Identify a good existing seed bank and allow for natural regeneration •! Actively restore high-priority sites inside the fence, considering surrogate species that may be tolerant of future climate conditions
Response	Use assisted colonization to	•! Identify and prioritize suitable habitat for release of

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Long-term approach	restore rare species (e.g., birds)	rare species •! Protect and prepare habitat for rare species introduction by increasing habitat quality and reducing threats (e.g., predators, invasive species, human disturbance) •! Release rare species into suitable habitat and monitor survival, dispersal, reproductive success, abundance, and genetic diversity
	Facilitate transition of species into new areas as climate regimes shift	•! Create assessment/test plots to determine where habitat will be and whether there may be unintended consequences
Knowledge *Near- to long-term approach*	Improve silvicultural practices for priority species	•! Improve seed storage capacity •! Improve methodology for seed propagation •! Improve silvicultural planting methods (i.e. seed collection, composition, spacing)
	Conduct research to support adaptive policies and technology that increase landscape-level protection and restoration	•! Research and develop new/improved methods of small predator control •! Research and develop new/improved methods of weed control
Collaboration *Near- to long-term approach*	Increase direct community restoration	•! Conduct place-based community education, organizing, management, and action focused on habitat restoration, cultural practices, and climate change impacts

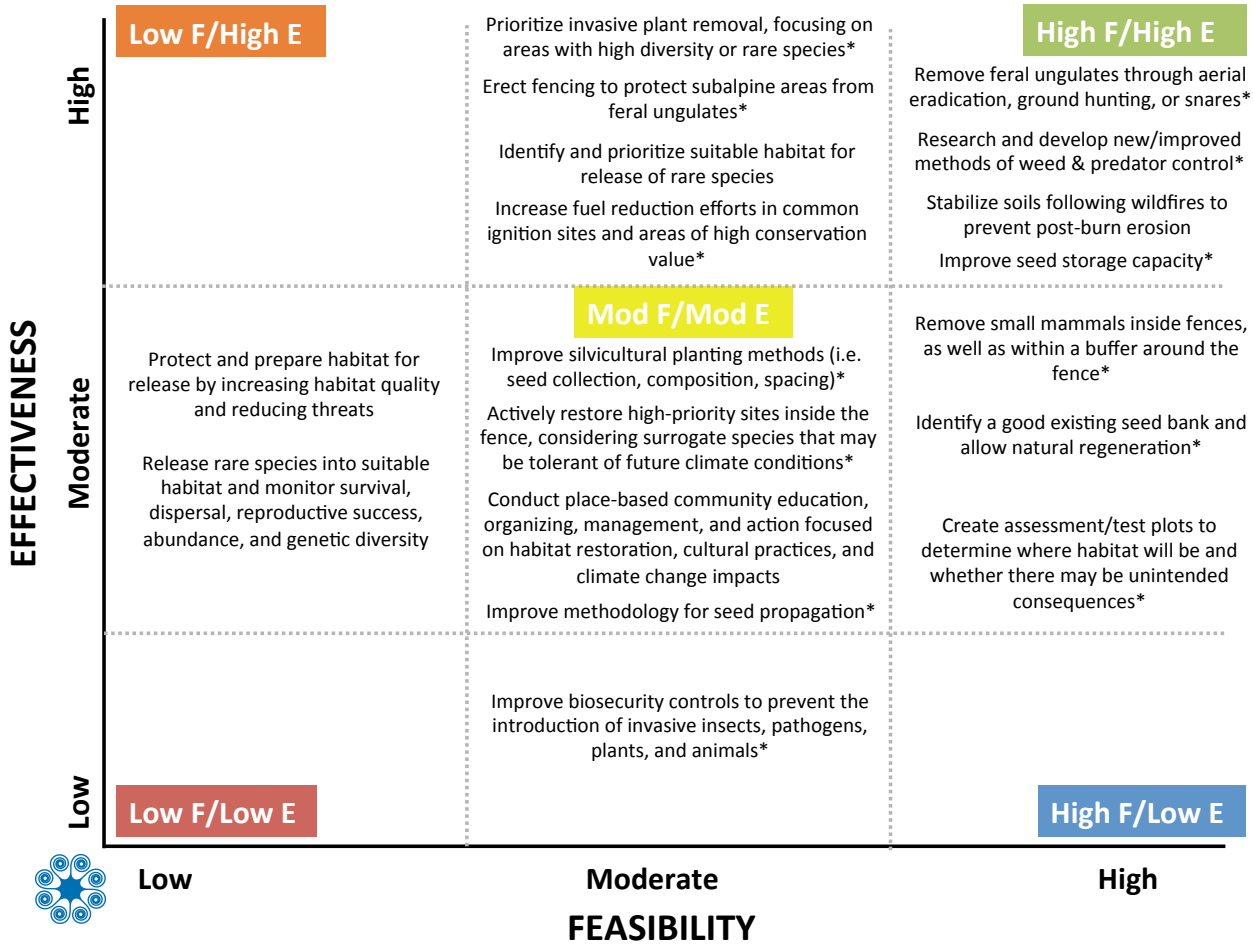


Figure 13. Maui Nui alpine and subalpine habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants, although in some cases the ranking was shifted based on expert opinion. All other adaptation action evaluations are based on expert opinion.

