MAKAWAO

FOREST RESERVE

Management Plan
2025

STATE OF HAWAIʻI
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF FORESTRY AND WILDLIFE

EXECUTIVE SUMMARY

This ten-year management plan for Makawao State Forest Reserve (FR) on Maui is one in a series of site-specific natural resources management plans to be prepared by the Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) for individual forest reserves in the State of Hawaiʻi. 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, and an account of infrastructure and intended use(s) of the area. These plans serve to (1) assist in the 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 Makawao State Forest Reserve was established by Governor's Proclamation on April 21, 1908. In a report that preceded the establishment of the reserve, the Territorial Forester stated that the objective was to protect the forested watershed and its freshwater resources, which were essential to the economic development of the territory. Hosmer mentioned the heavy precipitation that the area received, as well as several intermittent streams that fed into important tributaries that supplied fresh water to East Maui (Hosmer, 1907).

The government lands in Makawao, east of Kahakapao Gulch, were described as having forests comprised of ʻōhiʻa and koa with steep gulches of koa and kukui. The area west of Kahakapao Gulch was subleased to Haleakalā Ranch before it became a forest reserve and was impacted by more than a decade of grazing and wood harvesting.

Makawao State Forest Reserve is currently comprised of approximately 2,093 acres of public land located on the northwestern slopes of Haleakalā, in the ahupuaʻa of Makawao, which is part of the moku of Hāmākuapoko. At around 1420 A.D., early Hawaiians primarily settled along the coast of Hāmākuapoko, where ocean resources and freshwater were available (Kuaʻāina Consultants, 2015). Early Hawaiians didn't initially settle or develop Makawao, but likely made occasional trips to the forest to collect resources such as koa and ʻōhiʻa for waʻa (canoe) and hale (house) construction (Kuaʻaina Consultants, 2015). Aside from gathering building materials, it is also believed that bird feathers, medicinal plants, and alternative food sources during times of famine may have been occasionally harvested (Cultural Surveys Hawaiʻi, Inc. et al., 2003).

By 1620 A.D., Hawaiians started to migrate and settle upland in the lower stream sections of Makawao. Likely, crops such as kalo (taro) and ʻuala (sweet potato) were cultivated and harvested in addition to other forest resources (Kuaʻāina Consultants, 2015). There is no documented archaeological evidence of habitation or agricultural activities by early Hawaiians in the forest reserve boundary. However, the upland forests were an important place for cultural and religious activities, and were also a source of natural resources for subsistence, ceremony, and for the making of implements for various purposes. Forest resources that were gathered, likely included but is not limited to, construction materials, foliage, natural fibers, dyes, medicinal plants, and feathers from native forest birds.

Agricultural land use in the district of Makawao began in 1838 and continues today. Sugar and cattle operations altered the landscape, resulting in the removal of native forests. After the Mahele in 1848, the lands of Makawao FR were assigned as government land and eventually subleased to Haleakala Ranch from 1883 until its establishment as a forest reserve in 1904. During this time there were growing concerns that landscape-scale deforestation island wide was having a negative impact on groundwater recharge. Given the increased demand for water from the growing population and agricultural industries, protecting freshwater resources was a high priority. As such, early management of Makawao FR involved reforesting the barren landscape with timber species to aid in watershed health and to also create a timber resource that could supply local and export markets.

DOFAW's current management activities within Makawao FR include maintenance of existing fencelines and access infrastructure, monitoring and controlling invasive weeds, native ecosystem management and restoration, monitoring and protecting forest resources and native ecosystems, and management and maintenance of public recreation areas.

Forest reserve management priorities are divided into nine categories and ranked on a qualitative basis, taking into consideration the natural and cultural resources and public use opportunities of the reserves (see Table 18 for forest reserve management priorities). The summary of management goals for Makawao State FR is as follows:

- Watershed Values – Maintain forest cover, erosion reduction, and prevention; forest composition monitoring; maintain partner role in watershed partnership; and climate change adaptation.
- Resource Protection – Wildfire management and prevention; forest health monitoring (Rapid ʻŌhiʻa Death, insects, and disease); and monitoring weather conditions as they pertain to fire and other forest health issues.
- Cultural Resources – Protection of cultural resources and traditional and customary practices.
- Game Animal Management – Maintain public access and game mammal hunting opportunities; continue public education and outreach; and revise rules to designate the Kahakapao Recreation area as a safety zone.
- Threatened & Endangered (T&E) Species Management – Protection and recovery of threatened and endangered plants and animals; survey and monitor endangered species; build fenced enclosures; predator and ungulate control; release and reintroduction of endangered species; and critical mosquito biocontrol efforts.
- Native Ecosystems – Native ecosystem restoration and protection; monitoring; and climate change adaptation.

- Invasive Species Control – Control and monitor incipient and established invasive plant and animal populations; continue to collaborate with partner agencies on invasive species mitigation; and support relevant biocontrol, research, and biosecurity efforts.
- Access, Trails, and other Public Uses – Maintain public access to the forest reserve; increase public information and awareness; maintain infrastructure management; and assess the construction of new trails and rest stations in the recreation area.
- Commercial Activity – Generate income from suitable commercial activities to support forest management; management of salvage harvest permits; and explore the feasibility of revenue streams such as sustainable commercial tours, harvesting, and film industry permits.

Details of specific tactical goals and action items can be found in Table 18 on page 87 of this plan. This plan is intended to describe short-term resource management planning and implementation strategies, as well as to serve as a basis for future updates and modifications to accommodate evolving or additional objectives, such as wildfire prevention projects and/or expanded recreational opportunities for Makawao State FR.

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MAKAWAO STATE FOREST RESERVE
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 Makawao State Forest Reserve.

_____________________________________ ______________

Scott Fretz – DOFAW Maui District Manager 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 Makawao State Forest Reserve.

_____________________________________ _______________

David G. Smith – DOFAW Administrator 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, Hawaiʻi Revised Statues, and Chapter 13-104, Hawaiʻi Administrative Rules.

____

Dawn N. S. Chang – BLNR Chairperson

Approved by the Board of Land and Natural Resources at its meeting held on _____________.

DEVELOPMENT PROCESS TIMELINE

Makawao State Forest Reserve, Maui

Stage of Development	Date Achieved	Comments
District review	April 2025	Incorporated
DOFAW review	June 2025	Incorporated
Partner agency consultation		
Public consultation		
DOFAW approval		
BLNR approval		

1. INTRODUCTION

The Division of Forestry and Wildlife conducts ongoing 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 Hawaiʻi Tropical Forest Recovery Action Plan, which came about as a result of the 1992 Federal Hawaiʻi Tropical Forest Recovery Act.

Forest reserve management plans, in part, will include information on the natural resources, cultural resources, threats, goals, objectives, and the Division's management priorities for the area. This document represents the management plan for the Makawao State Forest Reserve. It addresses concerns and strategies for the public lands that are included within the boundary of the reserve.

The initial development of this plan consisted of reviewing DOFAW's historic and current files found at the Administrative and Maui District offices. 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, and the State Archives. Relevant data from the Hawaiʻi Statewide Geographic Information System (GIS) and the Office of Hawaiian Affairs Kīpuka Database, relating to biological, cultural, 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 reserve or the general area) were the Hawaiian Forester and Agriculturalist, Hawaiʻi Biodiversity and Mapping Program (HBMP), State of Hawaiʻi Forest Action Plan, Hawaiʻi'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 Makawao 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 plans and objectives, including issuance of permits, licenses, or contracts as necessary.

2. HISTORY

2.1 Early Hawaiians and Makawao

On the island of Maui, the ahupuaʻa of Makawao is in the ancient moku (district) of Hāmākuapoko (Figure 1). Nestled in the northern part of East Maui, the ahupuaʻa of Makawao was known to receive abundant rainfall, which allowed for the growth of dense ʻōhiʻa and koa forests (Hosmer, 1904). While there are many interpretations, Makawao can be translated literally to “forest beginning” or “eye of the inland forest” (Pukui et al., 1976: 142).

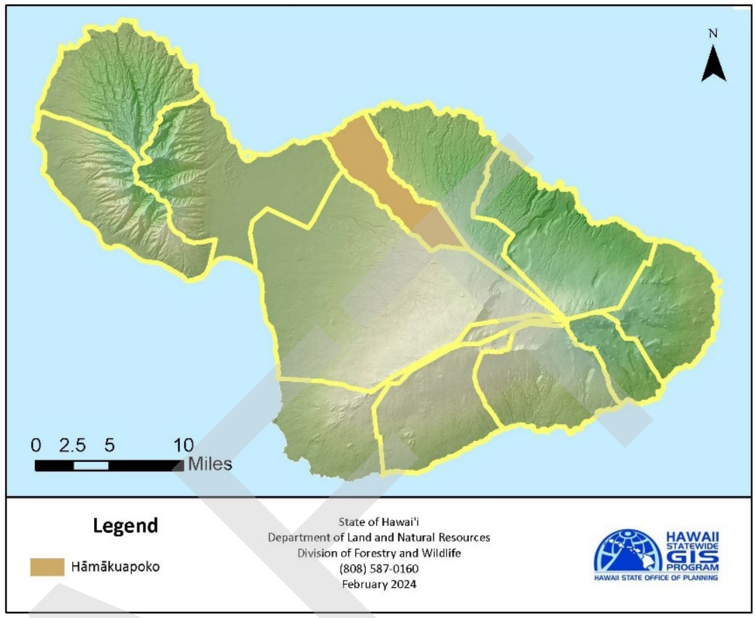


Figure 1. Ancient districts of Maui

At around 1420 A.D., early Hawaiians primarily settled along the coast of Hāmākuapoko, where ocean resources and freshwater were available (Kuaʻāina Consultants, 2015). Early Hawaiians didn’t initially settle or develop Makawao, but likely made occasional trips to the forest to collect resources such as koa and ʻōhiʻa for waʻa (canoe) and hale (house) construction (Kuaʻāina Consultants, 2015). Logs harvested for canoes were soaked, roughly shaped, and transported in Māliko Gulch before being finished in drier areas (Cultural Surveys Hawai'i, Inc. et al., 2003). Aside from collecting building materials, it is also believed that bird feathers, medicinal plants, and alternative food sources during times of famine may have been occasionally harvested (Cultural Surveys Hawaiʻi, Inc. et al., 2003).

By 1620 A.D., Hawaiians started to migrate and settle upland in the lower stream sections of Makawao. Likely, crops such as kalo (taro) and ʻuala (sweet potato) were cultivated and harvested in addition to other forest resources (Kuaʻāina Consultants, 2015). There was a special grove of kukui (candle nut) trees named “Lilikoi” that was known to produce fragrant and sweet nuts that were collected only for use by the chiefs (Fornander, 1918-1919).

2.2 Moʻolelo of Makawao

Piʻilani was the ruler of Maui and was recognized for unifying and strengthening East and West Maui as one. He is also known for The Alaloa, or “Long Road,” which ran around East and West Maui. Today, this connecting path exists as “Piʻilani Highway.”

Piʻilani had four children and designated his two sons, Lono-a-piʻilani (Lono) and Kiha-a-piʻilani (Kiha), as the heirs to the kingdom of Maui. However, at the time of Piʻilani’s death at the end of the 16th century, Kiha was on the island of Oʻahu, where he was born and raised. Kiha's absence led the government of Maui to be under the complete rule of Lono, putting Kiha under his brother's rule.

Peace was maintained between Lono and Kiha for the first few years. Eventually, tensions grew between the two brothers. Kiha developed a taro patch in Waiheʻe that exceeded the size of his brother's patch (Kamakau, 1992). Lono saw this as an attempt by Kiha to undermine his authority and seize the kingdom of Maui. Lono would go on to abuse his brother, prompting Kiha to flee as he feared for his life.

Kiha and his wife fled to Molokaʻi, Lānaʻi, and eventually returned to Maui. They eventually settled close to the boundary of Kula and Makawao. Poor and on the run, Kiha kept his identity a secret from the commoners he would live amongst. One year, famine struck the Kula and Makawao area, causing the people to forage for whatever edible weeds they could find. One night, Kiha cleared a large patch of ferns to plant ʻuala, a feat that would have required the labor of eighty men (Kamakau, 1992). Potato slips were acquired from other ʻuala farmers in Hāmākuapoko and Hāliʻimaile. Kiha single-handedly carried a large bundle of ʻuala slips that would have required the strength of ten men (Kamakau, 1992).

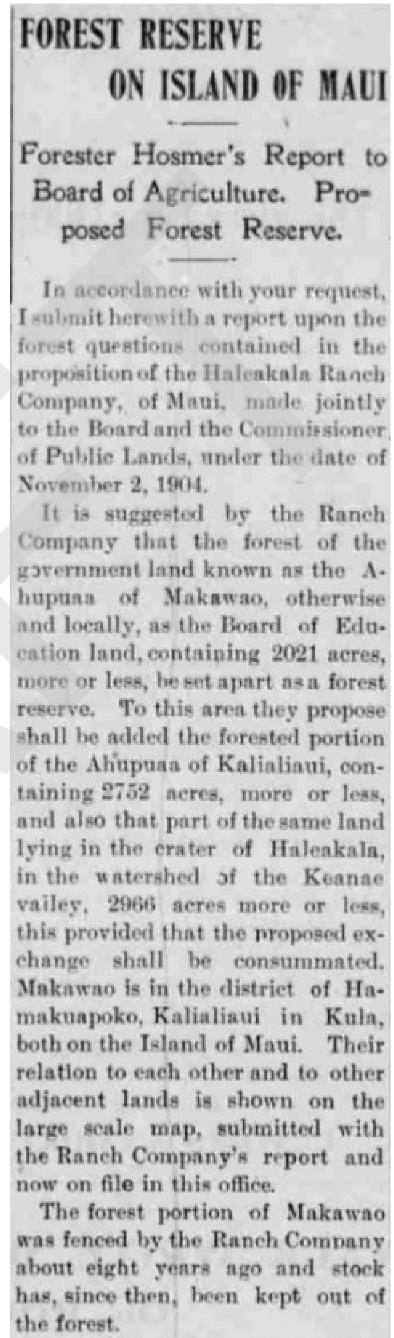
Kiha's identity would be revealed as he carried the load of ʻuala slips back to the boundary of Kula and Makawao. A native of the area, Kau-lani, noticed a rainbow arcing over the canopy, a sight they had never seen before. When confronted, Kiha admitted his royal ancestry, and Kau-lani swore to keep his identity a secret. Kiha would continue to plant his great patch of ʻuala, which was immediately followed by rain. Kiha's ʻuala patch would become famous and play an important role in Makawao's early history. Kiha would go on to kill his brother and become the ruler of Maui, creating a ruling legacy similar to his father. He is noted for maintaining the peace and prosperity of the commoners of Maui.

2.3 Agriculture in the Ahupuaʻa of Makawao

As the Hawaiian Kingdom envisioned becoming a self-sufficient nation, King Kamehameha III and Western advisors began to develop a marketplace of goods that would appeal to local and international markets and incoming whaling vessels. In 1838, the Governor of Maui, Hoapilikane, leased a portion of Makawao to William A. McLane and Edwin Miner for 50 years to develop a cattle and sugar cane operation (MacLennan, 1995). This lease included the right to water and a trail that extended to the shoreline to allow McLane and Miner to transport cattle for exportation (Maly et al., 2001). This marked the start of agricultural operations in the district of Makawao.

After the Mahele in 1848, foreigners could purchase and lease land. This contributed to an increase in the establishment of sugar plantations and cattle operations. By 1849, there were six plantations in the Makawao area, with only two remaining by 1857 after sugar exports from Peru and Manila began to dominate the market (MacLennan, 1995). Even after the closure of many plantations in the district of Makawao, the impacts of land clearing and infrastructure development remained.

In December 1874, government land in Makawao, which included a portion of land that was later set aside as a forest reserve, was leased to the Board of Education and eventually subleased from 1883 to 1904 to three successive ranching operations for cattle grazing (The Pacific Commercial Advertiser, 1907; Table 1). The final sublessee was Haleakalā Ranch, which grazed cattle in the pastures west of Kahakapao Gulch from 1890 to 1904. The topography of the gulch created a natural barrier that kept the cattle in the drier and more productive pastures. Haleakalā Ranch also installed fencing on the upper and lower sides of Kahakapao Gulch to restrict their cattle to the established pasture lands (Figure 2). On March 26, 1904, both the lease and sublease expired. This occurred when the territorial government was establishing the Forest Reserve System, setting aside important forested areas to ensure adequate fresh water supplies for the growing agricultural industry.



FOREST RESERVE ON ISLAND OF MAUI

Forester Hosmer's Report to Board of Agriculture. Proposed Forest Reserve.

In accordance with your request, I submit herewith a report upon the forest questions contained in the proposition of the Haleakala Ranch Company, of Maui, made jointly to the Board and the Commissioner of Public Lands, under the date of November 2, 1904.

It is suggested by the Ranch Company that the forest of the government land known as the Ahupuaa of Makawao, otherwise and locally, as the Board of Education land, containing 2021 acres, more or less, be set apart as a forest reserve. To this area they propose shall be added the forested portion of the Ahupuaa of Kalialiaui, containing 2752 acres, more or less, and also that part of the same land lying in the crater of Haleakala, in the watershed of the Keanae valley, 2966 acres more or less, this provided that the proposed exchange shall be consummated. Makawao is in the district of Hamakuapoko, Kalialiaui in Kula, both on the Island of Maui. Their relation to each other and to other adjacent lands is shown on the large scale map, submitted with the Ranch Company's report and now on file in this office.

The forest portion of Makawao was fenced by the Ranch Company about eight years ago and stock has, since then, been kept out of the forest.

Figure 2. Newspaper article of proposed Makawao Forest Reserve, Maui News, 1904

2.4 Forest Reserve Designation

The Makawao State Forest Reserve was established by Governor's Proclamation on April 21, 1908. The State Forester at the time, Ralph Hosmer, made the case for permanent protection of 1,796 acres of the forested watershed. It contained intermittent streams such as Waiahiwi, which were considered important tributaries that fed into Māliko Stream (Hosmer, 1907). Even though they were intermittent, these streams were considered valuable at the time as a freshwater resource (The Pacific Commercial Advertiser, 1907). Kahakapao Gulch, which was the natural western boundary of the proposed forest reserve, also received heavy precipitation (The Pacific Commercial Advertiser, 1907). Given the increased demand for water from the growing population and agricultural industries, protecting freshwater resources was a high priority.

Shortly after it was established, the Makawao Forest Reserve boundary was modified on June 5, 1909, adding 35 acres. When the original boundary was being determined, there were plans to establish homestead lots in Kahakapao Gulch to provide homesteaders access to freshwater resources (Hosmer, 1909). As such, the reserve's western boundary was set on the inside (or eastern side) of Kahakapao Gulch. However, the plan to establish homestead lots was abandoned, and the steep topography of the western side of the gulch was seen as a favorable natural barrier to keep livestock and trespassers out of the reserve.

To further control public access to Makawao Forest Reserve for the stated purpose of protecting the forest from “unnecessary injury,” an announcement was made that after May 1, 1909, access permits would be required for entry into the reserve (Hosmer, 1908). Permits would be issued to individuals who had “legitimate business” in the forest reserve, and those found without permits would be prosecuted for trespassing (Hosmer, 1908). We could not find any records of when or why this policy ended. Access permits are no longer required to access Makawao Forest Reserve.

The final changes to the boundary of Makawao Forest Reserve occurred on June 19, 1918, when an additional 263 acres of government land were added, bringing the total and current acreage of the reserve to 2,093 acres. The 263-acre addition was part of a larger government parcel that was being set aside for homestead lots (Judd, 1918). Superintendent of Forestry, Charles S. Judd, described the land as gulches consisting of koa and kukui, with slopes covered in ʻōhiʻa (Judd, 1918). The tops of flat ridges were largely deforested due to wood harvesting and grazing animals, but there were remnant patches of hala pepe and olopua (Judd, 1918). Because the adjacent land was already being protected from further forest destruction, it seemed like a logical decision to add the remnant government land to the Makawao Forest Reserve.

Table 1. Land use agreements issued for lands within Makawao FR

Type	Doc. #	Duration	Description	Acres	Map #[1]	Tax Map Key
Lease	188	21-Dec-1874 to 26-Mar-1904	Government land leased to the Board of Education	4,000[2]		
Sublease	211	12-Oct-1878 to 26-Mar-1904	Government land subleased by the Board of Education to Akanaliʻiliʻi and Company	100		
Sublease		12-Nov-1883 to 20-Oct-1890	Sublease transferred from Akanaliʻiliʻi and Company to East Maui Stock Company	100		

[1] CSF = Copy of Survey Furnished. Maps are available online at http://ags.hawaii.gov/survey/map-search/

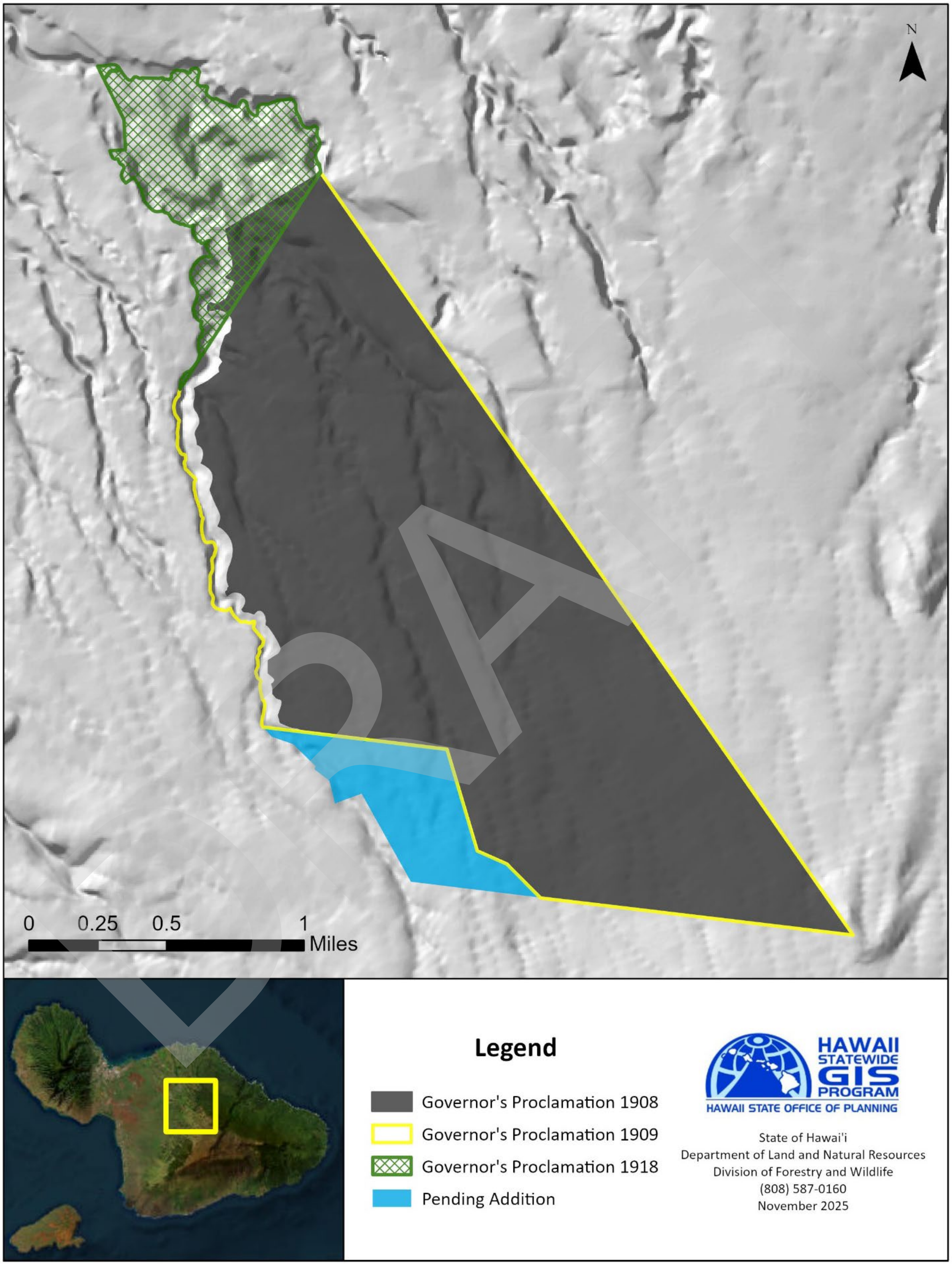
[2] Total lease acreage includes areas outside of the Makawao Forest Reserve

Sublease		20-Oct-1890 to 26-Mar-1904	Sublease transferred from East Maui Stock Company to Haleakalā Ranch	100		
Perpetual easement	lod26544	20-Nov-1975	Long-term lease to the County of Maui for water use (Piʻiholo Water Treatment Facility)	36.070	CSF 16579	(2) 2-4-016:002
Perpetual easement	lod28018	22-Apr-1988	Long-term easement to Maui Electric Co. Ltd. for utility use	6.461	CSF 19101	(2) 2-4-016:002

Table 2. Summary of lands added to the Makawao FR

Document	Date	Action	Description	Acres	Map #	Tax Map Key
GP1908	21-Apr-1908	Establish	Land set aside by Governor Frear for establishment of Makawao FR	1796	CSF 1792	(2) 2-4-016:002
GP1909	05-Jun-1909	Modify	Modification of original boundaries, addition of 34 acres	1830	CSF 2002	(2) 2-4-016:002
GP1918	19-Jun-1918	Addition	Addition of 263 acres to Makawao FR	2093	CSF 2754	(2) 2-4-016:002 (2) 2-4-016:005

Figure 3. Historical changes to Makawao FR boundary



2.5 Future Expansion

In 2022, the Board of Land and Natural Resources authorized a memorandum of understanding between DLNR DOFAW and Land Division in which both divisions agreed to collaborate on the Land Division Strategic Plan. The goal was to identify parcels in Land Division's inventory that can provide areas for conservation, preservation, recreation, and sustainable forest products to be transferred to DOFAW for management. After statewide public hearings, this process culminated on March 24, 2023, when the Board approved the set-aside of various parcels statewide to DOFAW as forest reserves, natural area reserves, and wildlife sanctuaries. Included in this approval was the addition of TMK (2) 2-4-016:001 (aka Pa Olinda) to Makawao Forest Reserve (Figure 3). The Division is still waiting for the issuance of a Governor's Executive Order to complete the administrative process and officially transfer management jurisdiction to DOFAW. A right-of-entry permit was issued on October 21, 2025, to DOFAW for management purposes of Pa Olinda.

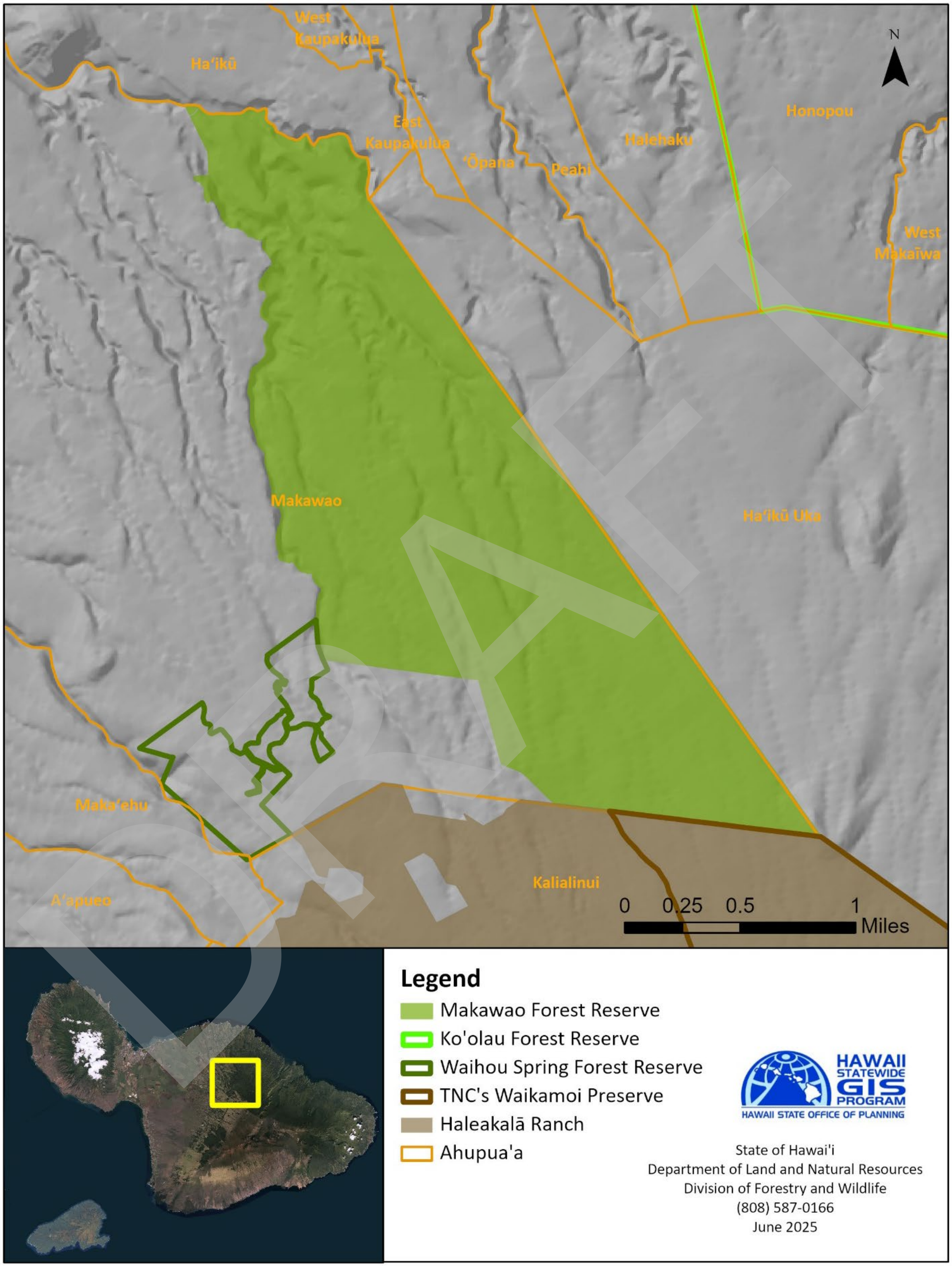
3. FOREST RESERVE DESCRIPTION

3.1 Location and Description

Figure 4. Wet-mesic forest in Makawao FR

The Makawao State Forest Reserve is located in the ahupuaʻa of Makawao, which is part of the moku of Hāmākuapoko on East Maui. The approximately 2,093 acres of public land are surrounded primarily by private land owned by Haleakalā Ranch and Alexander and Baldwin. The reserve also borders Waihou Spring FR to the southwest and the Nature Conservancy's Waikamoi Preserve to the southeast (Figure 5). The elevation of Makawao FR ranges from approximately 2,000 feet at the bottom of the northwest section to 4,900 feet at the summit. The vegetation within the forest reserve is described as wet-mesic, montane-mesic, montane rainforest, lowland rainforest, and managed tree plantations.

Figure 5. Current extent of public lands in Makawao



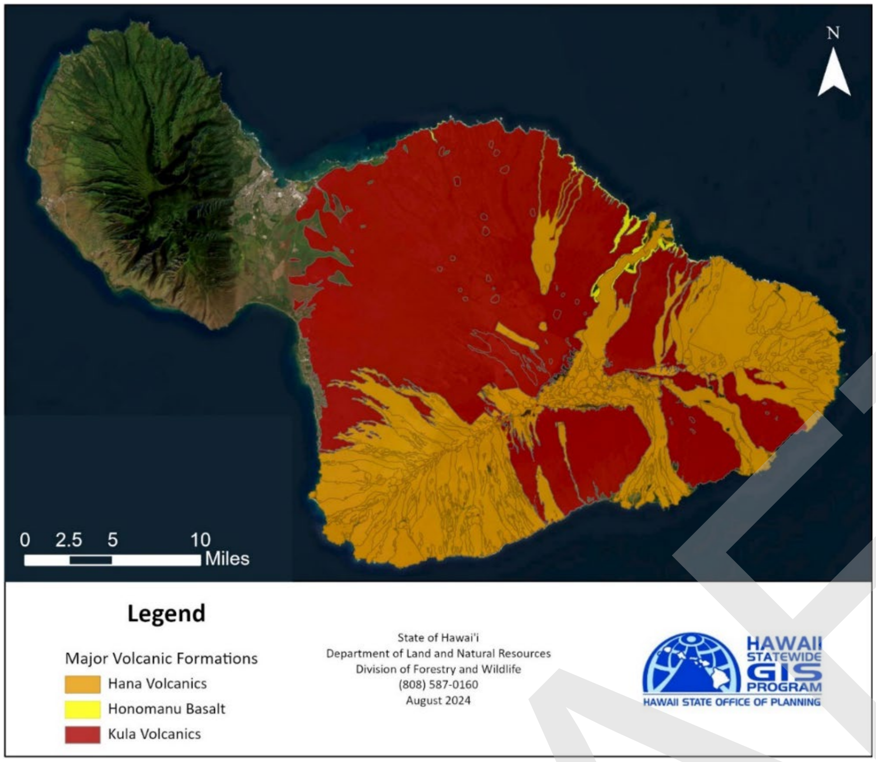
3.2 Geology

The islands of Maui, Molokaʻi, Lānaʻi, and Kahoʻolawe were once a connected and continuous landscape that was known as Maui Nui. It was created by the convergence of six separate volcanoes and was estimated to be larger than the current size of Hawaiʻi Island (Price & Elliot-Fisk, 2004). Around 300,000 to 400,000 years ago, Maui Nui was separated into two islands following sea level rise and subsidence (Price & Elliot-Fisk, 2004). After another 200,000 years, four distinct islands remained and became recognized as the Maui Nui complex (Price & Elliot-Fisk, 2004).

The island of Maui was created by two volcanoes: Haleakalā, which is an active volcano that formed East Maui approximately 1.1 million years ago, and an extinct volcano that formed West Maui approximately 1.6 to 2.0 million years ago (Hawaiian Volcanoes Observatory, 1995). Haleakalā has erupted at least ten times in the last 1,000 years, with the most recent sometime between 1480 and 1600, and it is expected to erupt again in the next several hundred years (Hawaiian Volcanoes Observatory, 1995).

A major rift zone crosses through East Maui, going from the southwest to the east. From this rift zone, volcanic flows over time created three major formations: the Honomanū Basalt, Kula Volcanics, and Hāna Volcanics (Figure 6; Sherrod et al., 2006). Of the three formations, the Honomanū Basalt series is the oldest, with lava flows dating back 1.1 million years, encompassing the northern portion of East Maui from Honomanū stream to Nāhiku (Hawaiian Volcano Observatory, n.d.). The Hāna Volcanics series is the youngest formation, with flows occurring within the last 150,000 years, encompassing Hāna, Kīpahulu, and the southern tip of East Maui (Hawaiian Volcano Observatory, n.d.). The Kula Volcanics series is composed of flows dating between 150,000-950,000 years old (Hawaiian Volcano Observatory, n.d.). The surface geology of Makawao FR is consistent with the lava flows from the Kula Volcanic series, which resulted in the formation of Waiohiwi Gulch and Kahakapao Gulch.

Figure 6. Major volcanic formations of East Maui



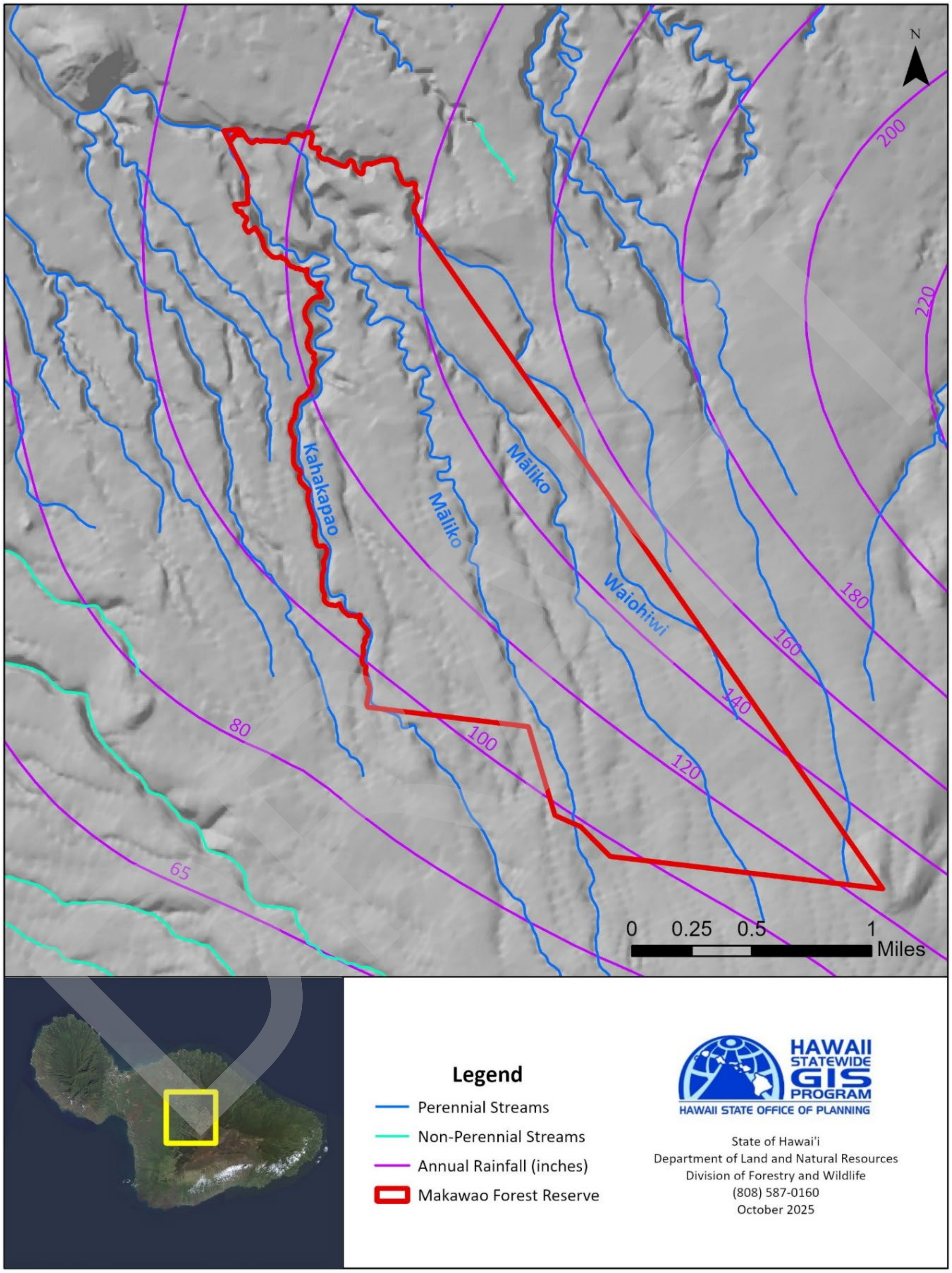
3.3 Climate

Figure 7. Stream in Makawao FR

Makawao FR is located on the windward side of Haleakalā and has a wet to mesic climate. The reserve receives quite a bit of rainfall with an annual average that ranges from approximately 90 to 150 inches (Figure 8). Precipitation in the reserve contributes to the recharge of the Haʻikū aquifer. Four perennial tributaries of Māliko Stream flow down gulches that either run through the forest reserve or along the reserve boundary. The tributary on the western boundary runs through Kahakapao Gulch, and the tributary that meanders along the eastern boundary runs through Waiohiwi Gulch.

Average air temperatures in Makawao FR range from 56.9 to 66.1°F, with February being the coolest month and August the warmest (Giambelluca et al., 2013; 2014). Average annual rainfall ranges from 98 to 153 inches, with March receiving the highest rainfall (17 inches) and September the least (6 inches) (Giambelluca et al., 2013; 2014). Average relative humidity ranges from 83.0-86.0%, and average windspeed ranges between 4.4-9.8 mph (Giambelluca et al., 2013; 2014).

Figure 8. Hydrological features of Makawao FR



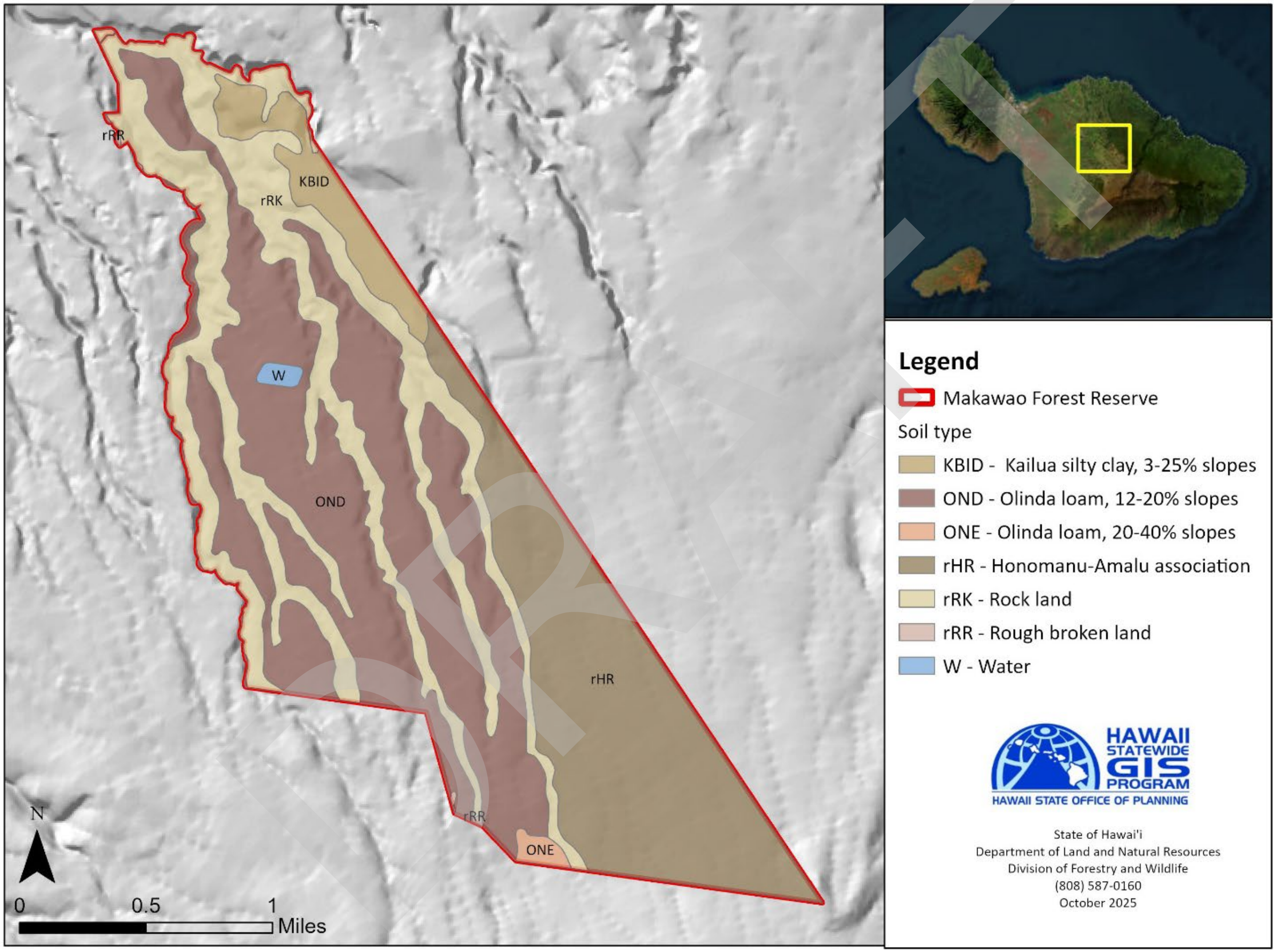
3.4 Soils

The United States Department of Agriculture's Natural Resource Conservation Service (NRCS) has mapped seven soil and land types (Table 3 and Figure 9) in Makawao FR, see Appendix A for soil descriptions. This agency provides online soil maps and data at https://websoilsurvey.sc.egov.usda.gov.

Table 3. Soils and land types of Makawao FR (NRCS Soil Survey Geographic Database, 2022)

Map Unit	Map Unit Name	Acreage	Percent Cover
OND	Olinda loam, 12 to 20% slopes	838.2	40.4%
rRK	Rock land	564.2	27.2%
rHR	Honomanu-Amalu association	554.7	26.7%
KBID	Kailua silty clay, 3 to 25% slopes	94.9	4.6%
ONE	Olinda loam, 20 to 40% slopes	12.0	0.6%
W	Water > 40 acres	7.7	0.4%
rRR	Rough broken land	1.9	0.1%

Figure 9. Soils of Makawao FR (NRCS Soil Survey Geographic Database, 2022)



3.5 Vegetation

Vegetation in Makawao FR has been severely altered by past cattle ranching and reforestation efforts with non-native species during the early 1900s. The majority of the reserve is dominated by large blocks of non-native tree plantations. The remaining native ecosystems in the mid to lower portions of the reserve are restricted to areas that were not subjected to forestry plantings, like steep gulches. Native wet forests still dominate the higher-elevation mauka portion of the forest reserve. According to the Carbon Assessment of Hawaiʻi Land Cover Map (Jacobi et al., 2017), the top three vegetation types that cover Makawao FR are alien mesic forests (39.4%), closed ʻōhiʻa mesic forest (17.5%), and closed ʻōhiʻa wet forest (10.4%; Table 4, Figure 11).

Table 4. Land cover types of Makawao FR (Jacobi et al., 2017)

Land Cover Type	Acreage	Percent Cover
Alien mesic forest	817.7	39.4%
Closed ʻōhiʻa mesic forest	363.3	17.5%
Closed ʻōhiʻa wet forest	216.1	10.4%
Alien wet forest	180.8	8.7%
Closed koa-ʻōhiʻa wet forest	152.4	7.3%
Very sparse vegetation to unvegetated	101.0	4.9%
Open ʻōhiʻa mesic forest	82.7	4.0%
Closed koa-ʻōhiʻa mesic forest	70.6	3.4%
Open ʻōhiʻa wet forest	47.5	2.3%
Low intensity developed	28.2	1.4%
Water	7.3	0.4%
Medium intensity developed	2.7	0.1%
Developed open space	1.2	0.05%
High intensity developed	1.1	0.04%

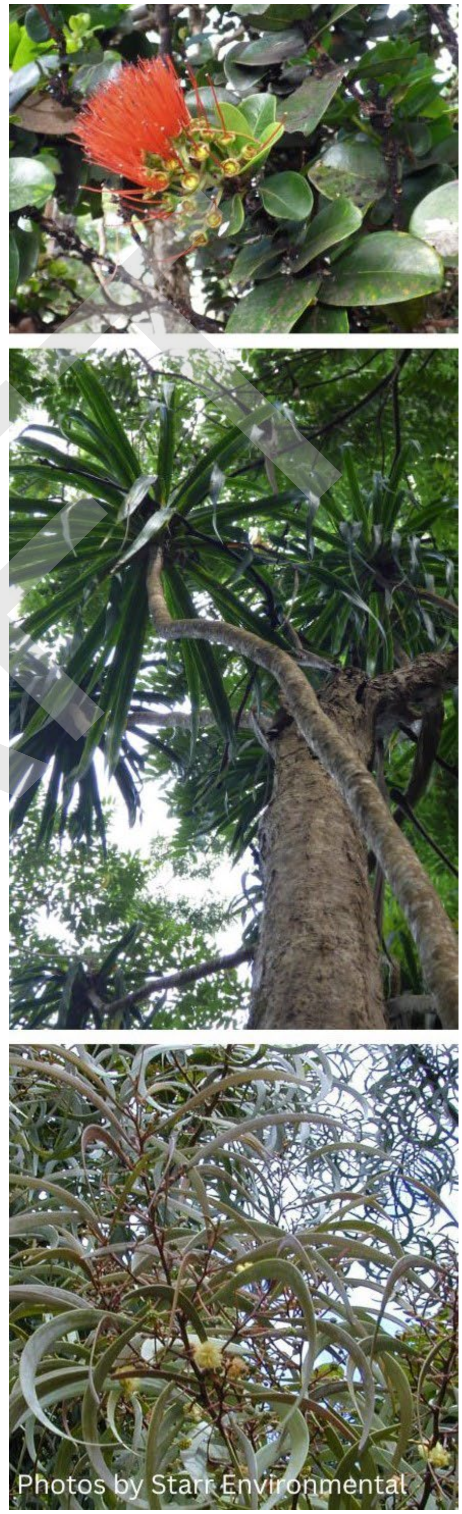
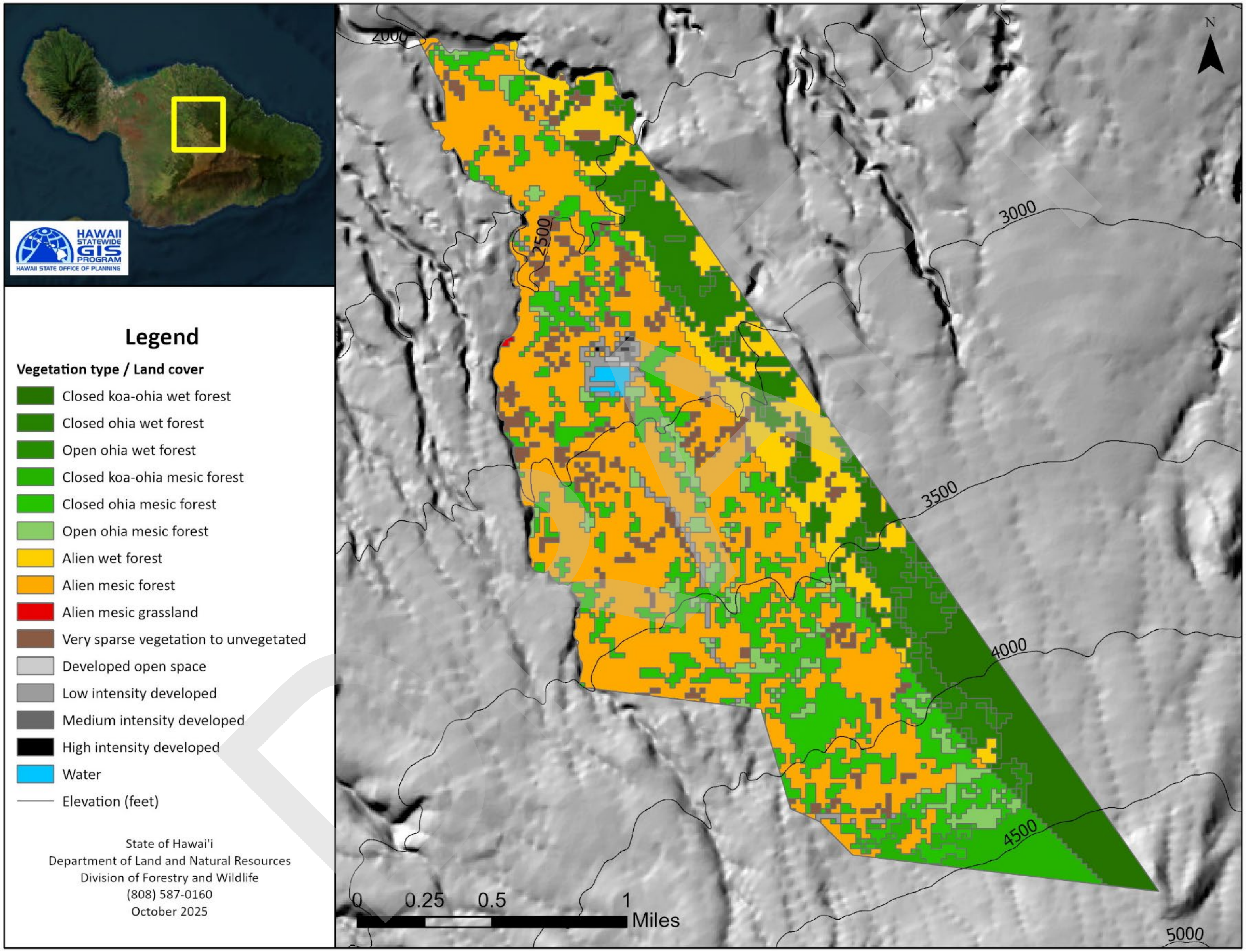


Figure 10. Plants of Makawao FR (top to bottom) Metrosideros polymorpha; Dracaena auwahiensis; Acacia koaia

Figure 11. Makawao FR vegetation cover (Jacobi et al., 2017)



3.5.1 Plantation Stands

Non-native tree plantations dominate Makawao FR between 2,000-3,500 feet in elevation. Experimental tree plantings began in 1910 in the Kaʻiliʻili area of Makawao FR, where they planted a variety of timber species that were being tested for growth viability in Hawai'i (Table 5). Intensive reforestation efforts started in the late 1920s and lasted through the late 1950s, leaving behind dense stands of non-native trees (Figure 14). Dominant species include tropical ash (*Fraxinus uhdei*), eucalyptus (*Eucalyptus* spp.), pines (*Pinus* spp.), Australian red cedar (*Toona ciliata*), and brush box (*Lophostemon confertus*). For more details on the history of timber plantings and the species utilized, please see Section 5.2 in this plan. Interspersed amongst these non-native plantation stands are large stands of koa (*Acacia koa*) trees.