Cultural Knowledge and Heritage Values

Natural resources and Native Hawaiian culture are closely interwoven. Cultural knowledge is closely tied to the provisioning of food, clothing, and shelter, crop cultivation, plant propagation, and general stewardship of natural resources. Cultural heritage incorporates past legacies that relate to ecosystems and a sense of place, and includes many aspects of identity and spirituality. Many cultural practices are dependent on natural ecosystems, such as the gathering of native plant and animal species for food, medicine, carving, tools, weaving, jewelry, hula or traditional dance, and ceremonial practices.

Vulnerability Assessment Results

Cultural knowledge and heritage values on Maui Nui were evaluated as having *high* vulnerability to climate change due to *high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *low* adaptive capacity. This ecosystem service is vulnerable to climate changes that impact the health and integrity of ecosystems and/or native species, and changes that damage or destroy valued cultural assets and heritage sites; these include changes in precipitation and drought, air and water temperatures, sea level rise, coastal erosion, and disturbance events such as

wildfire, flooding, insects, and disease. Disturbance events can affect large areas and cause extensive damage or loss of living things and landscapes of cultural importance, and they can also limit access to traditional gathering areas or the ability to carry out traditional practices. Many non-climate stressors are linked to increasing human populations and associated impacts of changes in land use and the overuse of natural resources (e.g., residential and commercial development, pollution and poisons, water diversions, recreation, etc.), which have fragmented and degraded natural habitats, exacerbating the negative effects of climate change. The introduction and establishment of invasive species, including plants, wildlife, insects, fish, and pathogens/parasites, have had an especially large impact on cultural knowledge and heritage by altering ecosystem functions and driving the loss of native species and habitats.

Native Hawaiian knowledge and heritage is still affected by colonialism, and these values receive relatively little public and societal recognition and support. However, the importance of cultural knowledge, as well as the benefits it offers to ecosystems and other ecosystem services, is starting to be incorporated into natural resource management and decision-making processes to a greater degree.

Adaptation Planning Results

Table 14 presents a summary of possible adaptation strategies and actions for Maui Nui cultural knowledge and heritage values, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 14 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 14. Summary of possible adaptation strategies and actions for Maui Nui cultural knowledge and heritage values.

Adaptation Category	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Protect cultural practices (e.g., fishing, gathering, farming, fiber collection and processing)	•! Protect/create dedicated spaces for cultural practices •! Protect water rights and public access to the shoreline and forest
Resilience *Near- to mid-term approach*	Prioritize and pair habitat restoration with cultural resource management	•! Restore culturally significant habitats from mauka to makai (e.g., loʻi, forests, beaches) •! Implement ahupuaʻa practices to encourage geographically based restoration and a sustainability mindset •! Articulate the value of culturally significant habitats (especially for cultural resource improvement)
	Increase biocultural landscape-based planning and management	•! Create policies that maintain public access to coastal, forest, and wetland areas •! Enforce existing conservation zoning laws (e.g., Haleakalā) •! Revise planning documents (e.g., Maui Island Plan) based on climate change data •! Revise the coastal erosion formula and setback

Adaptation Category	Adaptation Strategy	Specific Adaptation Actions
		requirements in Special Management Areas to account for projected sea level rise
Response *Long-term approach*	Anticipate and facilitate habitat migration	•! Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes
Knowledge *Near- to long-term approach*	Increase understanding of cultural resources in need of protection	•! Collect data from the community in order to better protect cultural resources
	Ensure community-wide intergenerational transmission of knowledge	•! Facilitate mentorship and knowledge exchange among and between practitioners
Collaboration *Near- to long-term approach*	Increase direct community restoration	•! Conduct place-based community education, organizing, management, and action focused on habitat restoration, cultural practices, and climate change impacts
	Create healthy communities	•! Increase cultural community input on water use decisions •! Create/build relationships within the community, non-profit, and government sectors •! Break plantation mentality and strengthen ancestral connections