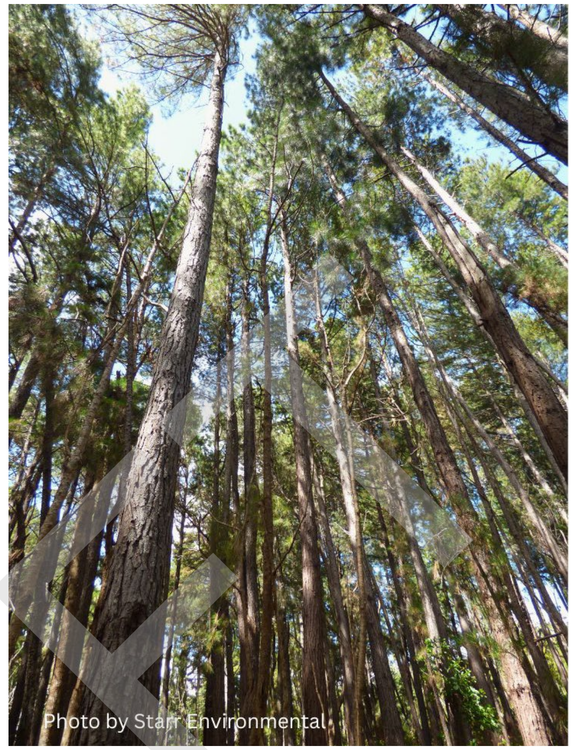


Figure 12. Pine timber stand

Table 5. List of species planted at experimental tree planting at Kaʻiliʻili in 1910 (Hosmer, 1914)

Species[3]	Common name
Eucalyptus gomphocephala	Tuart
Eucalyptus goniocalyx	Long-leaved box, olive-barked box, bundy
Eucalyptus moluccana (*hemiphloia*)	Grey box
Eucalyptus longifolia	Woollybutt
Eucalyptus leucoxylon	Yellow gum
Eucalyptus macrorhyncha	Red stringybark
Corymbia (*Eucalyptus*) *maculata*	Spotted gum
Eucalyptus marginata	Jarrah
Eucalyptus paniculata	Grey ironbark
Eucalyptus polyanthemos	Red box, silver dollar gum
Eucalyptus punctata	Grey gum
Eucalyptus robusta	Swamp mahogany
Eucalyptus saligna	Sydney blue gum
Eucalyptus siderophloia	Northern grey ironbark
Eucalyptus sideroxylon	Red iron bark
Eucalyptus tereticornis	Forest red gum

[3] Current species names are listed with the 1914 published name in parenthesis. Species may no longer be present in the forest reserve.

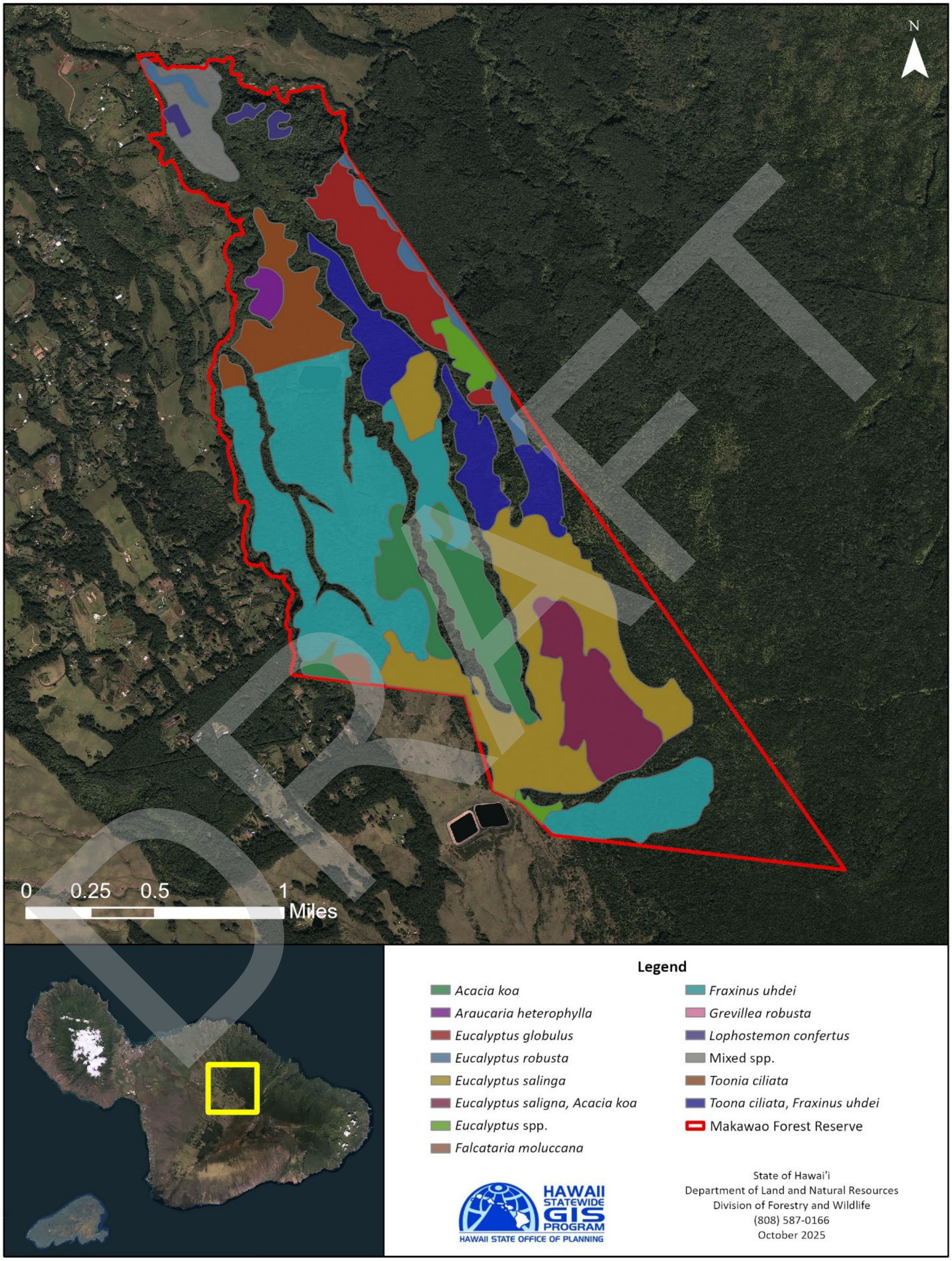
Pinus massoniana	馬尾松 (horsetail pine)
Pinus canariensis	Canary Island pine
Pinus radiata	Monterey pine
Pinus attenuate (*tuberculata*)	Knobcone pine

The understory in the non-native plantation stands is barren in most areas due to the thick canopy that decreases the amount of available sunlight. There are pockets of vegetation in the understory that are comprised mainly of non-native species such as Himalayan (kāhili) ginger (*Hedychium gardnerianum*), strawberry guava (*Psidium cattleianum*), and quinine (*Cinchona pubescens*). The non-native passion vine (*Passiflora edulis)* and thickets of blackberry (*Rubus argutus*) are also present. Groundcover species include the non-native palmgrass (*Setaria palmifolia*) and a few native species such as *Carex wahuensis* and kupukupu (*Nephrolepis exaltata*). Non-native ferns like the rough maidenhair fern (*Adiantum hispidulum*), brake fern (*Pteris cretica*), and downy wood fern (*Cyclosorus* spp.) are also present.

On the edges of the tree plantations, other native plants can be found persisting amongst the alien-dominated forest. Species present include koa*,* ʻōhiʻa (*Metrosideros polymorpha*), pilo (*Coprosma foliosa*), ʻaʻaliʻi (*Dodonaea viscosa*), manono (*Kadua affinis*), and pūkiawe (*Leptecophylla tameiameiae*). A few native species of fern that are also present but not abundant include palapalai (*Microlepia strigosa*), ōkupukupu (*Doodia kunthiana*), *Dryopteris* spp., and *Asplenium* spp. At higher elevations, native lianas and vines like maile (*Alyxia stellata*) and koali ʻawa (*Ipomoea indica*) are also present (Starr, 2022).

Figure 13. Timber stand with kupkupu (Nephrolepis exaltata) understory

Figure 14. Historical timber plantations in Makawao FR (Klingensmith, 1969)



3.5.2 Mesic Gulches

In the gulches between the plantation timber stands are pockets of diverse native ecosystems that were not bulldozed during reforestation efforts in the 1900s. These remnant native forests have the highest native species diversity in this portion of the reserve, especially on the steep gulch walls. The most common native tree species in the gulches is ʻōhiʻa, and its abundance increases with elevation. Other native tree species present include koaiʻa (*Acacia koaia*), hala pepe (*Dracaena auwahiensis*), olopua (*Nestegis sandwicensis*), kōlea (*Myrsine lessertiana*), hōlei (*Ochrosia haleakalae*), ʻālaʻa (*Planchonella sandwicensis*), and kāwaʻu (*Ilex anomala*).

Figure 15. A section of mesic forest where timber stands meet native species

Portions of the understory in this open native forest are dominated by uluhe ferns (*Dicranopteris linearis*) with scattered stands of hāpuʻu tree ferns (*Cibotium* spp.). In wetter portions of the gulch system, native ʻalaʻala wai nui (*Peperomia* spp.) can be found growing on rock faces. Patches of māmaki (*Pipturus albidus*) along with native vines such as maile, huehue (*Nephroia orbiculata*), and hoi kuahiwi (*Smilax melastomifolia*) are also present. ʻIeʻie (*Freycinetia arborea*) can be found climbing up native and non-native trees but is more abundant in native-dominated forests.

Figure 16. Species of the mesic forest (left to right): Myrsine lessertiana; Ochrosia haleakalae; Planchonella sandwicensis

Unfortunately, non-native tree species are spreading into the gulches from the plantation stands on the ridges. Tropical ash is the most aggressive, but eucalyptus and pines are also increasing in abundance. Other non-native species such as strawberry guava and quinine cover large areas in the gulches. Himalayan (kāhili) ginger has overtaken the understory along the river corridor. Night-blooming jasmine (*Cestrum nocturnum*) is locally abundant, and the invasive Australian tree fern (*Sphaeropteris cooperi*) is also spreading (Starr, 2022).

Figure 17. Non-native invasive species spreading into the mesic forests in Makawao FR (left to right): Hedychium gardnerianum; Spaheropteris cooperi

3.5.3 Wet Forests

Figure 18. Section of wet forest in Makawao FR

The north-eastern portion of Makawao FR from 3,000-4,900 feet in elevation has on average, a higher annual rainfall and is covered by native wet forests. The dominant tree species in this habitat zone are ʻōhiʻa and koa. Other native tree species that are present in lower numbers include ʻōlapa (*Cheirodendron trigynum*), kōlea (*Myrsine* spp.), alani (*Melicope* spp.), and kāwaʻu.

The most abundant native understory species in the wet forest is the uluhe fern. Other native ferns that can be found growing in the understory or epiphytically on trees include ʻamaʻu (*Sadleria* spp.), uluhe lau nui (*Diplopterygium pinnatum*), *Elaphoglossum* spp., palaʻā (*Odontosoria chinensis*), wahine noho mauna (*Adenophorus tamariscinus*), and ʻākōlea (*Athyrium microphyllum*). Tree ferns, such as the native hāpuʻu and the non-native Australian tree fern, are also found in this habitat zone. Native understory shrub species growing in this area include ʻōhā wai (*Clermontia* spp.), naupaka kuahiwi (*Scaevola chamissoniana*), ʻōhelo (*Vaccinium calycinum*), ʻākala (*Rubus hawaiensis*) and kanawao (*Hydrangea arguta*). Maile is also found sprawling through the wet forest, and ʻieʻie wrapping around the trunks of many trees.

Figure 19. Ferns in the wet forests of Makawao FR (left to right): Adenophorus tamariscinus; Sadleria spp.; Elaphoglossum spp.

Several aggressive non-native plant species are invading these stands of native wet forests. Himalayan (kāhili) ginger, which grows in dense mats, has taken over and pushed out native species and is currently the most abundant non-native species in the wet forest understory. Other invasive species present include palmgrass, strawberry guava, Koster's curse (*Miconia crenata*), and cane tibouchina (*Chaetogastra herbacea*). Invasive tree species from the plantation stands, such as tropical ash and eucalyptus, are slowly spreading to higher elevations.

Figure 20. Native shrubs in the wet forests of Makawao FR (left to right): Rubus hawaiensis; Clermontia kakeana; vaccinium calycinum

3.5.4 Rare and Endangered Plants

Many botanical surveys have been done in the Makawao area, dating as far back as 1879 (Oppenheimer et al., 2006). Currently, 19 rare and endangered plant species have been documented in Makawao FR (Table 6). Species observations that occurred more than 30 years ago are considered historical sightings. However, it is still possible that field botanists will locate individuals or populations of these species in future surveys. For a map of the density of rare plant populations in Makawao FR, see Figure 21.

Figure 21. Rare plant population density in Makawao FR

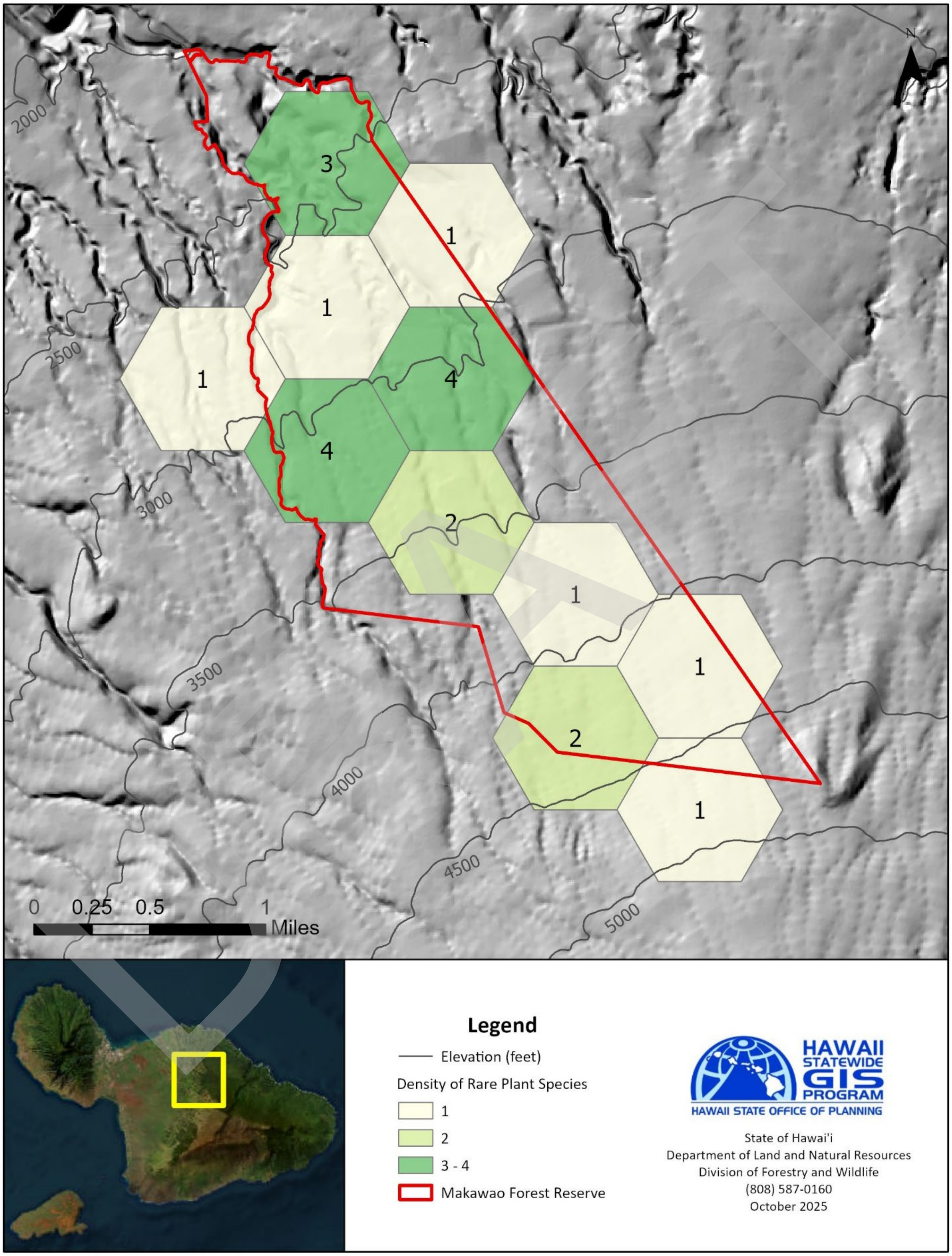


Table 6. Rare and endangered plants observed in Makawao FR. (Oppenheimer et. al., 2006; Starr, 2022)

Species	Common Name	Historical[4]	ESA	PEPP Species
Acacia koaia	Koai'a		At risk	No
Alectryon macrococcus var. *macrococcus*	Māhoe		Endangered	Yes
Anoectochilus sandwicensis	Honohono		At risk	No
Canavalia hawaiiensis	'Āwikiwiki		At risk	No
Clermontia oblongifolia subsp. *mauiensis*	'Ōhā wai		Endangered	Yes
Cyanea asplenifolia	Hāhā		Endangered	No
Cyanea maritae	Hāhā		Endangered	Yes
Cyanea obtusa	Hāhā		Endangered	Yes
Dissochondrus biflorus	Hawaiian false bristle grass	x	At risk	No
Doodia lyonii			At risk	No
Dryopteris fusco-atra var. *lamoureuxii*	'I'i		At risk	No
Dryopteris tetrapinnata			At risk	No
Geniostoma tinifolia var. *tinifolia*	Kāmakahala		At risk	No
Liparis hawaiensis	'Awapuhiakanaloa		At risk	No
Melicope hawaiensis	Mokihana kūkae moa		At risk	No
Ochrosia haleakalae	Hōlei		Endangered	No
Peperomia subpetiolata	'Ala'ala wai nui		Endangered	Yes
Stenogyne calycosa	Maui Stenogyne		Endangered	Yes
Zanthoxylum kauaense	A'e		At risk	No

Acacia koaia is a short-statured tree in the Fabaceae (legume) family. It is closely related to the more common koa (*Acacia koa*) but is found growing in drier and more open habitats on Moloka'i, Lāna'i, Maui, and Hawai'i. Morphologically, koai'a is significantly different from koa. Koai'a does not grow as tall (typically up to 15-30 feet, but occasionally 40-60 feet) as koa, it has a more "gnarled" habit, produces significantly harder wood, and has narrower pods with seeds longitudinally arranged (Wagner et al., 1999). While this species isn't federally listed as endangered, it is rare and considered at-risk. Koai'a can be found growing amongst koa in the lower and western portions of the reserve (Oppenheimer et. al., 2006).

Alectryon macrococcus var. *macrococcus* is in the Sapindaceae (soapberry) family. It is a long-lived perennial tree that can reach heights of 36 feet and is found growing at 1,180-3,500 feet in

[4] Observations are considered historical if they occurred more than 30 years ago.

elevation (Wagner et al., 1999). It was listed as an endangered species by the USFWS in 1992 after wild populations started to decline due to damage caused by black twig borer beetles *(Xylosandrus compactus*). These beetles burrow into, and feed on healthy woody tissue, disrupting the flow of water in the tree and ultimately killing infested limbs (USFWS, 2021a). In Makawao FR, the three known individuals have died, and the species is currently thought to have been extirpated from the area. However, future plant surveys may find other individuals in the reserve. Conservation efforts thus far include habitat protection, collecting and storing seeds (individuals in Makawao FR were all male), maintaining living collections in nurseries and botanical gardens, and outplantings in hopes of establishing new self-sustaining populations (USFWS, 2021a).

Anectochilus sandvicensis is in the Orchidaceae (orchid) family. It has pale green to yellow flowers and grows 4-20 inches tall. This species can be found in dense shade in the wet forest growing amongst bryophytes on the forest floor or on tree trunks at 1,180-4,000 feet in elevation (Wagner et al., 1999). While this species is not federally listed as endangered, it is rare and considered at-risk. In Makawao FR, a small population is known to exist at higher elevations (Oppenheimer et al., 2006).

Canavalia hawaiiensis is in the Fabaceae (legume) family. Like many legumes, this climbing vine produces leaves in sets of three and has magenta to light purple pea flowers. It can be found growing at 390-4,000 feet in elevation in dry to mesic forests of Maui and Hawaiʻi, and was once known to be found on Lānaʻi (Wagner et al., 1999). This species is not federally listed as endangered but is considered uncommon and at risk. In Makawao FR, it has been observed in the lower, western portion of the reserve (Oppenheimer et al., 2006).

Clermonita oblongifolia subsp. *mauiensis* is in the Campanulaceae (bellflower) family. It is a shrub that grows 6.5-23 feet tall with oblong leaves that are thick with rounded tooth edges and can reach up to 7.5 inches in length. It produces clusters of 2-3 flowers that are greenish-white or purplish and produce round, orange fruit (Wagner et al., 1999). This subspecies can be found growing at 1,310-3,940 feet in elevation in mesic valleys to wet forests on the islands of Lānaʻi and Maui (Wagner et al., 1999). The rarity of this species prompted it to be officially listed as an endangered species by the USFWS in 1992. In Makawao FR, there are a few individuals. The biggest threat to this species is habitat degradation from feral ungulates and aggressive non-native vegetation (USFWS, 2023a). Conservation efforts thus far include habitat protection, collecting and storing seeds, and outplanting in hopes of establishing new self-sustaining populations.

Cyanea asplenifolia is in the Campanulaceae (bellflower) family. It is a shrub that grows 4.3-6.6 feet tall with floral inflorescences that consist of 8-15 flowers that are often covered in spines. This species can be found at 1,850-2,900 feet in elevation in wet to mesic forests on Maui. Initially observed in the early 1900s, this species was thought to be extinct until it was rediscovered in 1998. The rarity of this species prompted it to be officially listed as an endangered species by the USFWS in 2013. There are approximately three populations on East

Maui, one of which was discovered in Makawao FR in 2000 (Oppenheimer et al., 2006). Currently, all known individuals of *Cyanea asplenifolia* from Makawao FR are dead and likely extirpated from the forest reserve. The biggest threat to this species is grazing and habitat degradation by feral ungulates such as pigs and goats (USFWS, 2020a). Conservation efforts thus far include genetic storage (seeds) and micropropagation at Lyon Arboretum (Oppenheimer et al., 2006).

Cyanea maritae is also part of the Campanulaceae (bellflower) family. It is a shrub that grows 6-7 feet tall, has leaves covered in spines, and produces floral inflorescences comprised of 9-45 gently curved flowers (USFWS, 2020b). This species was listed as an endangered species by the USFWS in 2013 after wild populations were observed to be in decline. There are seven known populations in the lowland wet and montane forests on the northwest, northeast, and southeast slopes of Haleakalā (USFWS, 2020b). In the Makawao FR, there are two locations with a total of five mature individuals (Oppenheimer et. al., 2006). Conservation efforts thus far include collecting and storing seeds, living collections in nurseries, and outplanting in hopes of establishing new self-sustaining populations.

Cyanea obtusa is also part of the Campanulaceae (bellflower) family. It is a shrub that grows 6.6-16 feet tall and produces floral inflorescences comprised of 6-12 hairy purple flowers (Wagner et al., 1999). It was listed as an endangered species by the USFWS in 2013 after wild populations were observed to be in decline. After nearly 100 years without observations of this plant, four individuals were found in Manawainui Gulch on East Maui in 1997 (USFWS, 2020c). As of 2020, only one wild individual remains, with 34 outplanted individuals throughout Nakula NAR and Manawainui gulch (USFWS, 2020c). There are old population records of *C. obtusa* in Makawao FR, but there are currently no known individuals, and it is thought to be extirpated from the reserve. Conservation efforts thus far include habitat protection, collecting and storing seeds, living collections in nurseries and micropropagation, and outplanting in hopes of establishing new self-sustaining populations.

Dissochondrus biflorus is in the Poaceae (grass) family. It is a short, creeping perennial grass with stalks that grow 1.9-3.9 feet tall and has spike-like inflorescences that are 3.6-7.8 inches long. This grass can be found on the main Hawaiian islands, excluding Niʻihau and Kahoʻolawe, in diverse mesic forests at 1,600-3,450 feet in elevation (Wagner et al., 1999). While it isn't federally listed as an endangered species, it is considered at-risk due to dwindling populations in the wild. This species was last documented in Makawao FR by botanist Robert Hobdy in the 1980s, in the lower Kahakapao drainage basin (Oppenheimer et. al., 2006).

Doodia lyonii is in the Blechnaceae (chain fern) family. It is a fern with 1-pinnate fronds that are 3.9-9.8 inches long and are arranged in a flattened rosette (Palmer, 2003). The sori, or clusters of spores, are on the bottom side of the pinnae and arranged in a single row parallel to the midrib (Palmer, 2003). This fern can be found on the islands of Kauaʻi, Oʻahu, and Maui along dark, moist overhanging banks of vegetation and streambeds at 1,600-2,890 feet in elevation (Palmer, 2003). While it isn't federally listed as an endangered species, it is considered at-risk. There are at least two known populations of this fern in Makawao FR.

Figure 22. (1) Ochrosia haleakalae; (2) Stenogyne calycosa; (3) Melicope hawaiensis; (4) Liparis hawaiensis; (5) Peperomia subpetiolata; (6) Alectryon macrococus var. micrococcus; (7) Cyanea maritae

Dryopteris fusco-atra var. *lamoureuxii* is in the Dryopteridaceae (shield fern) family. It is a fern with 2-pinnate fronds that are 1-2.6 feet long and grows in a shuttlecock arrangement (Palmer 2003). The fronds are green with narrow grey to black hairs (or scales). This particular variety of fern can be found at 3,010-3,940 feet in elevation (Palmer, 2003). Due to the limited range of this species and the ongoing threats of ungulates and habitat loss, this species is considered at-risk. Within the Makawao FR, several dozen individuals are known to exist (Oppenheimer et. al., 2006).

Dryopteris tetrapinnata is also in the Dryopteridaceae (shield fern) family. This fern gets its Latin name from the 4-pinnate fronds, which are green to dark green and sparsely covered in straw-colored scales, or hairs (Palmer, 2003). Considered possibly the largest *Dryopteris* in the world, fronds can reach lengths of up to 9.8 feet (Palmer, 2003). It is found only on Maui, growing on the north, east, and south slopes of Haleakalā at 4,590-6,000 feet in elevation (Palmer, 2003). While it isn't federally listed as an endangered species, it is considered at-risk. In Makawao FR, a population of this species is located on the eastern portion of the reserve where rainfall is more abundant (Oppenheimer et. al., 2006).

Geniostoma tinifolia var. *tinifolia* is in the Loganiaceae (logania) family. It is a shrub to small tree that grows 6.5-26.2 feet tall. Its leaves are elliptic to oval-shaped with flowers that are pale yellow to pale green (Wagner et al., 1999). This species can be found on Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, and Hawaiʻi, growing in mesic to wet forests at 980-3,020 feet in elevation (Wagner et al., 1999). While it isn't federally listed as an endangered species, it is considered rare. In Makawao FR, a few mature trees were observed growing on mid to lower slopes in the reserve (Oppenheimer et. al., 2006).

Liparis hawaiensis is in the Orchidaceae (orchid) family. It is a perennial herb that forms from pseudobulbs and sometimes grows epiphytically (Wagner et al., 1999). It develops two pale green leaves per bulb and a single flowering stalk with small green orchid flowers (Wagner et al., 1999). This species can be found growing in a variety of habitats, including wet to seasonally wet bare ground, bogs, and mesic to wet forests (Wagner et al., 1999). It has a wide distribution and is found at 1,310-6,560 feet in elevation on most of the main Hawaiian islands, excluding Niʻihau and Kahoʻolawe (Wagner et al., 1999). While it isn't federally listed as endangered, it is considered an at-risk species. In Makawao FR, a large population was found in the southwestern portion of the reserve (Oppenheimer et. al., 2006).