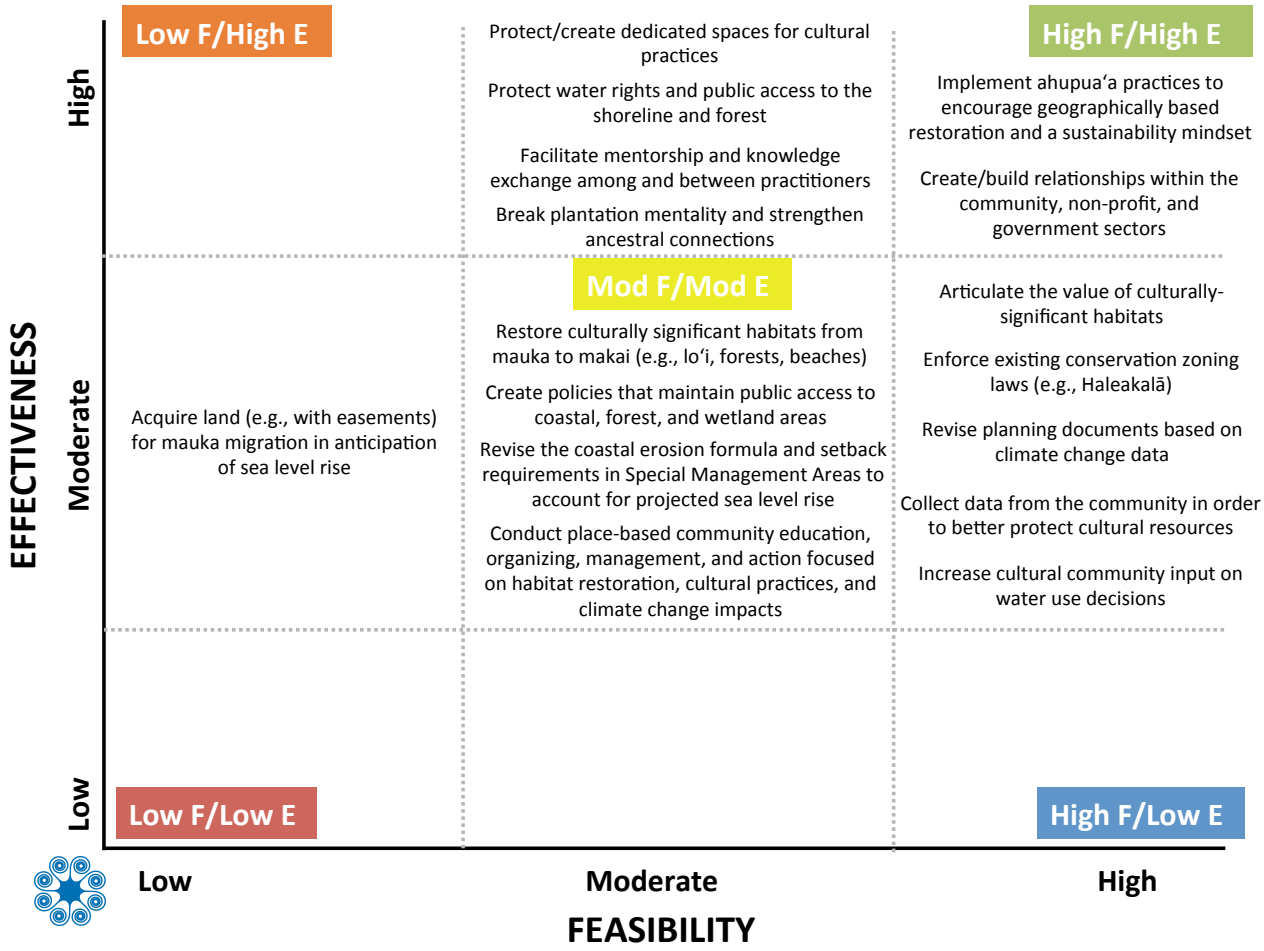


Figure 14. Maui Nui cultural knowledge and heritage values adaptation actions plotted according to implementation feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability). Those actions having high feasibility and effectiveness appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants, although in some cases the ranking was shifted based on expert opinion. All other adaptation action evaluations are based on expert opinion.

Flood and Erosion Control

Native terrestrial and aquatic ecosystems help regulate flooding and erosion by regulating surface and subsurface flow, storing and reducing rates of water discharge to water bodies, and anchoring and retaining sediment. For example, wetlands help slow floodwater velocity and attenuate sediment, and native forest landscapes intercept rain, slow runoff, and anchor sediment.

Vulnerability Assessment Results

The flood and erosion control ecosystem service on Maui Nui was evaluated as having *high* vulnerability to climate change due to *high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *moderate* adaptive capacity. Climatic changes such as extreme precipitation and flash flood events can overwhelm this service, while drought and wildfire impair or alter native ecosystems, affecting their ability to provide flood and erosion control. Non-climate stressors such as residential and commercial development, roads, highways, trails, recreation, and water diversions increase sheet flow and alter surface runoff patterns, typically increasing streamflow volumes and velocity. These stressors, along with agricultural land use and invasive species (e.g., grasses, ungulates, trees), also increase bare ground and reduce native vegetative cover, increasing erosion potential. Workshop participants indicated that best management practices in urban, agricultural, and

natural landscapes may help maintain flood and erosion control into the future, but also indicated that political will and public support for enhanced management will be needed.

Adaptation Planning Results

Table 15 presents a summary of possible adaptation strategies and actions for Maui Nui flood and erosion control, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 15 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 15. Summary of possible adaptation strategies and actions for Maui Nui flood and erosion control.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Manage invasive species	•! Use fencing in critical watersheds to exclude ungulates from upland forested areas •! Remove invasive plants (e.g., Miconia)
	Increase education and outreach to increase public engagement and stewardship in conservation	•! Increase education and outreach on invasive species risks and specific actions the public can take to reduce introduction and spread (e.g., sterilize recreation equipment)
	Improve fire prevention and response	•! Use managed grazing and fuel treatments to limit potential fire spread and severity •! Maintain fuel breaks below power lines and on road sides
	Decrease erosion and sediment delivery to improve water quality and protect municipal water supplies	•! Design and construct roads to minimize erosion and sediment production •! Increase and/or relocate road cross drains to decrease hydrologic connectivity between roads and streams
	Reduce non-climate stressors that affect water quality	•! Reduce pollutant and sediment runoff (e.g., revegetate slopes with native plants, reduce acreage of fallow agricultural land)
Resilience *Near- to mid-term approach*	Protect forests to increase recharge and water retention	•! Support healthy native forests through land acquisition and plant restoration
	Build fire-resilient native communities	•! Stabilize soils following wildfires to prevent post-burn erosion
	Maintain and restore water quality and quantity by controlling erosion and sedimentation	•! Plant species that control erosion (e.g., vetiver) •! Create and maintain check dams and retention basins to mechanically control erosion
Response *Long-term approach*	Facilitate transition of species into new areas as climate regimes shift	•! Prioritize the planting of native species that thrive in a wide variety of conditions (e.g., generalists, resilient native/endemic species)

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
	Provide sustainable recreation opportunities in response to changing supply and demand	•! Adjust the timing of actions (e.g. open/close dates, road or trail closures, food storage orders, special use permits) to accommodate changing climate conditions
Knowledge *Near- to long-term approach*	Anticipate and facilitate habitat migration	•! Conduct a cost-benefit analysis for a range of management alternatives based on climate change vulnerability assessments and prioritization processes
Collaboration *Near- to long-term approach*	Increase collaborative efforts to conserve streams and watersheds	•! Expand watershed conservation to lower elevations by enhancing watershed partnerships and seeking legislative changes at the state and local levels

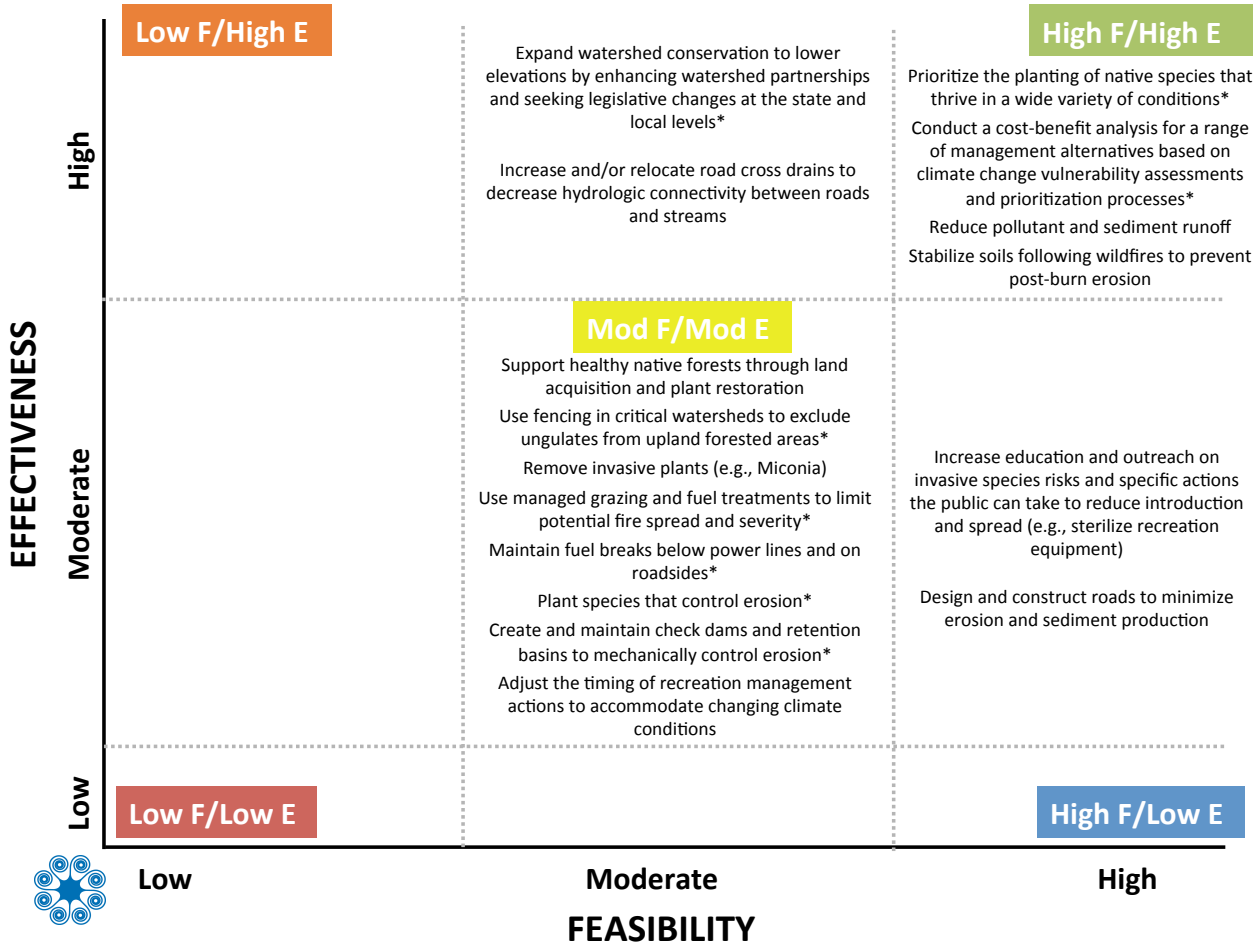


Figure 15. Maui Nui flood and erosion control adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants, although in some cases the ranking was shifted based on expert opinion. All other adaptation action evaluations are based on expert opinion.