Melicope hawaiensis is in the Rutaceae (rue) family. It is a shrub to small tree that can reach heights of 9.8-32.8 feet. It produces leathery textured leaves with flowers that are various hues of red. This species can be found predominantly in dry forests and sometimes mesic forests at 2,000-4,000 feet in elevation on Molokaʻi, Lānaʻi, Maui, and Hawaiʻi (Wagner et al., 1999). While it isn't federally listed as an endangered species, it is considered at-risk. In Makawao FR, several individuals and one small reproducing population are known to exist in the reserve (Oppenheimer et. al., 2006).

Ochrosia haleakalae is in the Apocynaceae (dogbane) family. It is a tree that grows 7-26 feet tall with smooth, green, elliptic leaves with a yellow midrib. It has greenish-white flowers that form at the ends of branches, and its fruits are yellow with brown streaks. This species is largely found on the slopes of Haleakalā in Auwahi, Kanaio, and Makawao, but is also present on Hawaiʻi Island. It grows at 2,300-3,940 feet in elevation in dry to mesic forests, and occasionally on lava flows (Wagner et al., 1999). It was listed as an endangered species by the USFWS in 2016 after wild populations were observed to be in decline. There are approximately 270-370 wild individuals on Maui and 3-4 on Hawaiʻi Island, with an additional 1,300 outplanted on Maui and

300 on Hawaiʻi Island (USFWS, 2021b). Conservation efforts thus far include habitat protection, collecting and storing seeds, living collections in nurseries, propagation, and outplanting in hopes of establishing new self-sustaining populations. In Makawao FR, a few dozen individuals are present, and natural recruitment is occurring around mature plants (Oppenheimer et. al., 2006).

Peperomia subpetiolata is in the Piperaceae (pepper) family. It is a short-lived perennial herb that has green stems with reddish-purple splotches, which grow from 2 to 4.9 feet high. The upper surface of leaves is dark green, while the lower surface is pale green. This species of *Peperomia* is unique due to its larger shrub-like growth habit, compared to the generally smaller herbaceous stature of the rest of the Hawaiian species in the genus. *Peperomia subpetiolata* can be found in the mesic forests of Maui in the lower Waikamoi area, at 4,100-4,500 feet in elevation (Wagner et al., 1999). It was listed as an endangered species by the USFWS in 2013 after wild populations were observed to be in decline. Management of this species is challenging due to its ease of hybridizing with other common species of *Peperomia*. Many wild plants appear to be hybrids, and with the lack of adequate genetic information, experts are currently unable to make species determinations (M. Keir, personal communication, May 2, 2023). Even specimens that are being maintained in living collections are believed to be hybrids (USFWS, 2020d). There are ongoing trials to selectively breed hybrids to produce true *Peperomia subpetiolata.* Conservation efforts thus far include habitat protection, storing seeds, living collections in nurseries and micropropagation, and outplanting in hopes of establishing new self-sustaining populations. In Makawao FR, there are a few small populations of wild and outplanted individuals (likely hybrids) of this species in the reserve as well as in the adjacent Waikamoi Preserve and historically in Koʻolau FR (Oppenheimer et. al., 2006).

Stenogyne calycosa is in the Lamiaceae (mint) family. It is a climbing vine with leaves that have a leathery texture and toothed edge. It produces dark red flowers that emerge above the petiole of the leaves in sets of 2-4 (Wagner et al., 1999). This species can be found only on the island of Maui in mesic to wet forests up to 3,280 feet in elevation. Due to its limited range and the ongoing threats of habitat loss caused by aggressive non-native vegetation, this species is considered at-risk. In Makawao FR, there used to be small populations with less than 40 individuals (Oppenheimer et. al, 2006). These populations are now gone, and the species has likely been extirpated from the reserve (M. Keir, personal communication, May 2, 2023).

Zanthoxylum kauaense is in the Rutaceae (rue) family. It is a small to medium-sized tree that can reach heights of 9.8-50 feet (Wagner et al., 1999). It produces thick, leathery, dark green, oval-shaped leaves. Floral inflorescences emerge at the ends of stems and are comprised of 15-150 white flowers tinged with pink to red hues (Wagner et al., 1999). This species is found in dry to wet forests at 985-6,500 feet in elevation on most of the main Hawaiian islands, excluding Niʻihau and Kahoʻolawe. The main threat to this species is black twig borer beetles (*Xylosandrus compactus*), which burrow into and feed on healthy woody tissue, disrupting the flow of water in the tree and ultimately killing infested limbs. This species is considered at-risk due to its limited range, ongoing threats from black twig borers, ungulates, and habitat loss. In Makawao FR, a few mature trees are found on slopes and gulch bottoms (Oppenheimer et. al., 2006).

3.6 Wildlife

3.6.1 Native Wildlife

Six endangered wildlife species that are protected by state and federal regulations have been documented to occur in Makawao FR (Table 7). Four species are still present, and they are the endangered ʻōpeʻapeʻa or Hawaiian hoary bat (*Aeorestes semotus*), the nēnē or Hawaiian goose (*Branta sandvicensis*), the ʻuaʻu or Hawaiian petrel (*Pterodroma sandwichensis*), and the ʻAʻo or Newell's Shearwater (*Puffinus newelli*). Two species have not been observed in the reserve for decades and are likely no longer present. They are the ʻākohekohe or crested honeycreeper (*Palmeria dolei*) and the kiwikiu or the Maui parrotbill (*Pseudonestor xanthophrys*).

Figure 23. Hawaiian hoary bat (ʻŌpeʻapeʻa)

ʻŌpeʻapeʻa, also known as the Hawaiian hoary bat, is the only living native terrestrial mammal in Hawaiʻi. *Aeorestes semotus*, which is in the Vespertilionidae (microbats) family, has been reported on all the main Hawaiian islands, except for Niʻihau, below 4,200 feet in elevation. ʻŌpeʻapeʻa are most active at night while they feed on insects and have been observed roosting in a variety of native and non-native trees. The largest threat to ʻŌpeʻapeʻa is roost disturbance due to habitat loss (Hawaiʻi Department of Land and Natural Resources, 2015f). Other threats that also impact this species include pesticides and collisions with structures such as wind turbines.

Nēnē, also known as the Hawaiian goose, is the only native species of goose currently found in Hawaiʻi. *Branta sandvicensis*, which is in the Anatidae (water birds) family, has been reported on Hawaiʻi, Maui, Kauaʻi, and Molokaʻi from sea level to 7,800 feet in elevation. They have been observed in a variety of habitats such as coastal dunes, grasslands, shrublands, and lava flows. Current threats to nēnē include habitat loss, predation by non-native mammals, exposure to diseases transmitted by non-native animals, human-caused disturbance and mortality, behavioral problems related to captive breeding, and inbreeding depression (Hawaiʻi Department of Land and Natural Resources, 2015e). While nēnē has not been documented in Makawao FR, they are likely present.

ʻĀkohekohe, also known as the crested honeycreeper, is in the Fringillidae (songbird) family. The plumage of *Palmeria dolei* is primarily black, with the tips of feathers ranging in color from orange-yellow to silver or white. A unique feature of this native forest bird is the tuft of white feathers that curls forward over the bill. It is the largest living honeycreeper and is currently found only on the island of Maui in the wet and mesic montane forests at 5,000-6,000 feet in elevation. They are primarily nectarivores that feed on the sugary nectar of ʻōhiʻa, but are also known to feed on arthropods. The largest threats to ʻākohekohe are habitat loss, predation by non-native mammals, and mosquito-borne diseases (Hawaiʻi Department of Land and Natural Resources, 2015a). While this species has not been observed in the reserve for several decades, it is still possible that they are present. Makawao FR is in close proximity to the Nature Conservancy's Waikamoi Preserve, where ʻākohekohe were being tracked and studied in 2020 (Wang et al., 2020).

Figure 24. (Left to right): 'Ua'u (Hawaiian Petrel), 'A'o (Newell's shearwater)

Kiwikiu, also known as the Maui parrotbill (*Pseudonestor xanthophrys*), is also in the Fringillidae (songbird) family. Kiwikiu have large parrot-like bills and are mostly olive-green with yellow feathers on the breast, belly, and cheeks. This species is currently found only on the northeastern slopes of Haleakalā at 4,000-7,700 feet in elevation. Kiwikiu inhabit the montane wet forests that are dominated by ʻōhiʻa but can also be found in mesic forests that have a high density of native plant species. They feed on insects such as beetle and moth larvae by using their beak to pry open bark and softer woody tissue to reveal their meal. The largest threats to kiwikiu are low reproduction rates, habitat loss, predation by non-native mammals, and mosquito-borne diseases (Hawaiʻi Department of Land and Natural Resources, 2015d). While this species has not been documented in Makawao FR, they are likely present since the neighboring Waikamoi Preserve, managed by the Nature Conservancy, is part of the Kiwikiu's current range and is actively managed for threats (USFWS, 2023b).

ʻUaʻu, also known as the Hawaiian petrel (*Pterodroma sandwichensis*), is in the Procellariidae (sea bird) family. They are medium-sized, nocturnal, gadfly petrels that get their Hawaiian name from the distinctive calls that they make. They are dark gray on top with white feathers on their face and underside. ʻUaʻu is currently found on Hawaiʻi, Maui, Kauaʻi, and Lānaʻi at varying elevations and habitats. Depending on the island, their nesting habitat can range from high-elevation lava fields with little vegetation, to lower-elevation forests comprised of an ʻōhiʻa canopy and uluhe understory. They hunt at sea, feeding on squid, fish, and crustaceans. They form long-term bonds with their mate and return to the same nesting site year after year to mate. The largest threats to ʻuaʻu are predation by non-native mammals, habitat loss by feral ungulates, artificial lighting, and collision with human infrastructure (Hawaiʻi Department of Land

and Natural Resources, 2015g). While ʻuaʻu has not been documented in Makawao FR, they are likely present.

ʻAʻo, also known as Newell's shearwater (*Puffinus auricularis newelli*), is in the Procellariidae (sea bird) family. They are sea birds that spend a large portion of their lives on the open ocean. ʻAʻo has dark brown feathers covering its head and back, and white feathers on its throat and underside. They have dark bills with hooked tips that they use to feed on fish and squid. Nesting colonies of ʻaʻo are only found on Hawaiian islands, specifically on Kauaʻi, Hawaiʻi, Molokaʻi, Oʻahu, Maui, and Lānaʻi at 525-3,936 feet in elevation. The largest threats to ʻaʻo are predation by non-native mammals, habitat loss, artificial lighting, collisions with human infrastructure, overfishing, and natural disasters that can wipe out an entire population (Hawaiʻi Department of Land and Natural Resources, 2015b). While ʻaʻo have not been documented in Makawao FR, they are likely present.

Four additional native birds were also documented (Table 8) during forest bird surveys (HBMP, 2018; Starr, 2022): the ʻapapane (*Himatione sanguinea*), ʻiʻiwi (*Vesiaria coccinea*), Hawaiʻi ʻamakihi (*Chlorodrepanis virens wilsoni*), and the Maui ʻalauahio (*Paroreomyza montana*). Species profiles from the Hawaiʻi State Wildlife Action Plan that contain information on their biology, distribution, threats, and conservation actions have all been included as Appendix C of this plan.

Figure 25. Top (left to right): 'I'iwi, 'ākohekohe (Crested honeycreeper), Maui 'alauahio; Bottom (left to right): Hawai'i amakihi, 'apapane

Table 7. Rare and endangered animals of Makawao FR. (HBMP, 2018; Starr, 2022)

Species	Common Name	Historical[5]	ESA
Aeorestes semotus	Hawaiian hoary bat, ʻŌpeʻapeʻa		Endangered
Branta sandvicensis	Nēnē		Endangered
Palmeria dolei	Crested Honeycreeper, ʻĀkohekohe	Historical	Endangered
Pseudonestor xanthophrys	Maui parrotbill, Kiwikiu	Historical	Endangered
Pterodroma sandwichensis	Hawaiian petrel, ʻUaʻu		Endangered
Puffinus newelli	Newell's Shearwater, ʻAʻo		Endangered

Table 8. Avian wildlife found in Makawao FR (HBMP, 2018; Scott et al., 1986; Starr, 2022)

Species	Common Name	Native/Non-native	Game Species	Injurious Species	Survey Year
Acridotheres tristis	Common myna	Non-native			1980
Alauda arvensis	Sky lark	Non-native			1980
Branta sandvicensis	Nēnē	Native			Likely present
Callipepla californica	California quail	Non-native	x		1980 (rare)
Cardinalis cardinalis	Northern cardinal	Non-native			2022
Chlorodrepanis virens wilsoni	Hawaiʻi ʻamakihi	Native			2022
Drepanis coccinea	ʻIʻiwi	Native			2022
Garrulax canorus	Hwamei	Non-native			2022
Geopelia striata	Zebra Dove	Non-native	x		1980 (likely present)
Haemorhous mexicanus	House finch	Non-native			2022
Himatione sanguinea	ʻApapane	Native			2022
Horornis diphone	Japanese bush-warbler	Non-native			2022
Leiothrix lutea	Red-billed leiothrix	Non-native			2022
Lonchura spp.	Mannikin/munia	Non-native			2022
Nycticorax nycticorax	Black-crowned night-heron	Indigenous			2022
Palmeria dolei	Crested Honeycreeper, ʻĀkohekohe	Native			1980

[5] Species observations that occurred more than 30 years ago are considered historical sightings.

Paroaria coronata	Red-crested Cardinal	Non-native			2022
Paroreomyza montana	ʻAlauahio, Maui creeper	Native			1980
Passer domesticus	House sparrow	Non-native			2022
Phasianus colchicus	Ring-necked pheasant	Non-native	x		1980 (likely present)
Pseudonestor xanthophrys	Maui parrotbill, Kiwikiu	Native			Likely present
Pterodroma sandwichensis	Hawaiian petrel, ʻUaʻu	Native			Likely present
Puffinus newelli	Newell's Shearwater, ʻAʻo	Native			Likely present
Spilopelia chinensis	Spotted dove	Non-native	x		1980 (likely present)
Zosterops japonicus	Japanese white-eye	Non-native		x	2022

3.6.2 Native Arthropods and Mollusks

Makawao FR has been a popular location for entomological research due to its relative ease of access to predominantly native forests (Oppenheimer et.al., 2006). The majority of the arthropod collecting has occurred in the higher-elevation wet forest due to the higher diversity of native plant species found there. However, during the most recent entomological survey in 2005, researchers focused their collections on lower-elevation native ecosystems. While most of the arthropod species collected were non-native, many native species were also found throughout the survey area. For a complete list of all arthropods documented during these surveys, see Table 9. Below are descriptions of a few notable and unique native species that were observed.

Two species of pinapinao, or native damselfly, have been documented in Makawao FR. Part of the Coenagrionidae (narrow-winged damselflies) family, *Megalagrion calliphya* and *Megalagrion blackburni* were observed along the Kahakapao Loop Trail and in other various parts of the reserve (Starr, 2022). Native damselflies can be found on all major Hawaiian Islands, except Kahoʻolawe (Hawaiʻi's State Wildlife Action Plan, 2015c). Adults prey on other insects and can be found flying along stream corridors, wetland areas, ridges, and gulches in search of food. Immature damselflies, or naiads, live in streams, ponds, and pools of water on vegetation. They feed on aquatic insects before pupating (Starr, 2022). The largest threats to pinapinao are habitat loss and degradation, and predation of nymphs by non-native invertebrates, fish, and frogs (Hawaiʻi's State Wildlife Action Plan, 2015c).

The Giant Hawaiian Darner (*Anax strenuus*) was also documented in the reserve. It is one of two native pinao, or dragonflies, found in Hawaiʻi. It is considered the largest dragonfly in the United States and is found at higher elevations on all major Hawaiian Islands except Kaho'olawe (Hawaiʻi's State Wildlife Action Plan, 2015c). They are part of the Aeshnidae (darner) family and were observed hawking (hunting insects midair) along the Waikamoi Flume Road (Starr, 2022). Much like pinapinao, pinao can be found along bodies of water such as streams and wetlands. Naiads live in slow-moving bodies of water typically devoid of native and non-native fish (Waipiʻo Valley Stream Restoration Study, 2010). Pinao naiads feed on aquatic insects and small shrimp. The largest threats to pinao are habitat loss and degradation via water diversions and feral ungulates, and predators such as native and introduced fish, and introduced crayfish.

Several species of native fancy-cased moths (*Hyposmocoma* spp.) were also observed in Makawao FR. They can be found inhabiting a variety of habitats ranging from flowing streams to rocky cliff faces. They are part of the Cosmopterigidae (cosmet moths) famil*y,* which represents one of the greatest examples of adaptive radiation and evolutionary diversity. There are estimated to be more than 400 species of *Hyposmocoma* in the Hawaiian Islands, "accounting for one-third of all butterfly and moth diversity" (Haines et al., 2014). Species in this genus have a wide range of case types that the larval stage uses as protection and shelter. In Makawao FR, the most prevalent case types were "burrito and cone" which were observed on large stones and cliff faces, and the "candy wrapper and purse" case types were present but less abundant (Starr, 2022). Most notably, the species *Hyposmocoma molluscivora* was first collected in the reserve. They are carnivorous and are known to encase snails in leaves with silk and proceed to eat them alive (Starr, 2022). There is still much to discover about these unique native moths, and new undescribed species will undoubtedly be collected from Makawao FR in the coming years.

Nananana makakiʻi, also known as the happy-faced spider (*Theridion grallator*), is a particularly charismatic native insect found on the underside of leaves in native wet and mesic forests. They are in the Theridiidae (tangle-web spiders) family and are found on Maui, Molokaʻi, Oʻahu, and Hawaiʻi island. Nananana makakiʻi are varying shades of translucent yellow with red, black, and white markings on their abdomen and cephalothorax. The patterns are unique between localized populations and habitats, but as its name suggests, the coloration and patterns often resemble a smiling face, with two distinct eyes and a mouth (Oxford & Gillespie, 1996). In Makawao FR, this species is locally abundant and found at higher elevations in wetter habitats. They have been observed on the undersides of the invasive Himalayan (kāhili) ginger (*Hedychium gardnerianum*) (Starr, 2022).

Five species of native leafroller moths (*Omiodes* spp.) were observed in the reserve at 2,460-4,365 feet in elevation. The larvae of most species in this genus are generalists that feed on both native and non-native grasses. However, two species found in the reserve have more specific host preferences. Larvae of *O. monogona* are believed to feed on plants in the Fabaceae (legume) family and *O. anastrepa* larvae only feed on native sedges*. Omiodes monogona, O.*

continuatalis, and *O. anastrepta* were once thought to be extinct, but surveys in 2005 proved otherwise (Oppenheimer et. al., 2006). *Omiodes monogona, O. accepta,* and *O. continuatalis* are believed to be widespread throughout the reserve due to their ability to thrive in non-native vegetation, while *O. anastrepta* appears to be restricted to native ecosystems.

A particularly exciting discovery in Makawao FR was the collection of a suspected “banana” *Omiodes,* a possible rediscovery of a species that was thought to be extinct. It was collected in a light trap that was set-up near a small population of an undescribed Hawaiian banana cultivar. Molecular work shows that this specimen might be grouped most closely with *Omiodes musicola*, which is believed to be extinct (Oppenheimer et. al., 2006). Bananas are not native to Hawaiʻi and were introduced by Polynesians 1,000-1,500 years ago. This specialized group of native leafroller moths that feed on Hawaiian banana cultivars is believed to be an example of rapid speciation (Oppenheimer et. al., 2006).

Eight species of native long-legged flies (*Campsicnemus* spp.) were also observed in the reserve at 2,440-4,360 feet in elevation, including four new undescribed species (Oppenheimer et. al., 2006). They were most abundant at higher elevations in the wet forests that border the Waikamoi Preserve at 4,360 feet in elevation, with *Campsicnemus capitulatus* representing the bulk of collected specimens.

The endemic koa moth (*Scotorythra paludicola*) was also observed during entomological surveys in Makawao FR. Larvae of this species feed on the leaves of koa. Occasionally, large, localized population outbreaks occur that result in mass koa defoliation. These outbreaks have occurred every 10-30 years for the past century in Makawao FR (Oppenheimer et. al., 2006). Six recorded outbreaks occurred in Makawao FR in 1896, 1926, 1946, 1971, 1977, and 2004. Typically, populations of *Scotorythra paludicola* are kept at reasonable levels by parasitoid wasps, such as *Cotesia marginiventris* and *Meteorus laphygmae.* Little is known about why population explosions of *Scotorythra paludicola* occur and what factors contribute to these natural events.

Other notable native insect species documented in the reserve include ʻōhiʻa psyllids (*Pariaconus* spp.), also known as jumping plant lice. They create galls, or little bumps, on the leaves, stems, and flowers of ʻōhiʻa. A single individual lives in each gall, which turns brown after the psyllid emerges and leaves its host (Starr, 2022).

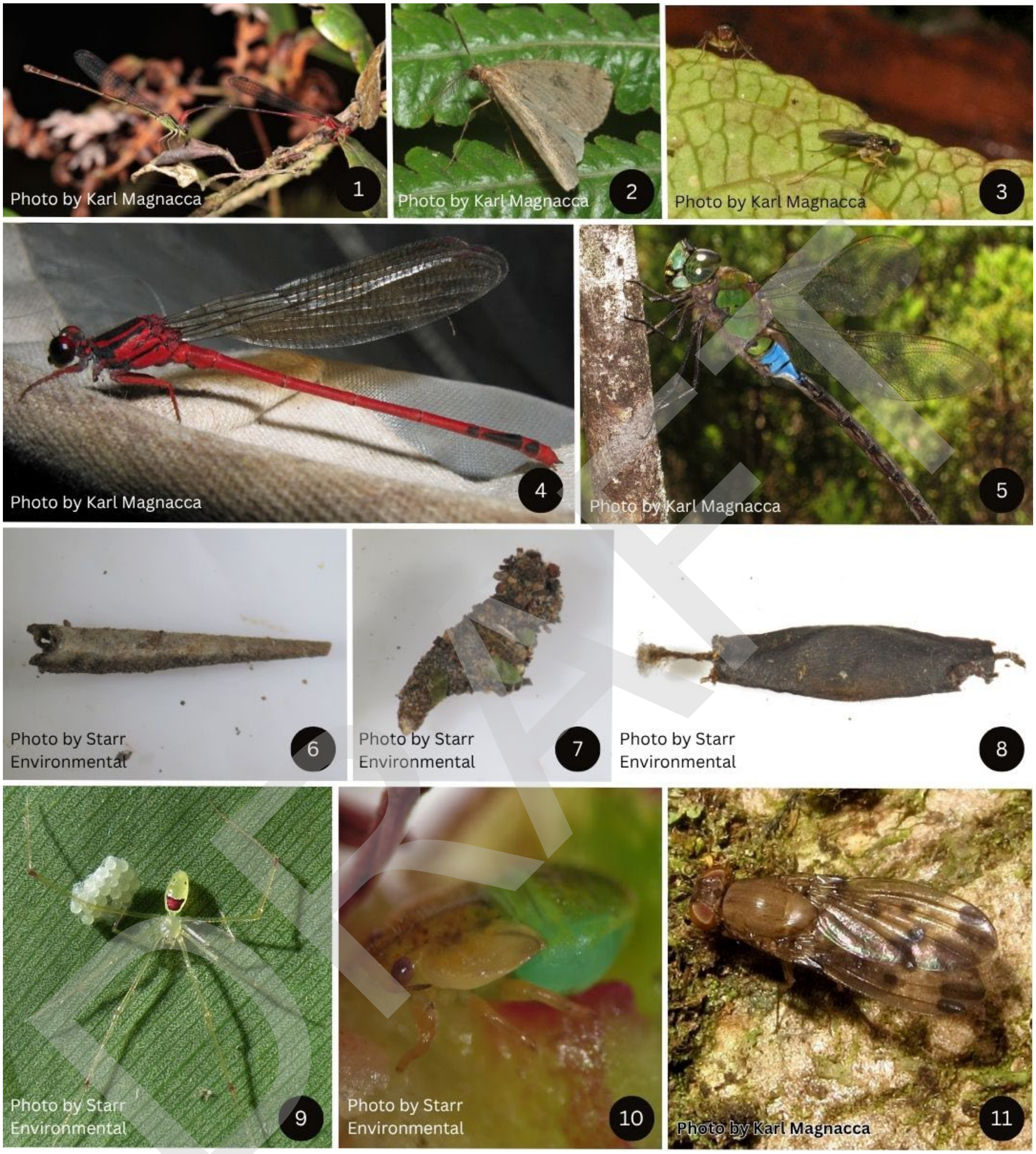


Figure 26. (1) Megalagrion calliphya; (2) Scotorythra paludicola; (3) Campsicnemus capitulatus; (4) Megalagrion blackburni; (5) Anax strenuus; (6) Hyposmocooma "cone case"; (7) Hyposmocoma "candy wrapper" case; (8) Hyposmocoma "purse" case; (9) Theridion grallator; (10) Pariaconus sp.; (11) Drosophila odontophallus

In terms of documenting snails in Makawao FR (Table 10), there have been two surveys that took place in 2020 and 2022. *Tornatellides terebra*, a native tornatellid snail, was found under rocks (Starr, 2022). Interestingly, this species is a known prey of the native carnivorous case moth *Hyposmocoma molluscivora*. Other native snails that have been observed in the reserve include *Auriculella* spp., *Elasmias* spp., *Lamellidea* cf *lanceolata*, *Lamellidea polygnampta*, *Philonesia perlucens*, and *Pupillidae* spp. (Yeung, 2020).

Table 9. Arthropods documented in Makawao FR (Magnacca, 2012; Oppenheimer et. al., 2006; Starr, 2022)

Species	Common Name	Native/Non-native
Adoretus sinicus	Chinese rose beetle	Non-native
Agrius cingulata	Pink-spotted hawkmoth	Non-native
Agrotis ipsilon	Dark sword-grass	Non-native
Allograpta obliqua	Common oblique syrphid	Non-native
Amorbia emigratella	Mexican leafroller	Non-native
Amyna sp.	Moth	Non-native
Anax strenuus	Pinao, Giant Hawaiian darner	Native
Aphodius lividus	Aphodiine dung beetle	Non-native
Apis mellifera	Western honey bee	Non-native
Asteia molokaiensis	Asteiid fly	Native
Asteia nr. *mudiseta*	Asteiid fly	Native
Athetis thoracica	Moth	Non-native
Atrichopogon jacobsoni	Biting midge	Non-native
Aumakua omaomao	Moth	Native
Botocudo marianensis	Seed bug	Non-native
Campsicnemus capitulatus	Long-legged fly	Native
Campsicnemus distinctus	Long-legged fly	Native
Campsicnemus fumipennis	Long-legged fly	Native
Campsicnemus mucronatus	Long-legged fly	Native
Campsicnemus perplexus	Long-legged fly	Native
Campsicnemus sp.	Long-legged fly	Native
Cardiocondyla sp.	Tiny myrmicine ant	Non-native
Chaetocnema confinis	Flea beetle	Non-native
Cheumatopsyche pettiti	Little sister sedge	Non-native
Chrysodeixis eriosoma	Green garden looper	Non-native
Chrysotus longipalpus	Moth	Non-native
Conocephalus saltator	Longhorned grasshopper	Non-native
Copris incertus	Black dung beetle	Non-native
Cryptamorpha desjardinsi	Desjardin's beetle	Non-native
Cryptophlebia illepida	Koa seedworm	Native
Ctenoplusia albostriata	Eastern streaked plusia	Non-native
Ctenosciara hawaiiensis	Dark-winged fungus gnats	Native
Cylindroiulus latestriatus	Millipede	Non-native

Diplonevra peregrina	Hump-backed fly	Non-native
Dolichopus exsul	Long-legged fly	Non-native
Drosophila adiastola	Pomace fly	Native
Drosophila adunca	Pomace fly	Native
Drosophila ancyla	Pomace fly	Native
Drosophila balioptera	Pomace fly	Native
Drosophila disticha	Pomace fly	Native
Drosophila fasciculisetae	Pomace fly	Native
Drosophila fundita	Pomace fly	Native
Drosophila grimshawi	Pomace fly	Native
Drosophila iki	Pomace fly	Native
Drosophila lanaiensis	Pomace fly	Native
Drosophila nigella	Pomace fly	Native
Drosophila latigena	Pomace fly	Native
Drosophila nr. *toxacantha*	Pomace fly	Native
Drosophila odontophallus	Pomace fly	Native
Drosophila orthoptera	Pomace fly	Native
Drosophila sp.	Pomace fly	Unknown
Drosophila torula	Pomace fly	Native
Drosophila variabilis	Pomace fly	Native
Drosophila waddingtoni	Pomace fly	Native
Dryopthorus sp.	True weevil	Native
Dyscritomyia hawaiiensis	Hawaiian blowfly	Native
Dyscritomyia sp.	Hawaiian blowfly	Native
Elaphria nucicolora	Sugarcane midget	Non-native
Enicospilus blackburni	Ophion wasp	Native
Enicospilus dispilus	Ophion wasp	Native
Enicospilus kaalae	Ophion wasp	Native
Enicospilus lineatus	Ophion wasp	Native
Enicospilus orbitalis	Ophion wasp	Native
Epinotia lantana	Lantana biocontrol	Non-native
Epiphyas postvittana	Light brown apple moth	Non-native
Eublemma accedens	Moth	Non-native
Eucalliphora latifrons	Blue bottle fly	Non-native
Eupetinus impressus	Sap beetle	Native
Euxesta annonae	Cornsilk fly	Non-native
Exaireta spinigera	Garden soldier fly	Non-native
Forcipomyia hardyi	Biting midge	Native
Glyphodes cyanomichla	Blue glyphodes moth	Native
Haliophyle ferruginea	Moth	Native
Herpetogramma licarsisalis	Grass webworm	Non-native
Homoneura unguiculata	Fly	Non-native

Hyles wilsoni perkinsi	Perkin’s sphinx moth	Native
Hyles wilsoni wilsoni	Wilson’s sphinx moth	Native
Hypena laceratalis	Lantana defoliator moth	Non-native
Hypoponera sp.	Ant	Non-native
Hyposmocoma molluscivora	Snail-eating caterpillar	Native
Hyposmocoma sp.	Fancy cased moth	Native
Leia sp.	Fungus gnat	Native
Leptocera abdominiseta	Lesser dung fly	Non-native
Leucania loreyimima	False armyworm	Non-native
Limonia hawaiiensis	Crane fly	Native
Limonia perkinsi	Crane fly	Non-native
Limonia stygipennis	Crane fly	Native
Limonia swezeyi	Crane fly	Native
Linepithema humile	Argentine ant	Non-native
Lispe metatarsalis	Stream fly	Native
Lispe sp.	True fly	Unknown
Lispocephala carita	Tiger fly	Native
Lispocephala confluens	Tiger fly	Native
Lispocephala flaccida	Tiger fly	Native
Lispocephala indecisa	Tiger fly	Native
Lispocephala ingens	Tiger fly	Native
Lispocephala longipes	Tiger fly	Native
Lispocephala mauiensis	Tiger fly	Native
Lispocephala planifemorata	Tiger fly	Native
Lispocephala sp.	Tiger fly	Native
Listroderes difficilis	Vegetable weevil	Non-native
Lonchaea polita	Lance fly	Non-native
Lophoplusia pterylota	Moth	Native
Lophoplusia sp.	Moth	Native
Lycophotia porphyrea	True lover’s knot moth	Non-native
Macaria abydata	Dot-lined angle moth	Non-native
Maruca vitrata	Bean pod borer	Non-native
Megalagrion blackburni	Pinapinao, Blackburn’s Hawaiian damselfly	Native
Megalagrion calliphya	Pinapinao, Beautiful Hawaiian damselfly	Native
Megalographa biloba	Bilobed looper moth	Non-native
Meijerella flavisetosa	Chloropid fly	Non-native
Melipotis indomita	Indomitable melipotis moth	Non-native
Metacolpodes buchanani	Ground beetle	Non-native
Meteorus laphygmae	Parasitoid wasp	Non-native
Muscina levida	Fly	Non-native
Neoloxotaenia gracilis	Grass fly	Non-native

Nesiomiris sp.	Mirid bug	Native
Nesoclimacias lanaiensis	Cinch bug	Native
Nesophrosyne sp.	Leafhopper	Native
Nezara viridula	Southern green stink bug	Non-native
Nomophila noctuella	Rush veneer	Non-native
Notioba purpurascens	Ground beetle	Non-native
Omiodes accepta	Sugarcane leafroller moth	Native
Omiodes anastrepta	Hawaiian sedge leafroller moth	Native
Omiodes continuatalis	Hawaiian leafroller moth	Native
Omiodes localis	Hawaiian grass leafroller moth	Native
Omiodes monogona	Hawaiian bean leafroller moth	Native
Oncocephalus pacifica	Assassin bug	Non-native
Oodemas sp.	Weevil	Native
Opogona omoscopa	Tineid moth	Non-native
Opogona sacchari	Banana moth	Non-native
Orthotylus clermontioides	Leaf bug	Native
Orthotylus kassandropsis	Leaf bug	Native
Orthotylus kopiko	Leaf bug	Native
Orthotylusa neopsychotrioides	Leaf bug	Native
Orthotylusa perrottetiopsis	Leaf bug	Native
Orthotylusa pisoniopsis	Leaf bug	Native
Orthotylusa ureraphila	Leaf bug	Native
Orthotylusa xylosmoides	Leaf bug	Native
Pariaconus sp.	ʻŌhiʻa "closed gall" psyllid	Native
Peridroma sp.	Moth	Native
Philonthus turbidus	Rove beetle	Non-native
Pimpla punicipes	Ichneumon wasp	Non-native
Poecilosomella punctipennis	Fly	Non-native
Priophorus morio	Raspberry sawfly	Non-native
Prognostola cremnopis	Moth	Native
Prosopeus concolor	Sap beetle	Native
Prosopeus similis	Sap beetle	Native
Proterhinus sp.	Primitive weevil	Native
Proteroiulus fuscus	Millipede	Non-native
Psammoechus insularis	Beetle	Non-native
Pseudaletia unipunctata	Armyworm moth	Non-native
Pseudoclerada kilaueae	Leaf bug	Native
Pterogramma brevivenosum	Fly	Native
Rhodesiella elegantula	Grass fly	Non-native
Rhyncogonus sp.	Beetle	Native
Salbia haemorrhoidalis	Lantana leaftier	Non-native
Sarcophaga peregrina	Flesh fly	Non-native

Sardia rostrata	Sedge planthopper	Non-native
Scaptomyza crassifemur	Pomace fly	Native
Scaptomyza varipicta	Pomace fly	Native
Schreckensteinia festaliella	Blackberry skeletonizer	Non-native
Scotorythra arboricolens	Moth	Native
Scotorythra corticea	Moth	Native
Scotorythra gomphias	Moth	Native
Scotorythra nephelosticta	Moth	Native
Scotorythra ortharcha	Moth	Native
Scotorythra paludicola	Koa moth, koa looper	Native
Scotorythra rara	Moth	Native
Scotorythra trapezias	Moth	Native
Sierola sp.	Flat wasp	Native
Siphanta acuta	Torpedo bug	Non-native
Solenopsis papuana	Papuan thief ant	Non-native
Sophonia rufofascia	Two-spotted leafhopper	Non-native
Spoladea recurvalis	Beet webworm moth	Non-native
Spolas sp.	Darwin wasp	Native
Stelidiota geminata	Strawberry sap beetle	Non-native
Taylorilygus apicalis	Broken-backed bug	Non-native
Tephrochlamys sp.	Fly	Native
Tetreuaresta obscuriventri	Fruit fly	Non-native
Theridion grallator	Nananana makaki'i, Hawaiian happy face spider	Native
Trathala flavoorbitalis	Parasitoid wasp	Non-native
Tylparua insularis	Fungus gnat	Native
Udara blackburni	Koa butterfly	Native
Udea sp.	Moth	Native
Uresiphita polygonalis	Moth	Native?
Vespula pensylvanica	Western yellowjacket	Non-native
Xylosandrus morigerus	Brown twig beetle	Non-native

Table 10. Mollusks documented in Makawao FR (Starr, 2022; Yeung, 2020; Yeung, 2025)

Species	Common Name	Native/Non-native
Arion intermedius	Hedgehog slug	Non-native
Auriculella crassula	Mollusk	Native
Deroceras laeve	Marsh slug	Non-native
Elasmias sp.	Mollusk	Unknown
Euglandia rosea	Rose wolf snail	Non-native
Hawaiia minuscula	Minute gem snail	Non-native
Lamellidea cf *lanceolata*	Mollusk	Native
Lamellidea polygnampta	Mollusk	Native

Lamellidea sp.	Mollusk	Native
Oxychilus alliarius	Garlic snail	Non-native
Oxychilus cellarius	Cellar glass-snail	Non-native
Oxychilus draparnaudi	Draparnaud's glass snail	Non-native
Partulina dubiosa	Mollusk	Native
Philonesia perlucens	Mollusk	Native
Philonesia sp.	Mollusk	Native
Pronesopupa sp.	Mollusk	Native
Pupillidae sp.	Mollusk	Unknown
Striatura sp.	Mollusk	Non-native
Succinea sp.	Mollusk	Unknown
Tornatellaria sp.	Mollusk	Native
Tornatellides terebra	Mollusk	Native
Tornatellides sp.	Mollusk	Native
Vertiginidae sp.	Mollusk	Non-native

3.6.3 Non-Native Wildlife

Ten non-native forest birds and game birds are known to occur in Makawao FR and are listed in Table 8 above. Additional information for non-native and native bird species, including photographs and bird call recordings, can be found on the Nā Ala Hele birding trails website (https://hawaiibirdingtrails.hawaii.gov/bird).

There are a total of nine non-native mammals that have been documented in Makawao FR and are listed in Table 11 below. There are populations of feral pigs (*Sus scrofa*) and axis deer (*Axis* axis) in the reserve. Feral pigs are found throughout the reserve but are most abundant in areas away from human activity. Other mammals in the reserve include cats (*Felis catus*), mongoose (*Herpestes auropunctatus*), mice (*Mus domesticus*), and rats (*Rattus* spp.).

Another notable non-native species in the upper wet forest is the Jackson's chameleon (*Trioceros jasksonii*). Jackson's chameleons escaped the pet trade and are now found in remote natural areas across the state. They do not discriminate on what they consume and prey on anything that fits in their mouths. Jackson's Chameleons have been known to prey on native insects, spiders, and snails, a few of which are rare and endangered.

As described above, there have been several surveys in Makawao FR to inventory arthropod species in the various habitats of the reserve. During these surveys, both native and non-native insects were collected and identified, and are all listed above in Table 9. Of the non-native arthropods documented, most notable were the invasive ants which were more abundant in the drier, lower elevation habitats. Ant species observed in the reserve include *Cardiocondyla* sp., *Hypoponera* sp., the Argentine ant (*Linepithema humile*, only seen along paved roads), and the thief ant (*Solenopsis papuana*). Ants negatively impact native ecosystems through predation and habitat disturbance of native birds and invertebrates, as well as indirect effects on native plants.

Figure 27. Top (left to right): Axis deer, feral pig; Bottom (left to right): Jackson's chameleon, Argentine ant

Table 11. Mammals found in Makawao FR

Species	Common name	Native/Non-native	Game species
Axis axis	Axis deer	Non-native	x
Felis catus	Feral cats	Non-native	
Herpestes auropunctatus	Mongoose	Non-native	
Aeorestes semotus	Hawaiian hoary bat, ʻŌpeʻapeʻa	Native	
Mus domesticus	Mice	Non-native	
Rattus spp.	Rats	Non-native	
Sus scrofa	Feral pigs	Non-native	x

3.7 Critical Habitat

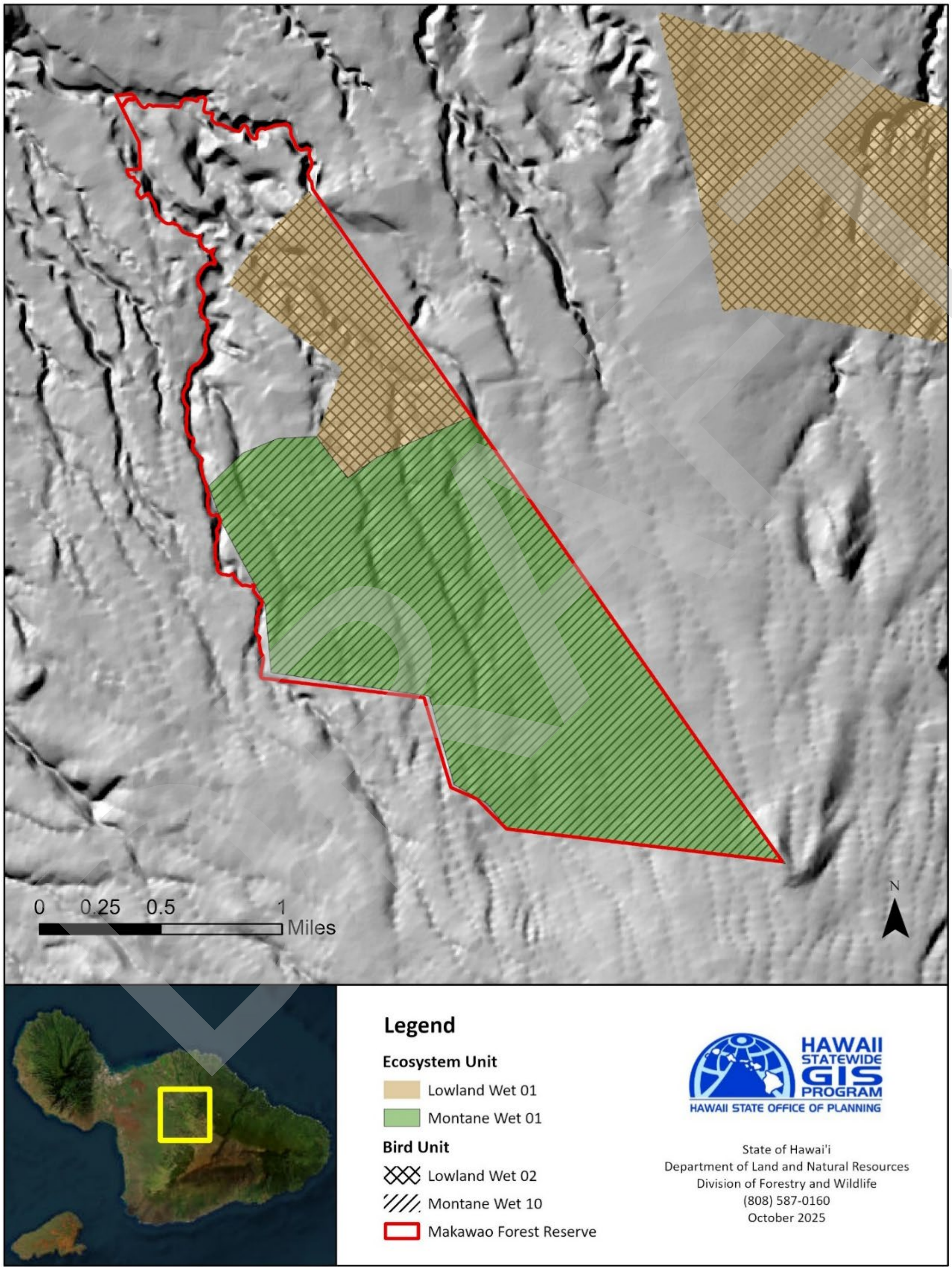
As outlined by the Endangered Species Act (ESA), Critical Habitat is defined as “specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rule” (USFWS, 2017). There are 1,050 acres in Makawao Forest Reserve that have been designated as Critical Habitat. There are two units (Figure 28) that are defined by ecosystem type: Lowland Wet and Montane Wet. Overlapping subsets of endangered species are assigned to each unit, and altogether they serve as critical habitats for 33 plant species and two species of forest birds. See Table 12 for a list of these species and which critical habitat units have been designated for their conservation. Only a few of these species are currently known to occur in Makawao FR.

Table 12. Ecosystem critical habitat designation in Makawao FR (USFWS, 2016)

Species	**Critical Habitat Ecosystem Unit**	
Plants	**Lowland Wet 01**	**Montane Wet 01**
Adenophorus periens		x
Asplenium peruvianum var. *insulare*		x
Bidens campylotheca subsp. *pentamera*		x
Bidens campylotheca subsp. *waihoiensis*	x	x
Clermontia oblongifolia subsp. *mauiensis*	x	x
Clermontia peleana	x	
Clermontia samuelii	x	x
Cyanea asplendifolia	x	
Cyanea copelandii subsp. *haleakalaensis*	x	x
Cyanea duvalliorum	x	x
Cyanea glabra		x
Cyanea hamatiflora subsp. *hamaiflora*	x	x
Cyanea horrida		x
Cyanea kunthiana	x	x
Cyanea maritae	x	x
Cyanea mceldowneyi	x	x
Cyrtandra ferripilosa		x
Diplazium molokaiense		x
Geranium hanaense		x
Geranium multiflorum		x
Huperzia mannii	x	x
Melicope balloui	x	x
Melicope ovalis	x	x
Mucuna sloanei var. *persericea*	x	
Peperomia subpetiolata		x
Phyllostegia bracteata		x
Phyllostegia haliakalae	x	x
Phyllostegia mannii		x
Phyllostegia pilosa		x
Platanthera holochila		x
Schiedea jacobii		x
Wikstroemia villosa	x	x
Birds		

Palmeria dolei	x	x
Pseudonestor xanthophyrys	x	x

Figure 28. Critical habitat in Makawao FR; Also see Table 12 (USFWS, 2016)



3.8 Archaeological and Historical Sites

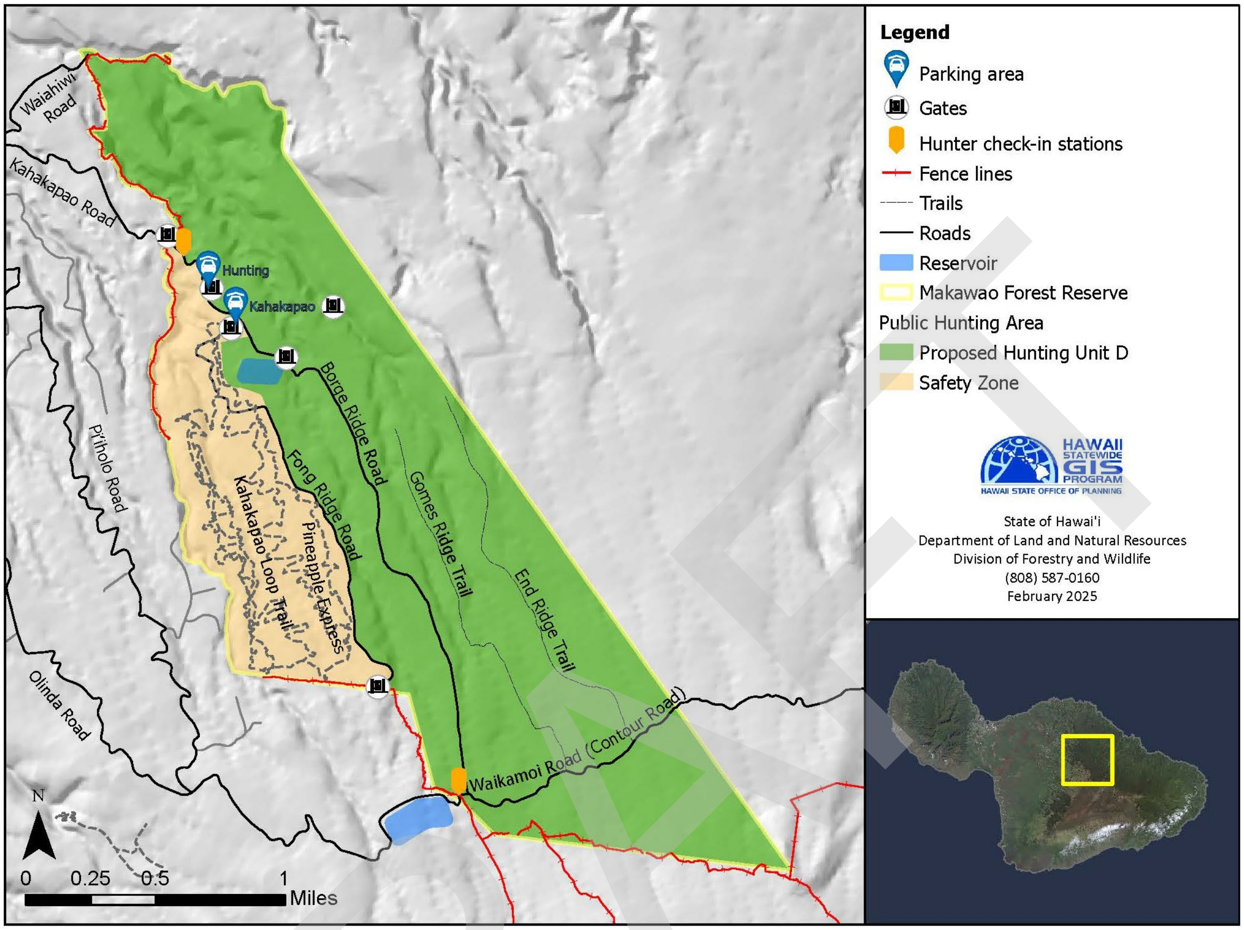
In 2013, an archaeological survey was conducted prior to developing the Kahakapao Recreational Area in Makawao FR. A cultural impact assessment completed for the recreational area found no archaeological sites within the trail corridors or immediate area (State of Hawaiʻi, 2013). Archaeological inventory surveys were also completed in 1988 for a proposed 36-inch waterline that ran between the Olinda Water Treatment Plant and the Waikamoi Reservoirs and the Kahakapao Reservoir. This survey also found no historical or archaeological sites, with the closest archaeological site being more than 15 miles northeast of the Kahakapao Recreational Area (State of Hawaiʻi, 2013).

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, is identified during any management activities, work will cease immediately in the area of discovery. The cultural resources found will be protected from further disturbance, and the State Historic Preservation District (SHPD) will be consulted regarding appropriate documentation. If cultural or historic properties are present that require mitigation, a detailed mitigation plan (e.g., archaeological monitoring plan or a preservation plan) will be submitted to SHPD for review, along with written and photographic documentation verifying that appropriate interim protection measures have been implemented.

3.9 Access

There is currently one public access point into Makawao FR at the end of Kahakapao Road. A paved road leads to two parking areas, one for the Kahakapao Recreational Area and one for hunters just a short distance below the Kahakapao Recreation Area. Makawao FR is open to the public between 6:30 am and 8:00 pm, which is regulated by an automatic gate at the boundary. There is also limited access via Waikamoi Flume Road (Contour Road) to the upper elevation section of the reserve. It crosses through private property, and permission is needed from Haleakalā Ranch to use the road. For a map of public access and infrastructure in Makawao FR, see Figure *29*.

Figure 29. Public access and infrastructure in Makawao FR



3.10 Infrastructure

Infrastructure in Makawao FR has been developed for watershed protection, to support management activities, and to allow for public access and recreational use. Ten miles of watershed protection fencing were built along the northwestern and southern boundaries of the reserve to keep cattle out of the forest.

In the middle of the reserve, there is a network of 4WD roads that were originally installed to support the reforestation efforts during the mid-1900s. Forestry staff continue to maintain Fong Ridge Road (aka Powerline Road), Borge Ridge Road, and Waikamoi Road (aka Contour Road) for public and management access. The Gomes Ridge and End Ridge Roads have not been maintained and are no longer used for vehicular access, but are still traversable by foot and are now considered trails. There are five forestry gates and one automated gate at key locations to control vehicular access as needed. There is also a network of multi-use trails for public recreation and parking areas for forest users.

There are two designated parking areas to accommodate the numerous and diverse recreational forest users (Figure 29). The first parking area is for hunters and is a gravel lot located on the left side of the road. The second parking area is a short distance up the road, adjacent to the Kahakapao Recreational Area trailhead. The parking area is intended for recreational users such as hikers, mountain bikers, and equestrian riders. The Kahakapao Recreational Area parking area has two lots. The lower parking lot has designated trailer parking stalls that can accommodate up to 5 horse trailers. The upper parking lot/overflow lot (nearest to the trailhead) can accommodate 25 personal vehicles. Much of the public recreational infrastructure in the forest reserve is located within the Kahakapao Recreational Area; for more information, see Section 3.11.1.

In the northwest corner of Makawao FR is the Piʻiholo Water Treatment Facility, which is completely fenced off and closed to the public. In 1975, the County of Maui was issued a perpetual easement across approximately 36 acres for water use and development of the Piʻiholo Water Treatment Facility. Construction of the Piʻiholo Water Treatment Facility was completed in 1996 to improve water quality for Lower Kula. The Kula Water Pipeline also runs through the reserve, transporting water from Hana to the rest of East Maui.

Several electrical power lines also run through various portions of the forest reserve. In 1988, Maui Electric Company (MECO) was granted a transmission line easement across a 6.46-acre corridor through Makawao FR to construct and maintain electric transmission and distribution lines and poles. Due to a history of wildfire ignition by downed powerlines, MECO conducts routine maintenance along utility corridors. Special use permits are issued to utility crews for maintenance along Fong Road and Powerline Road.

3.11 Public Use Opportunities

Due to its location and ease of access, several recreational activities occur year-round in Makawao FR. Regulations are in place to allow for hiking, mountain biking, equestrian trails, public hunting, and forest collection.

3.11.1 Outdoor Recreation

The Kahakapao Recreation Area is located in Makawao FR and encompasses two multi-use trails for hiking, equestrians, and mountain biking (Figure 31). The Kahakapao Loop Trail is 5.75 miles long, and along the route, there are entry points for a network of mountain bike trails. Paʻahao Road is 1.7 miles long and intersects the main loop trail several times. With a large volume and variety of activities occurring, to avoid conflicts, the general etiquette is as follows: hikers yield to equestrian riders, and bikers yield to both hikers and equestrian riders. Dogs are allowed in the Kahakapao Recreational Area but must be kept on a leash at all times.