Fresh Water

Fresh water is classified as a provisioning ecosystem service because it supplies both consumptive (e.g., drinking water, agricultural and industrial use) and non-consumptive human uses (e.g., power generation). Fresh water also supports other natural systems and processes that provide additional ecosystem services. For example, it supports aquatic habitats, which in turn provide ecosystem services such as food production, flood control, aesthetic values, and tourism and recreation. Native forests, wetlands, and other habitats help maintain fresh water supply by intercepting, slowing, and storing water. Native habitats also enhance water quality by anchoring and filtering sediment and filtering pollutants. Groundwater, surface water, and rainwater catchments represent the primary sources of fresh water on the Hawaiian Islands, including Maui Nui. On Maui, groundwater is the primary fresh water source for public supply (e.g., drinking water), while surface water has historically been predominantly used for irrigation. Overall, Maui had the highest fresh water use of all Hawaiian Islands from 1980–2010, largely due to irrigation.

Vulnerability Assessment Results

Fresh water was evaluated as having *high* vulnerability to climate change due to *high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *moderate-high* adaptive capacity. Climatic changes such as increasing drought frequency and severity, increasing precipitation variability, and warmer air temperatures are likely to reduce fresh water supply, and sea level rise may impair water quality. Shifting wind patterns may exacerbate changes in precipitation by altering orographic precipitation regimes, and changes in atmospheric circulation will likely increase TWI frequency, resulting in decreased rainfall. Other disturbance regimes such as wildfire and disease may reduce or alter native vegetation cover, impairing water capture and filtration. Non-climate stressors — including residential and commercial development, agriculture, energy development, water diversions, and groundwater development — alter water use and delivery, potentially exacerbating future climate-driven reductions in water availability. At a minimum, these stressors increase competition among water uses, which may become more problematic under drier climate conditions. Human land uses (e.g., roads, urban areas) and activities (e.g., recreation) can also impair water quality by introducing contaminants and alter water capture by increasing runoff and introducing invasive species. These invasive species — including invasive parasites/pathogens (e.g., ʻōʻhia rust), trees (e.g., strawberry guava, miconia, and kiawe), and ungulates (e.g., feral pigs, deer, goats, and cattle) — undermine watershed health and integrity, reducing water storage and degrading water quality.

The diverse uses of fresh water increase management challenges, particularly in the face of drier climate conditions. However, workshop participants indicated that fresh water is highly valued, which may support ecosystem service stewardship. Additionally, native landscape protection and restoration may help sustain fresh water quality and supply under variable climate conditions, although changes in societal water management, politics, and economics will also influence management opportunities.

Adaptation Planning Results

Table 16 presents a summary of possible adaptation strategies and actions for Maui Nui fresh water, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 16 plots adaptation

actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 16. Summary of possible adaptation strategies and actions for Maui Nui fresh water.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Improve water conservation efforts	•! Develop a water budget to account for all water sources, connectivity, uses/withdrawals, and disposal/discharge •! Increase agricultural water conservation (i.e. promote soil moisture management, capture rain water) •! Increase public and private water system conservation (i.e. alter rate structure, use low-flow fixtures, detect and fix leaks)
	Manage invasive species	•! Practice strategic watershed fence placement from mauka to makai to best enhance water quality •! Prevent introduction of new diseases and pathogens by increasing biosecurity controls (e.g., quarantines, intraisland policies, optional vs. mandatory restrictions)
	Maintain/improve water quantity and quality	•! Alter well drill depths and practice optimal well placement to minimize vulnerability to saltwater intrusion •! Investigate and reduce non-point source pollution
	Reduce non-climate stressors	•! Increase public education to minimize disturbance and/or degradation of vulnerable habitats or species
Resilience *Near- to mid-term approach*	Protect forests to increase recharge and water retention	•! Support healthy native forests through land acquisition and plant restoration
	Mandate acquisition of new technologies to maintain and enhance water quality	•! Extract sodium to increase fresh water supplies •! Install diversion gates
	Increase ecosystem resilience, connectivity, and integrity	•! Restore hydrologic function (i.e. reduce/remove diversions, convert ditches to pipes)
	Build fire-resilient native communities	•! Stabilize soils following wildfires to prevent post-burn erosion
Response *Long-term approach*	Increase ecosystem resilience, connectivity, and integrity	•! Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes
	Maintain/improve water quantity and quality	•! Integrate climate projections into Water Commission planning efforts
Knowledge *Near- to long-term approach*	Monitor pollutants to protect water quality	•! Monitor and regulate salinity and other indicators of water quality in wells and groundwater •! Monitor point- and non-point source pollutants associated with agriculture and development (e.g.,

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
		fertilizers, insecticides, agricultural byproducts)
Collaboration *Near- to long-term approach*	Increase collaborative efforts to conserve streams and watersheds	•! Expand watershed conservation to lower elevations by enhancing watershed partnerships and seeking legislative changes at the state and local levels