The network of mountain bike trails in the Kahakapao Recreational Area is the first public bicycle recreational area of its kind in the State of Hawaiʻi. Aside from human-powered bicycles, pedal-assisted Class 1 E-bikes are also allowed. Class 2 or 3 E-bikes and motorcycles are strictly prohibited from the Kahakapao Recreational Area. Mountain biking is an inherently dangerous activity, and riders are encouraged to ride on trails within their skill level to avoid accidents or injuries. It is strongly encouraged that riders wear helmets and protective padding while riding in the Kahakapao Recreational Area. For the safety of others, stopped riders should pull to the side of the trail and avoid stopping on blind corners and out of the line of sight of oncoming riders. It is also proper trail etiquette to avoid riding trails that are wet and muddy to avoid erosion and deterioration of the features.

Two downhill mountain bike trails are strictly one-way for safety: Pineapple Express and Renegade. Both trails start at the top of the Kahakapao Loop Trail and offer a variety of technical terrain and constructed features. Pineapple Express is a downhill trail that can be ridden by a wide variety of riders. There are features such as table tops and a large wooden berm that allow experienced riders to test their skills. Beginners have the option of safely riding around or through these features. Pineapple Express drops 1,300 feet in elevation and is over 2.1 miles long. Renegade is a cross-country trail that provides downhill flows and challenging climbing sections. The topography and natural elements (exposed tree roots, narrow sections, and turns) allow riders to test their technical riding capabilities. Signage of the trail name/feature with the difficulty rating is found at the start of each biking trailhead.

Three skill areas allow mountain bike riders of all levels to practice their technique. The ʻAkahi Akahi Skills Area is geared towards novices and beginners with berms and a small teeter totter that allows riders to get comfortable with typical mountain bike trail features. The Pauma Skills Area is intended for intermediate riders and includes two pump tracks and an uphill skills area. The Akamai Skills Area is a series of wooden step-up jumps that allow expert riders to dial in their skills and catch air.

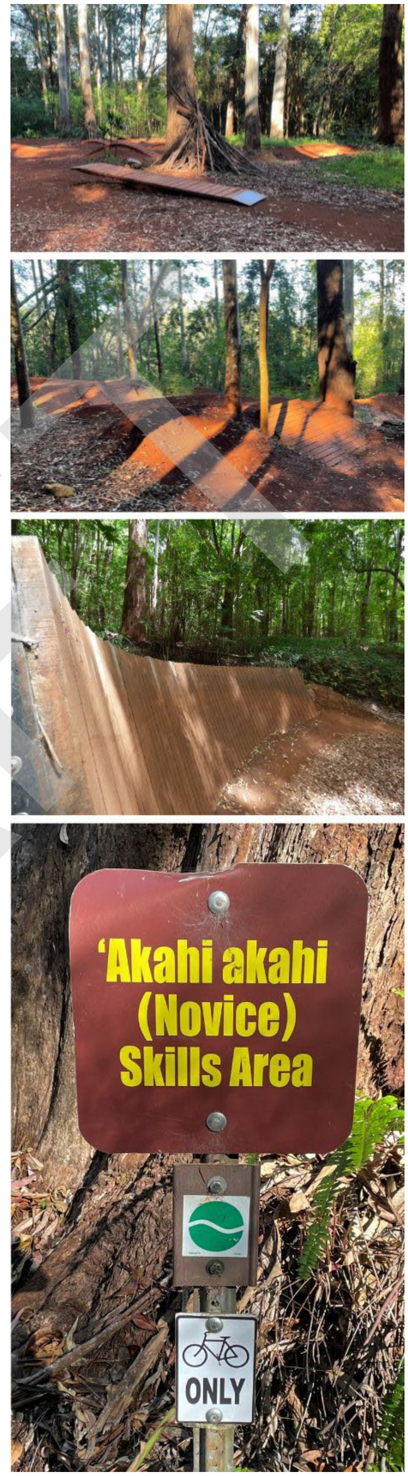
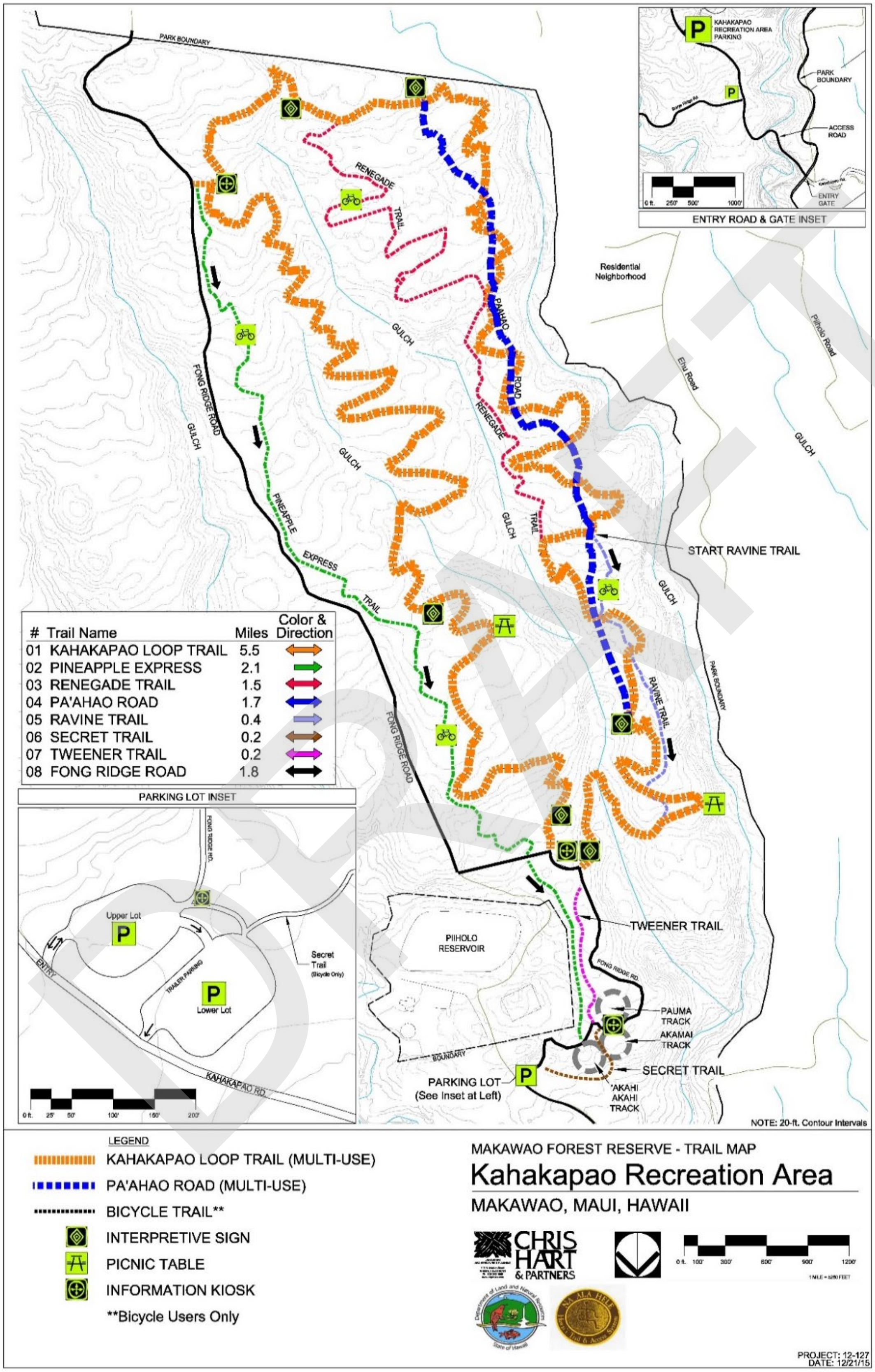


Figure 30. (Top to bottom): 'Akahi Akahi skills area, Akamai skills area, large constructed berm, and trail and skills area signage

Bird-watching enthusiasts also utilize the Kahakapao Recreation Area, as there are 19 different bird species that can be observed along the trails. Two native forest bird species (ʻalauahio and ʻamakihi) and one native migratory species (kōlea) can be seen in the reserve. For more information on bird watching in Makawao FR, visit https://hawaiibirdingtrails.hawaii.gov/birding_hotspot/kahakapao-recreation-area/.

Figure 31. Trails in the Kahakapao Recreational Area



3.11.2 Hunting

Figure 32. Gate located near the hunter parking area with Hunting Unit D signage to the right

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, Hawai'i Administrative Rules (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. Makawao FR is part of Hunting Unit D. To obtain a copy of the current hunting rules and regulations, visit https://dlnr.hawaii.gov/dofaw/rules/.

Game mammals in the reserve are primarily feral pigs (*Sus scrofa*) and occasionally axis deer (*Axis axis*). Rules for Hunting Unit D allow for year-round hunting of feral pigs and axis deer on Saturdays, Sundays, and state holidays. Despite the presence of game birds, hunting game birds in Makawao FR is prohibited. There is a hunter parking area (gravel lot) located on the left side of the road below the Kahakapao Recreation Area, and two hunter check-in stations at the two vehicular entry points into the reserve on Kahakapao and Waikamoi Roads (see Figure 29). Hunter access via Waikamoi Road is restricted and requires approval from the Maui District Game Biologist. For more information on access via Waikamoi Road, please contact the DOFAW Maui Branch office. To avoid areas frequented by other forest users and their animals, hunters utilize the forested area east of the main access road. Hunting is not allowed in the Kahakapao Recreational Area, which is proposed to be designated as a hunting safety zone during the next revision to the Hunting Rules.

3.11.3 Forest Product Collection

Non-timber forest products may be gathered from the Forest Reserve System. Examples of items that can be collected include, but are not limited to, ferns, flowers, fruits, and 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-native, non-listed native 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 any migratory bird species, is prohibited under state laws Chapter 183D and 195D, Hawai'i Revised Statutes (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. For more information on how to apply for permits for the Forest Reserve System, visit the DOFAW permitting webpage:

https://dlnr.hawaii.gov/dofaw/permits/

3.12 Traditional and Customary Rights

Traditional and customary rights of the native Hawaiian people are protected under Hawaiʻi law. In the Constitution of the State of Hawaiʻi, 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 ahupuaʻa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands before 1778, subject to the right of the State to regulate such rights."

As described in Section 3.8 of this plan, there are no documented archaeological sites in Makawao Forest Reserve. There is no evidence of habitation or agricultural activity in the high-elevation forest. However, the upland forests were an important place for cultural and religious activities, and a source of natural resources for subsistence, ceremony, and the making of implements for various purposes. Forest resources that were gathered likely included but were not limited to building materials, wood for canoes, sandalwood, foliage, natural fibers, dyes, medicinal plants, food during times of famine (State of Hawaiʻi, 2013), and feathers from native forest birds.

The management activities outlined in this plan are not expected to impact or diminish these protected traditional and customary rights. However, the collection of listed threatened, endangered, or other rare species, or any migratory bird species, is prohibited under state laws

Chapter 183D and 1995D, HRS, and subject to regulation under applicable HAR. See Section 3.11.3 for more information.

Anyone seeking to engage in an activity or collect any forest product from a State Forest Reserve that is normally prohibited by the forest reserve rules, Chapter 13-104, HAR, but are engaging in traditional and customary native Hawaiian cultural activities that are defined in, and protected pursuant to sections 1-1, 7-1, HRS; Article XII, Section 7 of the Hawaiʻi State Constitution; and rulings of Hawaiʻi case law, can apply for a permit. The Hawaiian traditional and customary practices permit application is available on the DOFAW Permits & Guidelines webpage (https://dlnr.hawaii.gov/dofaw/permits/) under the State Forest Reserve Section. Completed applications should be submitted to the Branch office that services the district where the forest reserve is located.

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, Hawaiʻi 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 Makawao FR. Each application for a commercial salvage timber 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 Makawao FR cannot exceed $10,000.

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 present in Makawao FR, or not yet present but are of concern, are listed below in Table 13. 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 for each species: control, containment, eradication, or early detection rapid response.

Figure 33. Invasive species found in Makawao - Top (left to right): Quinine, gorse, Koster's curse; Middle (left to right): Himalayan (kahili) ginger, silky oak; Bottom (left to right): fireweed, black wattle, Christmas berry

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 a 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 are critical defenses against the establishment of invasive populations.

Some non-native plant species are also designated as a noxious weed by the Hawaiʻi Department of Agriculture. A noxious weed is defined as a plant species that 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, seeds, or vegetative reproductive parts is prohibited under state law, Chapter 152, HRS, and subject to regulation under Chapter 4-68, HAR.

Table 13. Invasive plant species of Makawao FR

Species	Common name	DOFAW Objective	Regulatory Status
Acacia mearnsii	Black wattle	Control	Hawaiʻi Noxious Weed List
Ageratina adenophora	Maui pamakani	Control	None
Ageratina riparia	Hamakua pamakani	Control	None
Andropogon virginicus	Broomsedge	Control	Hawaiʻi Noxious Weed List
Chaetogastra herbacea	Cane tibouchina	Containment	Hawaiʻi Noxious Weed List
Cinchona pubescens	Quinine	Eradication	None
Cortaderia jubata	Pampas grass	EDRR	Hawaiʻi Noxious Weed List
Grevillea robusta	Silky oak	Control	None
Hedychium gardnerianum	Himalayan (kāhili) ginger	Control	None
Lantana camara	Lantana	Control	None
Megathyrsus maximus	Guinea grass	Control	None
Miconia crenata	Koster's curse	Eradication	Hawaiʻi Noxious Weed List
Psidium cattleianum	Strawberry guava	Control	None
Psidium guajava	Guava	Control	None
Rubus argutus	Blackberry	Control	Hawaiʻi Noxious Weed List
Schinus terebinthifolius	Christmas berry	Control	None
Senecio madagascariensis	Fireweed	Containment	Hawaiʻi Noxious Weed List
Spathodea campanulata	African tulip	Eradication	None
Sphaeropteris cooperi	Australian tree fern	Control	None
Ulex europeaus	Gorse	Control	Hawaiʻi Noxious Weed List

4.2 Invasive Animals

Invasive animals are non-native species that impact native ecosystems in Hawaiʻi by predating on native species or by creating disturbances in the forest that are often invaded by non-native species (Chynoweth et al., 2010). Invasive animals also spread introduced pathogens, disrupt ecosystem function, or, in more severe circumstances, cause landscape-scale deforestation and soil erosion.

The Division of Forestry and Wildlife has a dual mandate: 1) to conserve, manage, and protect native and endangered species and their ecosystems, and 2) to preserve, protect, and promote public hunting. The hunting program in Hawaiʻi is based entirely on non-native animal species. Introduced game mammals, such as pigs (*Sus scrofa*) and axis deer (*Axis axis*), contribute to the degradation of native ecosystems and watershed health. Impacts of introduced game mammals and other introduced animal species vary 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. For a list of animals present in Makawao FR and their potential impacts, see Table 14.

Since the majority of the vegetation in Makawao FR has been converted to non-native forests/timber plantation stands, maintaining recreational and hunting opportunities is a management objective for Makawao FR; therefore, eradication is not the goal for the larger landscape. However, to mitigate the most severe forest impacts by ungulates, fencelines were built around the forest reserve perimeter to exclude feral cattle from neighboring properties. Several smaller fenced exclosures were built and are being maintained around wild and outplanted populations of threatened and endangered plant species.

Table 14. Animal species that occur in Makawao FR and their potential impacts

Species	Common name	Potential impacts
Axis axis	Axis deer	Grazing and bark stripping on vegetation result in the loss of plant life. Vegetation loss over large areas can eventually lead to soil erosion and runoff into the ocean.
Felis catus	Feral cats	Predators of native and game birds, and vectors of toxoplasmosis, a zoonotic disease known to kill Hawaiian Monk Seals.
Herpestes auropunctatus	Mongoose	Predators of native and game birds.
Rattus spp.	Rats/mice	Predators of native plant fruits/seeds, native and game birds, and native snails.
Sus scrofa	Feral pigs	Disturb vegetative ground cover by browsing, trampling, rooting, and wallowing. If damage to vegetation is severe enough, negative impacts on groundwater recharge can occur. They also facilitate the invasion and establishment of weedy plant species and create a habitat for mosquitoes that are vectors for human and avian diseases.
Trioceros jacksonii	Jackson's chameleon	Predators of native insects, spiders, and snails, some of which are rare and endangered.

DOFAW has set management objectives for each animal species within Makawao FR (Table 15), 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 the geographic area

Table 15. DOFAW management objectives for animal species in Makawao FR

Species	DOFAW Management Objective
Axis axis (Axis deer)	Control
Felis catus (Feral cats)	Control
Herpestes auropunctatus (Mongoose)	Control
Rattus spp.(Rats/mice)	Control
Sus scrofa (Feral pigs)	Game species
Trioceros jacksonii (Jackson’s chameleon)	Control

4.3 Insects & Disease

Introduced insects and diseases are a serious threat to the natural areas of Hawaiʻi. Of particular concern are those that could cause widespread dieback of predominant forest canopy species such as koa and ʻōhiʻa. With globalization and increased dependence on imports, approximately 20 insect species become established in Hawaiʻi every year (State of Hawaiʻi, 2016).

4.3.1 Koa Moth Outbreaks

Figure 34. Left (top to bottom): Adult Hawaiian koa moth, larval stage; right: defoliated koa tree due to Hawaiian koa moth outbreak

The Hawaiian Koa Moth (*Scotorythra paludicola*) is an endemic moth that can be found on Oʻahu, Maui, and Hawaiʻi island that feeds on koa (*Acacia koa*) foliage. At normal population levels, the impacts of koa moth larvae feeding on koa foliage can go unnoticed. However, there are documented events of koa moth population outbreaks that have resulted in the defoliation of large koa stands. It is estimated that these outbreak events can result in as much as 35% mortality in koa forests (Haines et al., 2009). Even though this is a native species, outbreaks should be monitored to assess forest health and resilience, and to monitor the ecological impacts of these outbreaks, especially interactions with invasive species.

Many variables were studied and analyzed to help figure out what could be causing these population explosions of koa moths, but no significant correlations have yet been found. In Makawao FR, outbreak events have been documented in January 1926, January 1946, September 1971, January 1977, and February 2004 (Haines et al., 2009). Outbreak events are often short-lived, lasting approximately 3 months, which is the same time frame as the koa moth lifecycle. More research is needed to better understand why population outbreaks of *Scotorythra paludicola* occur.

4.3.2 Mosquito

Figure 35. (Left to right): Southern house mosquito, 'i'iwi

Mosquitoes are a non-native insect species first introduced to the Hawaiian islands in 1826 (Birds, Not Mosquitoes, 2023). These invasive pests thrive in the islands due to the warm and humid climate. While mosquitoes are more commonly known for the diseases that they transmit to humans, they also have a devastating impact on native forest bird populations in Hawaiʻi. Avian malaria and pox are both deadly blood-borne parasites that are transmitted to birds by infected mosquitoes. Because native birds did not evolve alongside mosquitoes, they lack resistance to these avian diseases. Since the introduction of mosquitoes, 23 Hawaiian honeycreepers have gone extinct, many of which are believed to have been caused by avian malaria and pox (Birds, Not Mosquitoes, 2023).

With rising temperatures brought on by climate change, the environmental range for mosquitoes has been increasing further into native forest bird territories at higher elevations. Recent efforts to control mosquito populations in forest bird habitats have employed an Incompatible Insect Technique (IIT). This method utilizes a naturally occurring bacterium, *Wolbachia*, which is found in half of all insect species worldwide. When a male mosquito with the bacteria mates with a non-infected female, the bacteria will prevent the eggs from hatching. Female mosquitoes only mate once, so the hope is that this will reduce the total population size over time (Birds, Not Mosquitoes, 2023). The National Park Service's environmental assessment for the proposed releases of IIT mosquitoes in and around Haleakalā National Park included

Makawao FR as a release site (National Park Service, 2022). The environmental assessment anticipates that mosquito releases would be done aerially via drone or helicopter, during the warmer summer and fall months when mosquito populations in Hawaiʻi peak (National Park Service, 2022).

4.3.3 Koa Wilt

Koa wilt is a soil-borne disease that causes dieback and decline of koa trees primarily in lowland plantation stands on former agricultural land. It is a vascular disease that affects the xylem tissue and water transport capabilities of koa and eventually leads to tree mortality. The first sign of infection is usually a yellowing or wilting of leaves on a single branch or part of the tree's canopy. If an infected branch is cut, there are usually dark stains in the sapwood. The disease is caused by the soil-borne fungal pathogen *Fusarium oxysporum* f. sp. *koae*, which invades susceptible plants through the root system. This disease can severely impact koa reforestation at most low to mid-elevation locations (sea level to approximately 1,000m elevation) with mortality rates commonly exceeding 75% (Dudley et. al 2017). Koa wilt has not been observed in Makawao FR, but it may be a pathogen of concern for trees in the reserve that fall within this elevation range.

Figure 36. (L-R) Yellowing and wilting koa leaves are the first sign of a koa wilt infection; Dark stains in the sapwood of a koa branch infected with koa wilt.

4.3.4 Strawberry Guava Dieback

Figure 37. Section of Makawao FR with strawberry guava dieback.

Also of concern is the strawberry guava dieback occurring in the mesic forest in the reserve. A scale insect *Tectococcus ovatus* has been released in Hawaiʻi as a biocontrol agent for strawberry guava, but it has already been determined that it is not the cause of this dieback. Based on the appearance and magnitude of impact, it may be caused by a spreading plant pathogen. In December 2021, to determine what was causing these dieback events, Dr. Mark Hughes and DOFAW staff collected samples of strawberry guava from three locations on Maui, which included Makawao. Based on the preliminary assessment of the data, the trees appear to be suffering from two maladies: 1) insect girdling near stem crotches, and 2) stem canker/necrosis on smaller diameter stems. It is still unknown which of the two maladies is the primary or secondary agent, but the damage that is caused appears to be localized and not systemic.

4.3.5 Rapid ʻŌhiʻa Death

The most significant forest disease threatening the forests of Hawaiʻi is Rapid ʻŌhiʻa Death (ROD). ROD is a disease caused by two fungi, *Ceratocystis lukuohia* and *Ceratocystis huliohia*, and the presence of ROD has been documented on the islands of Kauaʻi, Oʻahu, Maui, and Hawaiʻi. It has killed hundreds of thousands of mature ʻōhiʻa throughout the state and has impacted an estimated 130,000 hectares as of 2020 (Peroy et al., 2021). This forest disease is of major concern due to the importance of ʻōhiʻa in Hawaiian culture and its role as a keystone species in native forests. Many native species rely on ʻōhiʻa for their survival.

Ceratocystis lukuohia is the more aggressive species of the two, and it is responsible for approximately 80% of the documented mortality. Studies have shown that *Ceratocystis huliohia* is slower at killing a mature ʻōhiʻa tree, requiring multiple points of entry (Peroy et al., 2021). Both species can kill a perfectly healthy and mature tree in as little as two months. Initial visual signs of infection are browning of the leaves in the crown, and black striations can be found staining the sapwood of infected trees. Samples must be collected from symptomatic trees and tested to confirm that they are infected by *Ceratocystis*.

Ambrosia beetles, which bore into ʻōhiʻa trees, are responsible for releasing frass that contains fungal spores into the environment. Entomologists have conducted controlled studies demonstrating that beetles can carry the fungus on their bodies and directly infect living ʻōhiʻa seedlings (Cannon et al., 2022). However, beetles normally attack dead and dying trees, and scientists do not think that beetles serve as the main disease vector.

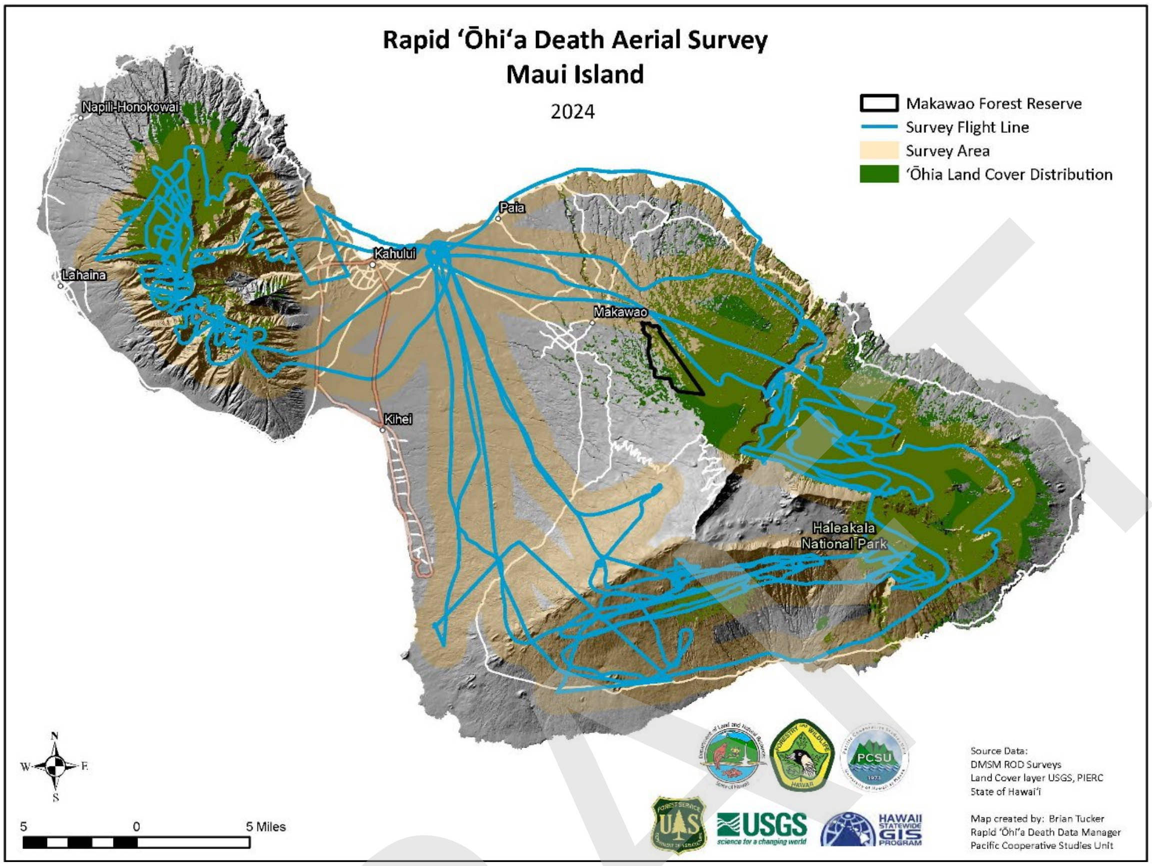
Another pattern that has been more recently observed is the higher incidence of *C. lukuohia* detections in areas where hoofed animals are present, compared to adjacent areas where animals have been removed (Peroy et al., 2021). In one area that was previously ungulate-free, managers saw a sharp uptick in both symptomatic trees and positive detections for *C. lukuohia* when fences were damaged, allowing animal ingress. The mechanisms are not fully understood, but it is thought that by wounding trees, animals might cause tree infection if spores are present. It is also possible that animals are moving spores of the fungus contained in the soil. Research on animals directly spreading ROD is currently underway.

The relationship to feral animals offers potential management tools for preventing wounding and the possible spread of the disease by removing animals from the landscape. It is not currently clear which animal species are responsible, but the pattern has been seen in forests with high populations of cattle and pigs, the former of which strip bark from ʻōhiʻa trees and the latter of which damage roots when digging for food. To protect important ʻōhiʻa stands and forests, managers can utilize ungulate management (exclusion fences, hunting, or animal removal) to reduce the incidence of ROD. This may be the most effective tool we have for managing ROD, but this only removes one potential vector and cannot prevent storm damage that leads to wounds and ROD. Areas that are animal-free are still likely to have ROD show up, but the rate of infection over time is likely to be reduced.