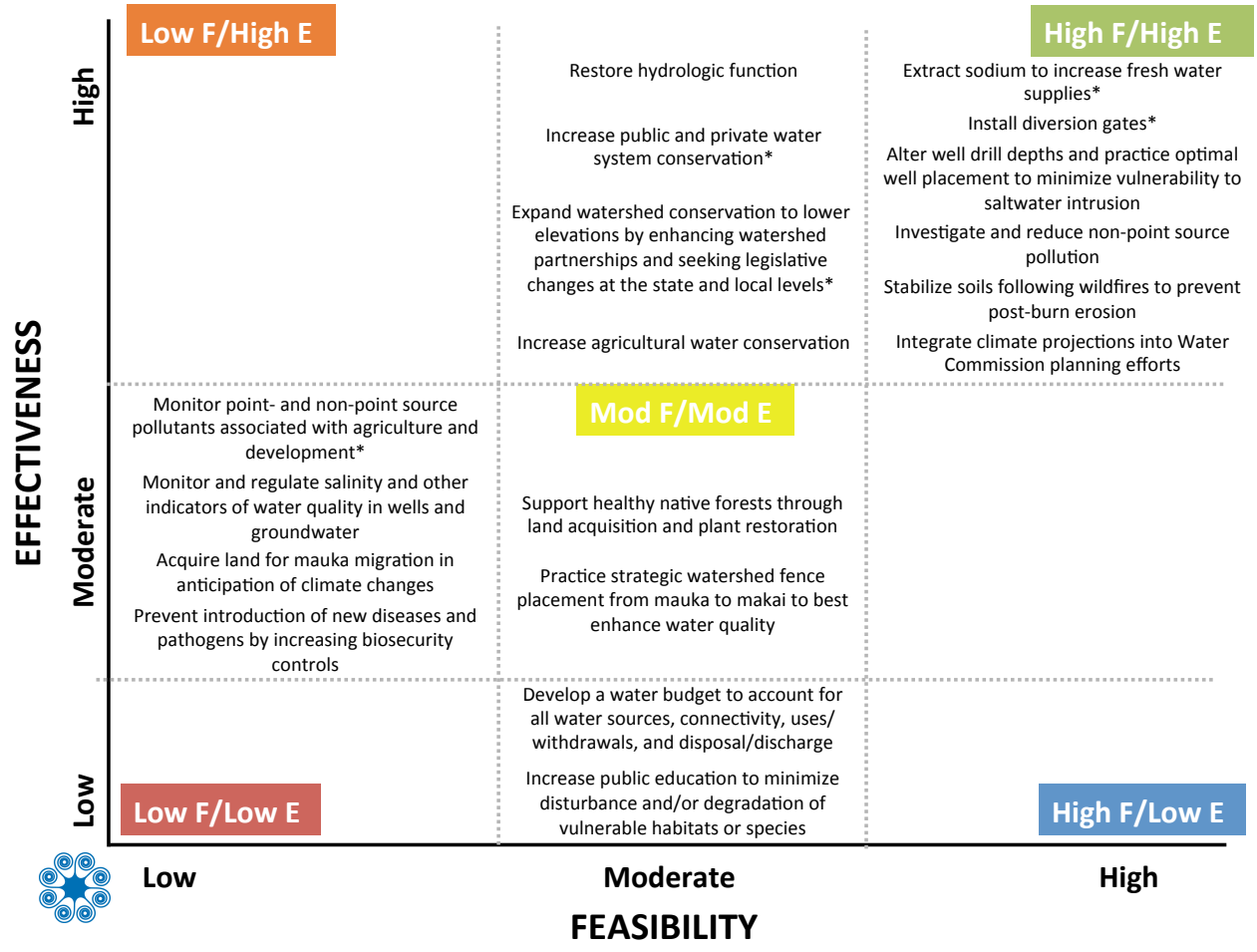


Figure 16. Maui Nui fresh water adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants, although in some cases the ranking was shifted based on expert opinion. All other adaptation action evaluations are based on expert opinion.

Food and Fiber

Agriculture, aquaculture, hunting, fishing, and gathering are used to obtain food and fiber resources, and these include many traditional cultural practices such as pig hunting, taro cultivation, fishpond aquaculture, and forest, marine, and shoreline gathering. Native species historically and currently harvested for these purposes are critical links to bridge past and present Hawaiian culture. Many food and fiber products are derived from canoe plants, a group of species that were transported to the Hawaiian Islands by early Polynesian voyagers several thousand years ago, and then carefully

propagated and cultivated for use as food and fibers. Notable canoe plants used for fiber include the hala tree, wauke, olonā, and hau bush; canoe plants used for food include ʻolena (turmeric), niu (coconut palm), ko (sugarcane), and maiʻa (banana).

Native Hawaiians also historically constructed and utilized coastal fishponds (loko iʻa) for aquaculture, although fishpond use and distribution has declined over time (Maui has 44 remnant fishponds). Remnant loko iʻa in Hawaiʻi are used to raise and harvest the following traditional native species: ʻamaʻama (mullet), awa (milkfish), āholehole (Hawaiian flagtail), moi (threadfin), pāpio (jack), ʻōʻio (bonefish), awaʻaua (ladyfish), and limu (edible seaweeds). Additionally, fishponds are used to raise some harvestable non-native species, including ogo (seaweed), rainbow trout, tilapia, and ornamental carp.

Vulnerability Assessment Results

Overall, food and fiber ecosystem services were evaluated as having *moderate-high* vulnerability to climate change due to *moderate-high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *moderate* adaptive capacity. Climatic changes such as water temperature, ocean acidification, and drought are likely to impact water supply and quality, increasing stress in cultivated and native species. These species may also be directly impacted by extreme events (e.g., storms) or disturbances (e.g., wildfire, insects, disease), which can impact water resources and damage infrastructure. Non-climate stressors introduce pollutants and diminish surface- and groundwater sources, degrading habitat quality and availability for harvestable species. Additionally, invasive plants and wildlife alter native ecosystems harboring species harvested for food, fiber, and other materials, in many cases out-competing native species for resources or leading to the damage or decline of cultivated and/or wild plants and animals. Although food and fiber ecosystem services are highly valued by the public, societal support for management is relatively low, and little funding is available to accomplish this. Food security in the Hawaiian Islands is low, but some efforts to restore fishponds and increase traditional taro cultivation have been successful.

Adaptation Planning Results

Table 17 presents a summary of possible adaptation strategies and actions for Maui Nui food and fiber, and consists of stakeholder input during an adaptation workshop as well as additional options from the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce habitat vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation. Figure 17 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 17. Summary of possible adaptation strategies and actions for Maui Nui food and fiber.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Manage invasive species	•! Provide erosion control by using fencing to exclude invasive species from upland habitats
	Increase food security to build resilient cultural communities	•! Preserve cultural foods
Resilience *Near- to mid-*	Protect cultural practices (e.g., fishing, gathering, farming, fiber	•! Create policies that maintain public access to coastal, forest, and wetland areas

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
term approach	collection and processing)	•! Protect and restore culturally appropriate taro farming areas and fishponds
	Increase food security to build resilient cultural communities	•! Use community gardens as pilot sites to test resilient crops
	Preserve water supplies by increasing water use efficiency	•! Investigate alternative agricultural crops that have economic benefit and capture water •! Improve rainfall capture to decrease groundwater withdrawals
Response *Long-term approach*	Increase ecosystem resilience, connectivity, and integrity	•! Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes
	Promote climate-adapted agricultural practices	•! Investigate alternative agricultural crop varieties and mixes with economic value
Knowledge *Near- to long-term approach*	Increase understanding of water quantity, quality, and allocations under changing climate conditions	•! Research options for water allocations under changing climate conditions •! Identify, map, and quantify groundwater and surface water conditions
Collaboration *Near- to long-term approach*	Increase direct community restoration	•! Conduct place-based community education, organizing, management, and action focused on native habitat restoration, cultural practices, and climate change impacts
	Create healthy communities	•! Increase cultural community input on water use decisions •! Create/build relationships within the community, non-profit, and government sectors

Forest Products Management – LNR 172		
Management of sustainable forest product opportunities.		
Class Name	Class Definition	Management Strategies
F-1: Large Scale Commercial	• Forest products are a primary objective, and large scale sustainable commercial timber harvesting or salvage is allowed; • Permits, licenses and environmental compliance are required; • Harvesting of non-timber forest products is allowed.	• Produce a sustainable timber supply in balance with other resource management objectives; • Activities may include site preparation, tree-planting, thinning operations, forest stand improvement and large-scale timber harvest; • Timber management plans are required to mitigate non-timber resource impacts, and assure sustainable yield and positive impact forestry.
F-2: Small Scale Commercial	• Areas where limited commercial timber harvesting or salvage is allowed in balance with other land uses; • Required permits, licenses and environmental compliance depend on scope and scale of operations; • Harvesting of non-timber forest products may be allowed.	• To produce a sustainable supply of forest products while minimizing other resource impacts; • Activities may include site preparation, tree-planting, thinning operations, forest stand improvement and small-scale timber harvest; • Impacts of harvesting distributed over the resource area through controlled seasons and harvest; • Timber management plans are required to mitigate non-timber resource impacts, and assure sustainable yield and positive impact forestry; • Forest management activities performed in coordination with other resource management activities.
F-3: Personal Use	• Areas where selective non-commercial timber harvesting and targeted commercial timber salvage is allowed in balance with other land use objectives; • Permits for harvest of non-timber products issued on a case by case basis. •	• Limited timber harvest performed as appropriate to bring materials to local market, and produce other positive resource outcomes; • Minimize human impacts to native species and native ecosystems; • Accommodate harvest of forest products for sustainable personal use.
F-4: Restricted	• Harvesting of timber only considered if activity improves other priority resource outcomes; • Permits for harvest of non-timber forest products will be considered on a case by case basis for research and education, improving forest science and health, watershed protection, traditional and customary practices, and conservation efforts.	• Resource protection is the top priority; • Prioritize protection of native species and native ecosystems; • Permitted activities in these areas are minimally disruptive, and focused on improving forest and watershed health, native ecosystems, and other conservation efforts.

Conservation Resources - Native Species Habitat, Water Resources – LNR 402/407		
Class Name	Class Definition: May have one, all, or a combination of conservation values	Management Strategy
C-1: High Conservation Resources	• High level of native biological resources, native ecosystem intactness, and/or recovery potential; • Essential to the conservation and/or recovery of native species; • Important restoration areas, such as rare ecosystem remnants, native wildlife habitat, wetlands, and offshore islands; • High degree of conservation related regulatory encumbrances - critical habitat, restricted watershed, conservation easements and/or zoning; • High watershed conservation value per CWRM, USGS, BWS, and/or DOFAW.	• Intensive management applied, as necessary, to protect watershed values, and native species and ecosystems, as resources permit; • Management may include animal exclusion fencing, predator control, vegetation/weed control; • Work may include out-planting of native vegetation and reintroduction of native wildlife, as needed.
C-2: Medium Conservation Resources	• Moderate level of native biological diversity and/or native ecosystem intactness; • Contributes to the conservation and/or recovery of native species (i.e. T&E / native species habitat, water resources); • Medium degree of conservation related regulatory encumbrances; • Medium watershed conservation value.	• Management activities to control priority threats and improve watershed, native species or ecosystem outcomes; • Work may include out-planting of native vegetation and reintroduction of native wildlife, as needed. • Other uses may include forest products gathering, hiking, and liberal hunting.
C-3: Low Conservation Resources	• Low level of native biological diversity and/or native ecosystem intactness; • Low conservation and/or recovery of native species but may contribute to conservation (i.e. individual or small clusters of rare plants; genetic collection); • Low degree of conservation related regulatory encumbrances; • May have low watershed conservation value.	• Native species management occurs mostly in remnant patches and fenced units; • Mixed use area with forest products gathering, hunting and non-hunting recreation, as appropriate.
C-4: Little to No Conservation Resources	• Little to no native biological diversity and/or native ecosystems highly degraded or absent; • Little to no contribution to the conservation and/or recovery of native species; • Very little or no conservation related regulatory encumbrances; • May have low watershed conservation value.	• Area managed for a variety of uses not appropriate for more pristine environments, including timber harvest, regulated hunting and more intensive non-hunting recreation (hiking, equestrian and/or off-road vehicles).