Aerial surveys for ROD are being done statewide and were initially done semi-annually on Maui starting in 2016 (Figure 38). Field staff collected 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. In January 2025, *C. huliohia* was detected in three landscaped ʻōhiʻa trees at an elementary school. The response was quick for both incidents, and the trees were 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.

To reduce the risk of spreading ROD fungal spores on hiking trails, boot decontamination stations are situated at several popular hiking trailheads across the state. Most stations include a boot brush to remove any foreign debris, such as invasive plant seeds, from the bottom of hiking footwear. Some stations also include a pump sprayer with isopropyl alcohol for trail users to disinfect their footwear to prevent the spread of fungal pathogens, such as ROD. In Makawao FR, two boot brush stations are located at the Kahakapao Recreation Area trailhead and the hunter check-in. Both stations in Makawao FR are equipped with boot brushes, alcohol sprayers, and informational signage.

Figure 38. Maui Rapid ʻŌhiʻa Death Aerial Surveys



Based on potential impacts, distribution in the FR, and available control methods, DOFAW has set a management objective for insects and diseases (Table 16) that are of concern:

- Control - Reduce populations and/or the vigor of individuals.
- Containment - Stops or minimizes population growth and geographic spread.
- Monitor - These species have the potential to negatively impact the environment, but management decisions to implement control activities require additional information.
- 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 are a critical defense against the establishment of invasive populations.

Table 16. DOFAW management objectives for insects and diseases in Makawao FR

Species	Common Name	DOFAW Objectives
Ceratocystis huliohia; *Ceratocystis lukuohia*	Rapid ʻŌhiʻa Death	EDRR
Culex spp.	Mosquitoes	Control
Fusarium oxysporun f. sp. *koae*	Koa wilt	EDRR
Scotorythra paludicola	Koa looper moth	Monitor
unknown	Strawberry guava dieback	Monitor

4.4 Fire

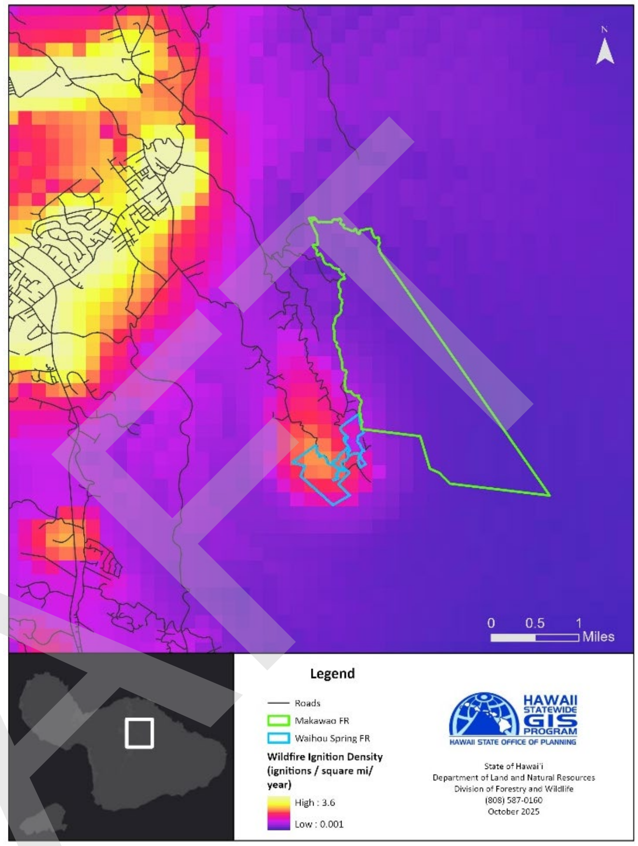


Figure 39. Wildfire Ignition density (Trauernicht and Lucas 2016)

Wildfires are a serious threat to human safety and property, and they 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, non-native species of grasses and shrubs. Approximately 25% of the total land mass in Hawaiʻi (Trauernicht, 2014) is now covered by these fire-prone fuels. This, combined with an increase in human-caused ignition, has resulted in a fourfold increase in area burned by wildfires in Hawaiʻi annually (Trauernicht and Pickett, 2016).

Wildfire ignition density based on historical fire data is relatively low for Makawao FR (Figure 39), and the threat of wildfire ignition within Makawao FR is considered relatively low due to the wet forest conditions throughout the reserve. One fire started in Makawao FR due to trees touching powerlines, but wet conditions contained the fire to the ignition site. However, to the west of Makawao, the adjacent Waihou Spring FR experienced a wildfire in 2013, which ignited from a downed power line. In 2023, wildfires in the Upper Kula and Olinda area started because strong winds downed electrical lines, and the fire burned into Waihou Spring FR. Prevailing winds make it unlikely that a wildfire would travel east from these high-density ignition areas to the Makawao FR, but it is still possible under certain weather conditions. Additionally, there are large plantation stands of fire-prone species of *Eucalyptus* on the southwestern boundary of Makawao FR (Figure 14). Drier conditions brought on by climate change, along with an abundance of wildfire fuels, may exacerbate future wildfire risk.

Figure 40. DOFAW Wildfire Photos - Top (left to right): West Kaua'i 2012, O'ahu 2015; Bottom: Waihou Springs Forest Reserve, Maui 2023

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 elevations), decrease in regional rainfall, decrease in groundwater 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, an increase in extreme weather events, flooding and erosion, an increase in non-native biological invasions, an increase in the frequency and size of wildfires, and an increased risk of species extinction (Keener et al., 2012).

The primary mitigation for climate change is the 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 Hawaiʻi took this commitment further by pledging to achieve carbon neutrality, also by 2045.

Forest ecosystems in Hawaiʻi will face new climatic conditions associated with climate change. Individual species and ecosystem 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 Hawaiʻi species, but additional information is needed at local scales to determine impacts within individual watersheds and forest reserves.

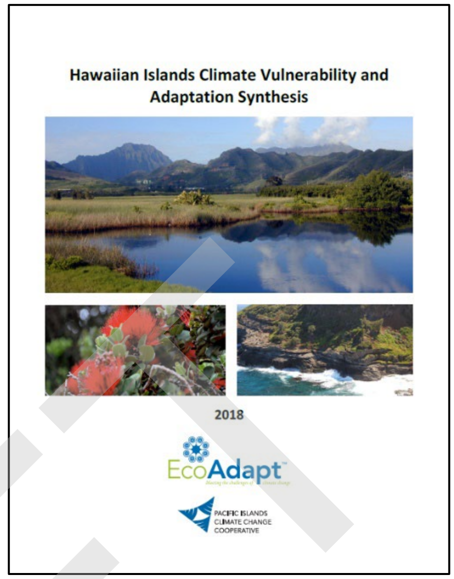


Figure 41. Hawaiʻi climate synthesis: https://www.ecoadapt.org/programs/awareness-to-action/HawaiianIslands/products

In 2018, the Pacific Island Climate Change Cooperative (PICCC) and EcoAdapt completed the Hawaiian Islands Climate Vulnerability and Adaptation Synthesis (Figure 41). 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, increase capacity to reduce impacts, and facilitate decision-making by land managers (Gregg, 2018).

The climate synthesis contains summaries of adaptation strategies and actions for Maui habitat types and ecosystem services. Summaries that are relevant for Makawao FR include those for dry forest, mesic and wet forest, cultural knowledge and values, flood and erosion control, fresh water, food and fiber, and recreation and tourism. To anticipate and mitigate climate change impacts, all strategies and action items were reviewed and, if applicable, incorporated into management objectives for the reserve.

5. MANAGEMENT

5.1 Past Planning

This is the first management plan the Division of Forestry has completed for Makawao State Forest Reserve. However, Makawao FR has been included as part of other larger landscape watershed planning processes and other state action plans.

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

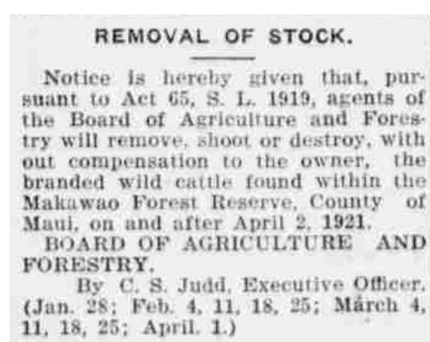
- East Maui Watershed Partnership Management Plan
- Hawaiʻi's State Wildlife Action Plan
- State of Hawaiʻi Forest Action Plan
- DOFAW Draft Management Guidelines
- Maui Invasive Species Committee Strategic Plan
- Waihou Spring State Forest Reserve Management Plan
- USFWS Endangered Species Recovery Plans
- DOFAW Pittman-Robertson Wildlife Restoration Program Game Management Plan

5.2 Summary of Management

Prompted by the increased demand for irrigation water to support developing, large-scale agricultural operations on Maui, the Territory of Hawaiʻi increased efforts to protect important watersheds and freshwater resources. During the 1900s, early foresters started reforestation efforts with non-native tree species that they believed were of "real timber value." They targeted higher-elevation degraded forest lands that were not suitable for grazing and were more valuable for the conservation of water resources.

The watershed in Makawao FR was severely impacted by decades of forest clearing and agricultural use. In the late 1800s, semi-wild cattle roamed and grazed the area, damaging vegetation. The Makawao area was also heavily utilized for wood harvesting until 1914. In correspondence from the District Forester Karl H. Korte in 1962, he describes how approximately half of the forest was cleared by wood harvesting for firewood by plantations and domestic consumers. Korte also mentioned that a wildfire swept through the area in 1912, burning 350 acres of forest.

Early management of Makawao FR focused on reforestation, which started in 1910. The Maui Agricultural Company planted 90 acres in exchange for the right to take dead wood. The Territorial Foresters and Maui Agriculture Company also installed an experimental planting on private and government lands in Makawao near Kaʻiliʻili. The purpose of the experimental plantings was to test which tree species would grow well in the area and provide quality timber resources (Table 5). In the winter of 1911, approximately 170,000 seedlings of *Eucalyptus globulus*, *Eucalyptus robusta*, and *Cryptomeria japonica* (Japanese cedar) were also planted at Kaʻiliʻili (Hawaiian Gazette, 1912).


REMOVAL OF STOCK.

Notice is hereby given that, pursuant to Act 65, S. L. 1919, agents of the Board of Agriculture and Forestry will remove, shoot or destroy, without compensation to the owner, the branded wild cattle found within the Makawao Forest Reserve, County of Maui, on and after April 2, 1921.

BOARD OF AGRICULTURE AND FORESTRY.

By C. S. Judd, Executive Officer.

(Jan. 28; Feb. 4, 11, 18, 25; March 4, 11, 18, 25; April. 1.)

Figure 42. Newspaper notice of cattle removal from Makawao FR, Maui News 1921

Other watershed protection actions taken by the territorial government included the construction of a boundary fenceline in 1918, and beginning in 1921, agents of the Board of Agriculture and Forestry started removing cattle found in Makawao FR (Judd, 1921). Cattle were to be removed, shot, or destroyed by agents with no compensation to the owner (Figure 42).

Following the Great Depression of 1929, the Emergency Conservation Work Act of 1933 mandated the establishment of the Civilian Conservation Corps (CCC) to stimulate the economy and employ citizens in the United States (US). The CCC recruited unemployed young men for conservation work throughout the forests, parks, and fields in the US and its Territories. The CCC helped build trails and outdoor infrastructure on government lands in Hawaiʻi when it was a territory of the US, many of which continue to be utilized. In Makawao FR, the CCC planted trees on over 300 acres between 1939 and 1940. Low-security prisoners being housed at the Olinda Prison Camp (now the current site of the Maui Bird Conservation Center) were also used as labor to plant trees in the forest reserve from 1960 to 1962 (State of Hawai'i, 2013).

Figure 43. Aerial image from USDA of timber plantings in 1965

In the 1960s, state foresters surveyed and devised a plan to clear and intensively plant degraded sections of forests in the reserve. Starting in April 1962, bulldozers cleared existing brush and created wind rows with the debris along contours to prevent soil erosion. Trees were planted by hand at a density of 435 trees per acre, giving each tree a 10-foot by 10-foot growing space. Forestry experienced a few challenges during the planning and implementation of tree planting in Makawao FR. In the early stages, shortages of planting material and unfavorable environmental conditions impacted progress. Correspondence in forestry records from Maui District Forester Karl Korte dated February 1963 indicated there was significant tree mortality due to severe wind, old planting stock, and unusually dry winter conditions. There was also an outbreak of rodents in October 1963, and feeding damage was observed on outplanted trees.

By 1969, a total of 1,380 acres of Makawao FR had been turned into plantation timber stands consisting of 13 different stand types, a few of which are mixed species (Figure 14). Forestry records indicate that the final timber planting in Makawao FR occurred in 1973.

Table 17. Makawao FR forestry plantings (Board of Agriculture and Forestry, 1928, 1930, 1934, 1936, 1942, 1944, 1960, 1964)

Year planted	Number of trees planted	Acres

1927-1928	3,419	
1929	11,347	
1931	5,153	
1932	13,583	
1933	8,505	
1935	15,172	
1936	31,230	
1937	21,467	
1938	117	
1940	8,861	20.3
1941	4,680	10.7
1943	1,018	2.34
1944	656	
1945	656	
1959	2,901	3.13
1962		844
1963		263
1973		8

To monitor the success of timber plantations for commercial production, growth plots were established to track growth metrics of the different tree species. Detailed measurements were taken, including height, diameter at breast height, basal area, and volume. Sixteen 3-acre koa (*Acacia koa*) growth plots were established in Makawao FR on Borges Ridge by the U.S. Forest Service (USFS). The koa in the growth plots were relatively young as they recruited naturally after a fire swept through the area in 1962. Forestry staff site prep activities on Borges Ridge after the fires likely stimulated the germination of koa from the existing seed bank. The sixteen growth plots were put in place to study the effects of stand thinning and fertilization on koa growth.

Thinning of the koa stands was done from October 1974 to March 1975 by DOFAW staff, which resulted in a 50% reduction in stand density (Scowcroft & Stein, 1986). Fertilizer applications were done with a fixed-wing crop duster on May 8 and 20, 1975 (Scowcroft & Stein, 1986). Measurements of the growth plots were taken in 1975 and 1978. The results indicated that koa sapling growth increased after precommercial thinning, and the application of fertilizer did not have any measured effect on koa growth but increased the growth of non-native blackberry (*Rubus argutus*), which likely created competition for water and nutrient resources (Scowcroft & Stein, 1986). After the study was published, monitoring and maintenance of the growth plots were continued by Forestry staff but ended around 2013.

In addition to tracking tree growth, tree maintenance was also a significant component of the management of the timber stands. Supplemental tree planting was done regularly to compensate for tree mortality. Trees were pruned and thinned to encourage the straight linear growth ideal for timber production. Weed control, insect and disease control, and fertilizer applications were also done regularly to optimize tree growth.

Several insect infestations swept through Makawao FR, which were serious forest health concerns. The Eurasian pine aphid (*Pineus pini*) was accidentally introduced and first documented at Waikiʻi on the island of Hawaiʻi in 1970. Infestations were known to weaken and sometimes kill various pine species. Pines were used in reforestation efforts throughout Hawaiʻi, and concerns of widespread mortality triggered statewide control efforts by state and federal agencies. The Eurasian pine aphid was found in Makawao in 1971 during population distribution surveys. Aerial application of insecticides was done until strong public opposition halted these efforts. Three biological control agents were subsequently introduced to control the pine aphid, *Leucopis nigraluna*, *Leucopis tapiae*, and *Scymnus suturalis* (Culliney et al. 1988). Correlation analysis of population densities indicates that *Leucopis tapiae* successfully controlled pine aphid populations to below economically significant levels (Culliney et al. 1988).

Population explosions of the native koa moth (*Scotorythra paludicola*) have also been observed in Makawao FR. Forestry managers collaborated with researchers to determine what environmental factors may cause the unpredictable outbreaks, but nothing was determined. For more information, see Section 4.3 of this plan.

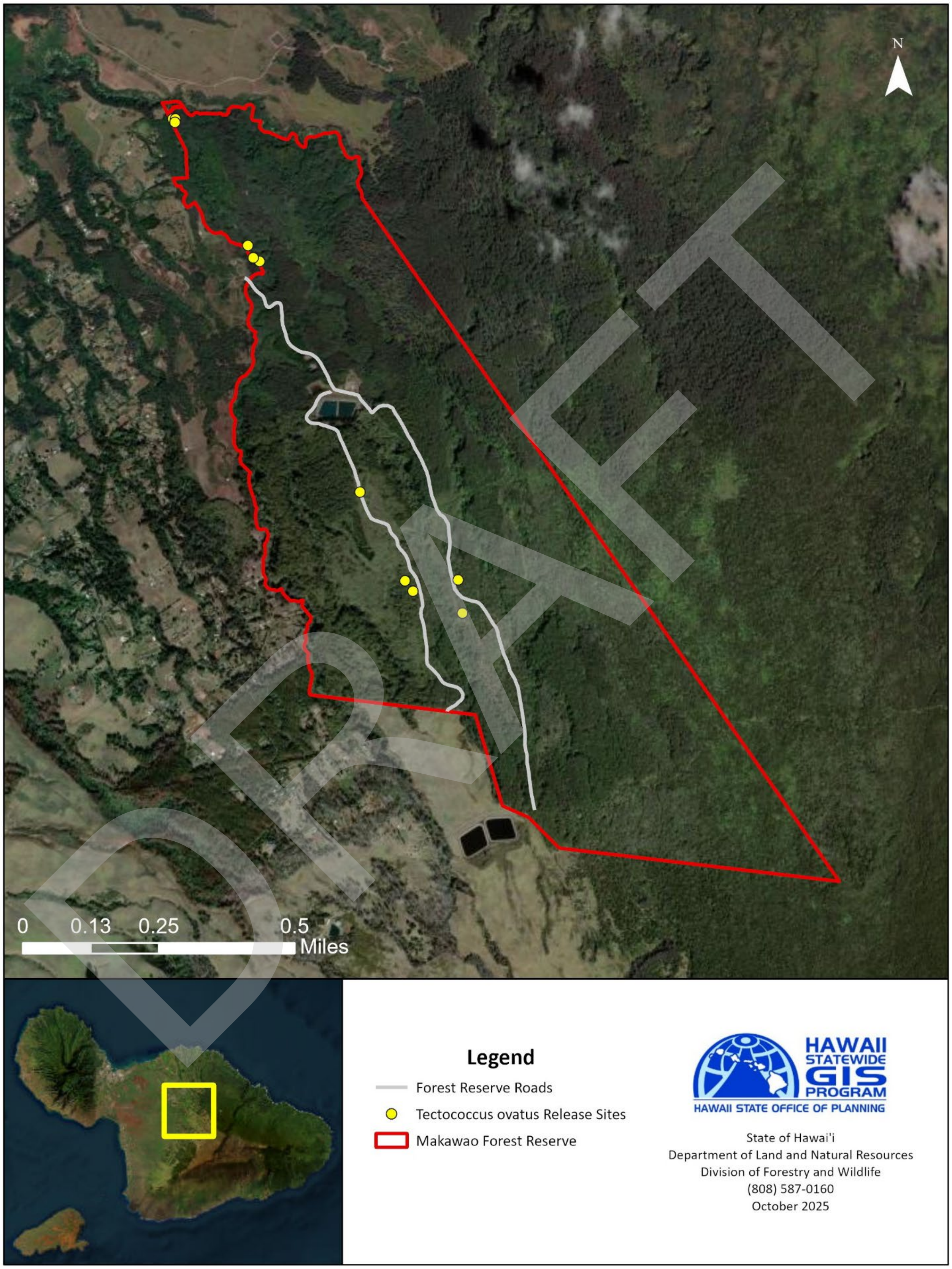
Weed control efforts outside of the timber plantations focused on non-native plant species that have invasive growth habits. In April 1973, 20 acres of gorse were controlled in the reserve to prevent landscape-wide infestations. Currently, the Maui Invasive Species Committee (MISC) also surveys Makawao FR for incipient and invasive species. Forestry staff have also released the biocontrol *Tectococcus ovatus* in Makawao FR to try and slow the spread of strawberry guava (Figure 45).

At higher elevations, DOFAW is actively removing large patches of Himalayan (kāhili) ginger (*Hedychium gardnerianum*) quarterly to create a buffer along The Nature Conservancy's Waikamoi Preserve. In areas where the ginger has been removed, forestry staff observed the natural recruitment of native species, such as koa. To augment native forest recovery, small-scale ungulate fence exclosures have been constructed in conjunction with the planting of native common plant species to help replace the monotypic stands of ginger. DOFAW has also been planting native plant species commonly gathered by the public to help reduce the collection pressure on wild populations. As of 2023, approximately 200 maile (*Alyxia stellata*) and 100 māmaki (*Pipturus albidus*) have been planted in the fenced ginger removal areas.

Figure 44. (Left to right): Ungulate fencing constructed around restoration area, maile seedling planted by DOFAW staff, drastic difference between the Himalayan ginger removal area on the left and untouched infestation on the right.

As described in Section 2.5 of this plan, in 2023, the Division obtained BLNR approval for the addition of TMK (2) 2-2-004:016 (aka Pa Olinda) to Makawao Forest Reserve (Figure 14). The Division is still waiting for the issuance of a Governor's Executive Order to complete the administrative process and officially transfer management jurisdiction to DOFAW. Management of this area will include an agroforestry approach. Native canopy tree species, such as koa, have been planted with wider spacing in the area. Once trees reach a certain size, controlled grazing will be incorporated to reduce wildfire fuel loads and non-native vegetation cover. Eventually, native midstory and understory species will be incorporated to build an intact ecosystem.

Figure 45. *Tectoccocus ovatus* release sites in Makawao FR



There are also several wild and outplanted populations of endangered plant species in Makawao FR that are being managed and monitored by the Plant Extinction Prevention Program (PEPP) in partnership with DOFAW. Management of endangered plant species in the reserve includes maintenance of small ungulate-proof fences, habitat protection, removal of invasive plant species, predator control, collecting and storing seeds, establishing living collections in nurseries and micropropagation, and outplanting to establish new self-sustaining populations. For more information about each species and its conservation, see Section 3.5.4 of this plan.

In 1997, the Kahakapao Road was opened to facilitate access to the Piʻiholo Water Treatment Facility, which is located within the Makawao FR boundary. This established the first legal public access to Makawao FR. In 2003, the 5.75-mile Kahakapao Loop trail was constructed to provide a relatively flat and easy multi-use trail for beginner to intermediate recreational users. After the loop trail was opened to the public, several illegal mountain bike trails were constructed in the surrounding area, two of which looped into Kahakapao trail. The illegal trails were evaluated to see if they met Nā Ala Hele standards for bicycle trails. Trails that did not meet those standards were rehabilitated and removed from the forest reserve.

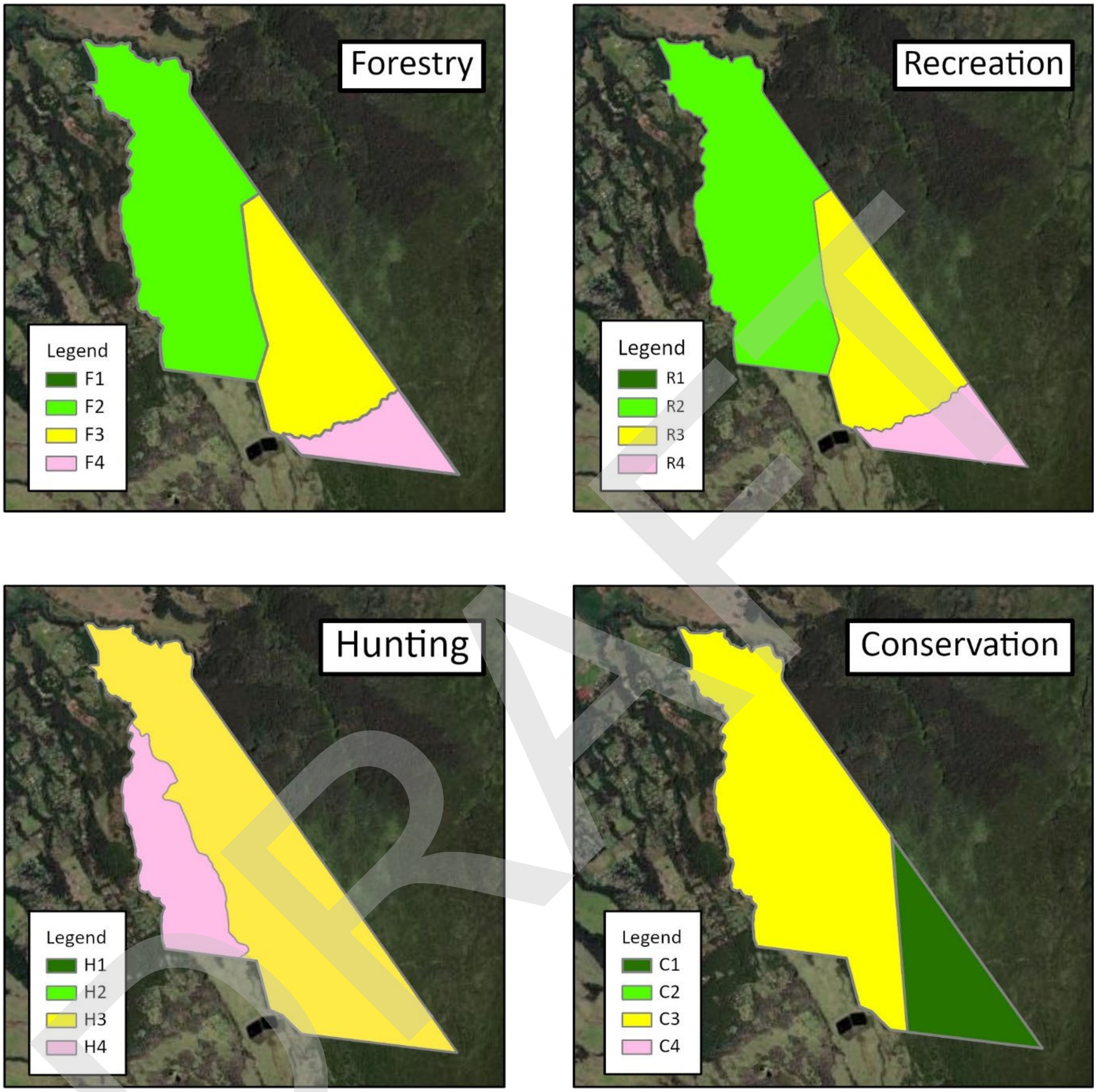
Due to the increased interest and direct inquiries from the public to expand the Kahakapao Loop Trail, DOFAW began developing the Kahakapao Recreation Area in 2013. The Kahakapao Recreational Area contains officially designated and maintained trails for hiking, mountain biking, and horseback riding over approximately 452.6 acres of the reserve (State of Hawaiʻi, 2013). Given the wide variety of desired recreational activities and difficulty levels, creating opportunities and a safe space for all recreational users was of the utmost importance. Nā Ala Hele (NAH) worked together with the International Mountain Biking Association (IMBA) to develop a network of biking trails. See Section 3.11 of this plan for more information.