Hunting Management – LNR 804		
Management for public recreation, subsistence hunting and animal damage control.		
Class Name	Class Definition	Management Strategy
H-1: Active Hunting Management:	• Public hunting is a high priority land use; • Area is suitable for a high degree of active management for public hunting; • Management of the area is designed to provide maximum sustained yield of game animals.	• Hunting regulations for the area are designed to provide maximum sustained yield while minimizing environmental impacts; • High degree of management to maintain or improve hunting program infrastructure; • Habitat is managed to maintain or increase game animal carrying capacity, while maintaining healthy vegetative cover for proper range management and erosion control.
H-2: Moderate Hunting Management:	• Area is suitable for a moderate degree of active management for animal enhancement and habitat management to increase animal productivity for public hunting; • Public hunting opportunities may be improved or maximized; • Public hunting is balanced with other objectives.	• Hunting regulations established to manage animal harvest; • Moderate degree of infrastructure for animal management; • Habitat modification for game animal production as appropriate for the area; • Balance animal impacts with other resources.
H-3: Low Intensity Hunting Management:	• Area not suitable for game enhancement and habitat management to increase animal densities - hunters play an important role in limiting animal impacts; • Minimal public hunting restrictions provide maximum public hunting opportunity; • Public hunting management includes maintaining access and monitoring hunter effort and success.	• Hunting seasons, bag limits and other hunting regulations liberalized to maximize hunting opportunity; • Hunting opportunities may include permitted hunts if needed to improve access; • No habitat modification for production and/or enhancement of game animals.
H-4: No Hunting Management:	• Area is not suitable for open public hunting due to environmental sensitivity, access, or safety; • No active management for public hunting; public hunting may be used for animal damage control on a permit basis; • Public hunting is not a primary land management objective.	• Area not open to regular public hunting seasons for either management, access or safety reasons; • Animal control to be conducted by staff, permitted and/or guided hunters, and other cooperators as appropriate.

Recreation Management – LNR 804		
Class Name	Class Definition	Management Strategy
R-1: High Recreation Management:	• Areas where outdoor recreation is a primary objective; • High level of visitor use is received and accommodated; • May include recreation, transit and/or urban elements; • Approximate average daily use: 100 - 1000+ users.	• Area can sustain heavy recreational use; recreation plays a major role in use of the area; • Trails maintained to sustain heavy use which may include hiking, mountain bike riding, equestrian and/or off-road vehicle use; • Improvements commensurate with use.
R-2: Medium Recreation Management:	• Areas where outdoor recreation is of moderate intensity, and may be integrated with other uses; • Includes a wide range of trails and roads requiring a moderate level of management and maintenance to meet user needs and balance other land use objectives; • Approximate average daily use: 0 – 500 (+/-) users.	• Area can sustain moderate recreational use; recreation integrated with other management programs; • Roads and trails maintained to sustain moderate use which may include hiking, mountain bike riding, equestrian, and/or off-road vehicle improvements; • Improvements commensurate with use.
R-3: Low Recreation Management:	• Areas where outdoor recreation is of low intensity, and is integrated with other uses; • Trails and roads that receive limited use, or whose character and terrain require little maintenance relative to the usage; • Approximate average daily use: 0 – 100 (+/-).	• Areas may be inaccessible or remote; facilities and improvements are limited, in keeping with the level of use; • Areas may be managed for multiple uses including forest protection, conservation, hunting, and hiking, or protected and managed to preserve natural conditions; activities may include hiking, biking, equestrian and/or off-road vehicles; • To protect both the trail environment and experience, improvements are typically minimal, and designed to fit the setting and need.
R-4: Recreation Management (Restricted access):	• Areas where outdoor recreation is restricted or controlled; • Areas sensitive to human disturbance due to natural, cultural or archaeological features; • Access primarily for management purposes, and/or limited or programmatic recreational or educational uses.	• Areas may be classified “restricted” due to hazardous conditions, watershed protection, sensitive wildlife, fragile ecosystems, cultural resources, limited accessibility, or management practices incompatible with recreational activities; • Managed to limit impacts from human activities; • Facilities and improvements are very limited and generally associated resource management; • Trails will not feature extensive recreational amenities and will generally incorporate only facilities necessary to protect and manage the resource; • Access may be controlled via permits, group number limitations, or other restrictions as appropriate for the area.