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 46. Makawao FR DOFAW Management Guidelines



State of Hawaiʻi
Department of Land and Natural Resources
Division of Forestry and Wildlife
(808) 587-0166
April 2024

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). Makawao FR is classified as F-2, F-3, and F-4 (Figure 46). The lower elevation portion of the reserve contains plantation stands of non-native timber species such as eucalyptus, tropical ash, and various pines. This area is classified as F-2 or Small-Scale Commercial, where the harvest of timber is allowed to produce a sustainable supply of forest products while minimizing other resource impacts. A timber management plan is required for the harvesting of living trees, and depending on the scope and scale of operations, permits, licenses, and environmental compliance may be required.

The mid-elevation portion of the forest reserve is classified as F-3, or Personal Use, where the harvest of forest products will be accommodated for sustainable personal use. Any impacts on native species and ecosystems are to be minimized. Non-commercial timber harvesting and targeted commercial timber salvage are allowed, but balanced with other priority land use objectives. Permits for non-timber forest products will be issued on a case-by-case basis.

The most mauka portion of the reserve is classified as F-4, or Restricted, where natural resource protection is the highest priority, as it contains the most intact native ecosystems. Any forest product utilization activities allowed are minimally disruptive. Harvesting of timber will only be considered if such activities improve other priority resource outcomes. Permits for harvesting 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) (Figure 46). Due to the difference in environmental impacts of game birds versus mammals, they were given separate hunting classifications. However, according to Chapter 122 HAR, game bird hunting is not allowed in Makawao FR, as such management guidelines were set for game mammals only.

The Kahakapao Recreational Area is classified as H-4, or no hunting management. Due to the high volume of non-hunting recreational forest users, the area is considered a "safety zone" and is proposed to be removed from Hunting Unit D. Any animal control activities in this area would be done by DOFAW staff or agency designees.

The area outside of the Kahakapao Recreational Area of Makawao FR is classified as H-3, or Low Intensity Hunting Management, where management is focused on maximizing public access and monitoring hunter effort and success. There are minimal hunting restrictions in the reserve to provide maximum hunting opportunities. However, game enhancement and habitat management to increase animal densities will not be done in the area. Feral pigs are the most abundant species. There is an increasing population of axis deer, which is a game species, but is also a natural resource and public safety concern.

Recreation Management Guideline

DOFAW's Management Guidelines separate recreation management into four classifications: High Recreation Management (R-1), Medium Recreation Management (R-2), Low Recreation Management (R-3), and Restricted Access (R-4) (Figure 46). The majority of the Makawao FR is classified as R-2, or Medium Recreation Management, where outdoor recreation is of moderate intensity. The Kahakapao Recreational Area and a portion of the actively used public hunting area north of the access road are included in this unit, as it contains a wide range of trails and roads that require a moderate level of management and maintenance. Public use of this area is relatively high and can reach up to 500 visitors per day.

The mid-elevation portion of the reserve is classified as R-3, or Low Recreation Management, where recreation is limited to certain areas or occasional levels of use. While this zone is outside the Kahakapao Recreational Area, it also contains a portion of an actively used public hunting area.

The higher elevation portion of the reserve is classified as R-4, or Restricted Access, where outdoor recreation is restricted or controlled due to hazardous conditions and for ecosystem protection. This portion of Makawao FR is still accessible to the public; however, facilities and improvements are very limited and generally associated with resource management, as it has the most intact native ecosystems in the reserve. Trails are not managed by Nā Ala Hele, will not feature recreational amenities, and will generally incorporate facilities necessary to protect and manage natural resources.

Conservation Resource Guideline

DOFAW's Management Guidelines separate conservation resources into four classifications: High Conservation Resources (C-1), Medium Conservation Resources (C-2), Low Conservation Resources (C-3), and Little to No Conservation Resources (C-4) (Figure 46). The upper elevation section of Makawao FR is classified as C-1, or High Conservation Resources, due to the density of native vegetation that provides habitat for T&E plants, native forest birds, and bats. Management for this classification zone may include animal exclusion fencing, predator control, and vegetation/weed control. The lower elevation section of Makawao FR is classified as C-3, or Low Conservation Resources, due to the low level of native biological diversity. This area is appropriate as a multi-use area and is currently experiencing relatively high levels of public recreation and hunting.

5.3.2 Maui Nui Conservation Planning

Global biodiversity is being lost at rates unprecedented in human history, threatening the essential ecosystem services that support national economies, food security, and societal well-being. Island ecosystems have been particularly vulnerable, and Hawaiʻi is no exception. More than 60% of native habitats in the Hawaiian Islands have been destroyed or severely degraded.

Hundreds of native Hawaiian species have already gone extinct, and an additional 416 species across Maui Nui are at risk of extinction due to habitat loss, invasive species, and climate change.

DOFAW holds statutory responsibility for conserving the state's biodiversity and works in partnership with a wide network of public agencies, private landowners, and conservation organizations to fulfill this mission.

A Strategic Approach to Biodiversity Conservation

Effective planning is critical for the conservation of threatened species and the ecosystems on which they depend. However, implementing conservation plans can be difficult—particularly when addressing the needs of hundreds of species, each subject to diverse and overlapping threats. These include habitat degradation, climate instability, complex landownership, and the logistical challenges of managing remote areas. Conservation efforts in these contexts are resource-intensive and require managers to make strategic, data-driven decisions about how best to deploy limited funding and operational capacity.

To address these challenges, DOFAW and its partners are developing the **Maui Nui Landscape Conservation Plan (MNLCP)**—a comprehensive, spatially explicit strategy for conserving biodiversity across the islands of Maui Nui. The MNLCP integrates population-level recovery goals into landscape-scale conservation planning. It identifies efficient, multi-species management areas and actions that help decision-makers:

- Determine the full area needed to conserve all at-risk species.
- Prioritize areas within that landscape.
- Maximize efficiency and overlap of conservation actions.
- Identify the most urgent and impactful actions to implement.
- Guide long-term adaptive management and monitoring.

An Innovative and Inclusive Planning Framework

The MNLCP represents a new generation of conservation planning in Hawaiʻi. It is:

- **Comprehensive**, with actionable guidance to fully recover all at-risk species and major native ecosystem types.
- **Integrated**, uniting conservation strategies across taxonomic groups and land jurisdictions.
- **Collaborative**, involving all conservation partners and land areas available for biodiversity management across Maui Nui.

Key Outcomes of the MNLCP

- **Prevent the near-term extinction** of the most critically imperiled species.

- **Recover all 416 at-risk species**—plants, invertebrates, and vertebrates—by identifying cost-effective, multi-species conservation opportunities.
- **Protect and restore native ecosystems**, such as forests, shrublands, wetlands, coastal habitats, and freshwater systems, to ensure climate resilience, habitat connectivity, and support for unlisted native species.
- **Monitor outcomes** to track progress, support adaptive management, and ensure accountability in implementation.

Planning Strategies and Tools

Spatial Planning for Species at Risk

Managing recovery for hundreds of imperiled species across a fragmented and remote landscape is an immense challenge. Effective conservation requires action at both the species and ecosystem scale, accounting for local threats and management feasibility.

To address this, the MNLCP applies a customized **Spatial Conservation Prioritization (SCP)** framework. This novel tool was designed for taxonomic groups with large numbers of at-risk species and emphasizes **transparency, flexibility, and expert engagement (TFE)**. Unlike conventional SCP models, this framework incorporates:

- Detailed habitat suitability models
- Species population recovery targets
- Logistical and cost constraints
- Biogeographic representation needs

Developed with expert input (Fortini et al. 2024), the SCP enables managers to generate spatially optimized, multi-species recovery plans. Importantly, the approach retains species-specific data throughout, enabling local adaptation and visualization of trade-offs. Results demonstrate major efficiency gains over single-species strategies while maintaining robust habitat prioritization.

Conservation Action Planning

While spatial planning highlights where to act, action planning identifies what to do. The MNLCP uses a modified **Priority Threat Management (PTM)** framework to evaluate which actions yield the greatest benefit per dollar spent.

Input was gathered from approximately 100 land managers and scientists representing state, federal, and private entities. Participants assessed the cost, feasibility, and expected conservation benefit of key management actions for 372 species projected to face extinction in the next two decades without intervention.

The analysis found that:

- No single threat abatement strategy is sufficient alone.
- Effective conservation requires a combination of actions, including ungulate control, invasive species management, predator control, and ecosystem restoration.
- Specialized interventions—such as fencing for snails and seabirds, mosquito control for avian malaria, and propagation facilities for plants and invertebrates—are essential for certain species groups.
- The greatest gains in species persistence result from integrated, cross-taxa management strategies tailored to specific threats and local contexts.

These findings guide resource allocation and enable managers to maximize biodiversity outcomes across landscapes and taxa.

Ecosystem Restoration and Application

Ecosystems at Risk: Makawao Forest Reserve

Makawao Forest Reserve (FR) contains rare mesic native ecosystems that have been severely degraded by invasive species. These habitats, once widespread, now persist only in fragments. Yet Makawao FR remains a high-priority restoration site due to the presence of remnant native vegetation and viable seedbanks, which provide a foundation for recovery.

The MNLCP offers a structured framework to assess ecosystem condition, define restoration goals, and identify cost-effective strategies. Restoring native ecosystems in Makawao FR contributes directly to the conservation of threatened habitat types and the species they support.

Application of MNLCP Tools in Makawao Forest Reserve

The MNLCP equips managers with a suite of decision-support tools and user-friendly web applications designed to optimize conservation planning and implementation. These tools help identify priority areas, assess management options, and target conservation actions for maximum impact.

In Makawao FR, these tools will guide planning decisions to enhance the cost-effectiveness and ecological outcomes of biodiversity conservation efforts. Implementation of MNLCP-informed strategies in Makawao FR will serve as a model for applying this integrated approach throughout Maui Nui.

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 nine 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 soil erosion control.
- **Native Ecosystems** – Maintain and restore native ecosystems by establishing viable populations of native species in natural patterns of abundance and distribution. Restore ecological function, ecosystem services, and evolutionary processes, and adapt to the impacts of climate change.
- **Cultural Resources** – Protection of cultural resources and traditional and customary practices.
- **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 gatherings, 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.

5.3.3 Management Objectives

Expanding on the management priority categories defined above, general management actions, along with tactical goals, action items, and estimated costs associated with these actions for the management of Makawao FR, are presented in Table 18.

Table 18. Management of Makawao FR

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
Resource Protection	Wildfire management and prevention	Fire pre-suppression	Development of fire management plans.	Staff and mgmt. costs only
			Work with HWMO to re-evaluate the CWPP plan every 5 years.	Staff & mgmt. costs only
			Implement flash grazing at Pa Olinda to control gorse and for fire fuel mitigation.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Prevention	Consider restricting access to Makawao FR if KBDI readings and other predictive services indicate extremely dry conditions.	Staff & mgmt. costs only
			Report powerline maintenance needs with MECO and monitor the powerline corridor for any hazards (vegetation, road conditions, etc).	Staff & mgmt. costs only
			Review existing utility easement documents and assess the need and feasibility of updating general conditions to ensure that fuels are removed by the easement holder after vegetation management operations.	Staff & mgmt. costs only
	Monitor weather conditions	Use data to determine district fire preparedness levels	Implement fire preparedness level activities.	Staff & mgmt. costs only
		Use data (Keetch-Byram Drought Index) to monitor the 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 an annual survey report to the Forest Health Coordinator.	Staff & mgmt. costs only
			Rapid response to mitigate forest health issues.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Koa Looper Moth (*Scotorythra paludicola*) population monitoring and management	Monitor levels of *Scotorythra paludicola* populations and their impact on koa stands.	Staff and 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 modes 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 landowners to collect samples to test for ROD.	TBD
			Document and report any sightings of dead or dying ʻōhiʻa trees during routine field operations.	TBD
			Implement biosecurity measures in the event ROD is detected in Maui Nui, including rapid response to contain and eradicate.	Staff & mgmt. costs only
			Adopt sanitation procedures proven to be effective.	$1k/year
			Include ROD sanitation and prevention procedures in all permits designated for Makawao FR.	Staff & mgmt. costs only
			Maintain ROD sanitation stations at trailheads.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Increase public information and awareness for Rapid ʻŌhiʻa Death	Continue to participate in outreach activities targeting ROD.	$5k/year + staff costs
Cultural Resources	Cultural Resource Protection	Increase understanding of cultural resources in need of protection	Collect data from the community to better protect cultural resources.	Staff & mgmt. costs only
		Cultural site restoration and management	If cultural sites are identified, explore co-management alternatives with established Hawaiian community groups.	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 traditional and customary practices	Protect cultural practices (e.g., fishing, gathering, farming, fiber collection, and processing)	Protect/create dedicated spaces for cultural practices.	Staff & mgmt. costs only
		Maintain the application and permit process for protected cultural activities that require a forest reserve permit	Maintain and update the cultural application process.	Staff & mgmt. costs only
			Review applications and issue applicable forest reserve permit(s) when approved.	Staff & mgmt. costs only
Watershed Values	Increase land holdings protected under the Forest Reserve System	Support healthy forests through land acquisition and forest restoration	Complete administrative process to add TMK: (2) 2-4-016:001 (Pa Olinda) to the Makawao FR to secure access and reforestation efforts.	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 the communities of Maui	Re-establishment of appropriate vegetative cover.	$75k/year + staff costs
		Monitor and manage cattle ingress into the FR from adjacent private property	Maintain FR boundary fences to exclude cattle.	$5K/year
			Monitor for non-game mammal species (cattle). If detected, initiate rapid response control operations. Locate and remove cattle with the owner's assistance.	Staff & mgmt. costs only
		Post-fire mitigation	Continue to collect and store seeds of common natives and rare T&E plants to be used for post-fire mitigation work.	$15k/year
			Restore fire-resilient native plant communities following wildfires to stabilize soils and prevent post-burn erosion.	$500k
	Collaboration	Maintain DOFAW's partner role in the EMWP	Improve communication and coordination between agencies.	Staff & mgmt. costs only
			Establish regular communications, schedules, and protocols with EMWP.	Staff & mgmt. costs only
			Participate in EMWP quarterly meetings.	Staff & mgmt. costs only
			Annual renewal of EMWP's Forest Reserve Special Use Permits.	Staff & mgmt. costs only
	Climate Change Adaptation	Monitor the latest publications and available information for climate change, vulnerability, modeling, and adaptation	Participate in climate change seminars, meetings, and workshops.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		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 healthy forests through land acquisition and forest restoration.	TBD
Invasive Species Control	Reduce the impact of invasive species on the Forest Reserve and surrounding areas	Continue to work with cooperating agencies, including MISC and EMWP	Invasive species specialists, technicians, 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
			Prioritize invasive plant removal, focusing on areas with high diversity or rare species.	Staff & mgmt. costs only
			Collaborate and support MISC to conduct surveys for incipient and invasive species.	$50k/year
		Invasive species monitoring and control	Write a comprehensive weed plan for the reserve.	$5k
			Manual, chemical, and mechanical control.	$50k/year
			Quarterly trips to control Himalayan (kāhili) ginger control along the Waikamoi Preserve boundary.	$20k/year
			Maintain common native outplantings and small fenced exclosure in Himalayan (kāhili) ginger control area.	$5k/year
			Implement flash grazing at Pa Olinda to control gorse.	Staff & mgmt. costs only
		Support biological control efforts in	Support applied research for potential biocontrol agents, including labor and helicopter time.	TBD

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		FR and adjacent lands	Strawberry guava (*Psidium cattleianum*) biocontrol: Additional releases of *Tectococcus ovatus* to increase spread as needed.	$5k/year
			Continue to monitor *Tectococcus ovatus* release sites for effectiveness and spread.	$5k/year
		Conduct research to support technology that increases 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
	Biosecurity	Prevent the introduction of invasive insects, plants, animals, new diseases, and pathogens by increasing biosecurity controls	Support implementation of quarantines, interisland policies, and optional vs. mandatory restrictions.	Staff & mgmt. costs only
T&E Species Mgmt	Protection and recovery of listed rare plants and animals	Cooperate with PEPP, USFWS, and other rare plant agencies to prioritize rare plant species protection	Work with PEPP staff and state botanists to conduct botanical surveys.	Staff & mgmt. costs only
			Conduct surveys and monitoring efforts to obtain baseline data that will be used to help protect species and areas of interest.	Staff & mgmt. costs only
		Implement management of T&E species recovery and management plans	Build fences and maintain exclosures around wild populations of rare plants. Conduct predator and ungulate control as needed.	$10k/year
			Outplant T&E species into exclosures.	

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
		Collaborate with MFBRP, MNSRP, SEPP, USFWS, and other agencies on prioritized endangered wildlife species protection	Build and maintain enclosures around wild populations of rare wildlife species. Conduct predator and ungulate control as needed.	$10k/year
			Assist MFBRP on their forest bird transect surveys.	Staff & mgmt. costs only
			Support forest bird enhancement and protection through planned mosquito biocontrol releases (*Wolbachia*).	Staff & mgmt. costs only
			Protect and prepare habitat for rare wildlife species introduction by increasing habitat quality and reducing threats (e.g., predators, invasive species, human disturbance).	$20k/year
			Release rare wildlife species into suitable habitat and monitor survival, dispersal, reproductive success, abundance, and genetic diversity.	$20k/year
			Remove and control invasive species in predominantly native ecosystems, especially around populations of endangered and rare native plant species.	$10k/acre
Native Ecosystems	Maintain and restore, 1) native ecosystem types, 2) viable populations of all native species in natural patterns of abundance and distribution, 3) ecological function and ecosystem	Non-native vegetation removal	Outplant common native species that benefit the ecosystem and are used for forest product collection by the public (e.g., maile and māmaki).	$10k/acre
		Revegetation	Actively restore high-priority sites, considering surrogate species that may be tolerant of future climate conditions.	$10k/year

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
	services, 4) carbon sequestration by natural ecosystems, and 5) evolutionary processes and adapt to the impacts of climate change		Identify existing native seed banks and implement management actions that stimulate natural regeneration of native vegetation.	$10k/year
			Install small-scale ungulate fences around restoration areas to protect against feral ungulate damage.	TBD
		Monitoring	Survey and monitor areas cleared of non-native vegetation. Retreat areas as needed to encourage native ecosystem restoration.	Staff & mgmt. costs
			Design a monitoring protocol for native species richness and diversity to establish a baseline and track long-term trends.	$10k/year
	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
			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 a biome shift.	$100k/ year
			Monitor the abundance of native and invasive species as temperature rises and precipitation changes.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
			Map transitional areas between different habitats (e.g., 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 native seed storage capacity, seed propagation methods, and silvicultural planting methods (e.g., seed collection, composition, spacing).	$10k/year
			Consider climate projections in the timing and seasonality of planting to increase outplanting survival rates.	Staff & mgmt. costs only
Game Animal Mgmt	Promote public hunting through Chapter 122, HAR, and implement game mammal management actions as provided in the Pittman Robinson Game Management Plan (2016)	Provide hunter access	Maintain public access in Makawao FR to Hunting Unit D.	$15k staff cost
			Securing easements for access to the upper portion of FR for hunter access.	TBD
		Review existing long-term strategic goals set by the DOFAW Management Guidelines	Evaluate every five years.	Staff & mgmt. costs only
			Designate Kahakapao Recreation Area as a safety zone and remove it from Public Hunting Unit D.	Staff & mgmt. costs only
		Rule Revision	Continue hunter education program, and other public outreach as required.	$2K staff cost and materials
		Public education	Maintain game mammal hunting opportunities in Makawao FR.	Staff & mgmt. costs only
		Regulate hunting as per Chapter 122, HAR	Continue to manage the fee collection of salvage harvest permits.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
Commercial Activity	Generate income from suitable commercial activities in the Forest Reserve to supplement funding of natural resource management activities	Facilitate the permitting process for salvage harvest permits	Determine the feasibility of commercial tour permits for the Kahakapao Recreation Area, commercial harvest permits, and potential revenue from the film industry.	Staff & mgmt. costs only
		Determine future income possibilities of low-impact sustainable activities	Determine protocol to manage fee collection for commercial use permits.	Staff & mgmt. costs only
			Meet with surrounding landowners, neighboring landowners, and leaseholders to formalize access agreement as appropriate for Makawao FR.	Staff & mgmt. costs only
Access, Trails, and Other Public Uses	Secure public access to the FR	Formalize or update historical access agreements (as needed) with adjacent landowners	Meet with surrounding landowners, neighboring landowners, and leaseholders to formalize access agreement as appropriate for Makawao FR.	Staff & mgmt. costs only
		Create new access as needed	Initiate the administrative process to issue a perpetual non-exclusive easement to Maui County for access to the Piʻiholo Water Treatment Facility.	Staff & mgmt. costs only
	Provide access to FR inholdings	Formalize access agreements for Maui County inholdings	Install Makawao Forest Reserve entrance signs and other signage as needed.	$10k/year + staff costs
			Review land survey documents for Kahakapao Reservoir. If research confirms that a portion of the reservoir is included within TMK (2) 2-4-016:001 and there are no existing easements or set-asides, work with the County to resolve potential dual jurisdiction issues.	Staff & mgmt. costs only

Management Priority	General Management Action	Tactical Goals	Action Items	Estimated Cost
	Increase public information and awareness	Install informational signage	Maintain and repair trails, trail infrastructure, and access-related infrastructure (e.g., restrooms, access roads, parking lots, trail/gate usage counters, and automatic forest reserve entrance gate).	$25k/year + staff costs
	Infrastructure management and construction	Maintain trails and other trail infrastructure in accordance with NAH program standards and plans, as outlined in the Kahakapao Recreation Area EA	Conduct risk assessment for all trails to determine mitigation needs.	Staff & mgmt. costs
			Continue to work with contractors to maintain mountain biking trails in accordance with International Mountain Biking Association standards. Maintain the terms of the contract, which includes workshops for the biking community.	$75k/year
			Complete a carrying capacity study for trail and FR use.	$85k
		Develop new trails and other trail infrastructure in the Kahakapao Recreational Area in accordance with NAH program standards and plans, as outlined in the Kahakapao Recreation Area EA	Assess and develop new trails and covered rest stations throughout the recreation area.	$75k/year for new trail construction

5.4 Overall Measures of Success

Measures of success for individual forest reserve management plans can be derived from the State of Hawaiʻi annual variance reports. Initial measures of success that may be applicable to Makawao FR include:

- Acres of invasive plants controlled
- 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 being protected
- Number of cultural resources protected
- Number of recreational users
- Number of volunteer service projects
- Metric tons of carbon sequestered
- Revenue generated from the 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 cattle-proof fencing and forest restoration areas
- Stable to increasing populations of threatened and endangered species
- Healthy native ecosystems
- Protection of cultural resources
- Maintain and improve public recreational opportunities
- Sustainable harvest level of feral ungulates
- Negotiate cooperative agreements with neighboring landowners to secure management and public access in perpetuity
- 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 the area for watershed protection, natural resource conservation, and public recreation and hunting.
- Develop alternative funding opportunities that support forest management and sustainable use, such as commercial use permits, small-scale or salvage timber harvesting, or film industry permits.
- Enhance district forestry program capacity of personnel and equipment resources to ensure the successful implementation of management plans.
- Work with neighboring landowners and East Maui Watershed Partnership on landscape-scale projects for wildland fire, invasive species control, and native forest restoration.

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8. APPENDICES

Appendix A: NRCS SSURGO Soil Map Unit Descriptions
Appendix B: Botanical and Faunal Survey Makawao 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 38-70)
Appendix F: DOFAW Management Guideline Classification Definitions

Island of Maui, Hawaii

OND—Olinda loam, 12 to 20 percent slopes

Map Unit Setting

National map unit symbol: hqb3
Elevation: 2,500 to 5,000 feet
Mean annual precipitation: 40 to 60 inches
Mean annual air temperature: 59 to 64 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

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

Description of Olinda

Setting

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

Typical profile

H1 - 0 to 6 inches: loam
H2 - 6 to 28 inches: silty clay loam
H3 - 28 to 40 inches: very gravelly silty clay loam
H4 - 40 to 50 inches: bedrock

Properties and qualities

Slope: 12 to 20 percent
Depth to restrictive feature: 40 to 60 inches to lithic bedrock
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: C
Ecological site: R160XY007HI - Isothermic Ustic Naturalized Grassland

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

rRK—Rock land

Map Unit Setting

National map unit symbol: hqcq
Elevation: 0 to 6,000 feet
Mean annual precipitation: 15 to 60 inches
Mean annual air temperature: 57 to 75 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

Rock land and similar soils: 55 percent
Rock outcrop: 45 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rock Land

Setting

Landform: Pahoehoe lava flows
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank, side slope, riser, rise
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Basalt

Typical profile

H1 - 0 to 4 inches: silty clay loam
H2 - 4 to 8 inches: silty clay
H3 - 8 to 20 inches: bedrock

Properties and qualities

Slope: 0 to 70 percent
Depth to restrictive feature: 4 to 10 inches to lithic bedrock
Drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Very low (about 1.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Hydric soil rating: No

Description of Rock Outcrop

Typical profile

H1 - 0 to 60 inches: bedrock

Properties and qualities

Slope: 10 to 70 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 supply, 0 to 60 inches: Very low (about 0.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

rHR—Honomanu-Amalu association

Map Unit Setting

National map unit symbol: hqcm
Elevation: 1,000 to 5,500 feet
Mean annual precipitation: 75 to 399 inches
Mean annual air temperature: 57 to 63 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

Honomanu and similar soils: 60 percent
Amalu and similar soils: 40 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Honomanu

Setting

Landform position (two-dimensional): Summit
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Volcanic ash

Typical profile

H1 - 0 to 11 inches: silty clay
H2 - 11 to 37 inches: silty clay
H3 - 37 to 60 inches: extremely cobbly loam

Properties and qualities

Slope: 5 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: High (about 10.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: A
Ecological site: F164XY002HI - Organic Surface Forest
Hydric soil rating: No

Description of Amalu

Setting

Landform: Plateaus
Landform position (two-dimensional): Shoulder
Landform position (three-dimensional): Interfluve
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Organic and volcanic ash material

Typical profile

H1 - 0 to 8 inches: peaty silty clay
H2 - 8 to 16 inches: silty clay
H3 - 16 to 17 inches: cemented material
H4 - 17 to 40 inches: very cobbly silt loam
H5 - 40 to 60 inches: bedrock

Properties and qualities

Slope: 3 to 20 percent
Depth to restrictive feature: 16 to 23 inches to placic; 17 to 24 inches to paralithic bedrock
Drainage class: Poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 2 to 6 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7w
Hydrologic Soil Group: D
Ecological site: F164XY001HI - Gleyed Soil Forest
Hydric soil rating: Yes

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

KBID—Kailua silty clay, 3 to 25 percent slopes

Map Unit Setting

National map unit symbol: hq8j
Elevation: 200 to 2,000 feet
Mean annual precipitation: 90 to 160 inches
Mean annual air temperature: 66 to 72 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

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

Description of Kailua

Setting

Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Overlies basalt

Typical profile

H1 - 0 to 9 inches: silty clay
H2 - 9 to 40 inches: silty clay
H3 - 40 to 60 inches: silty clay loam

Properties and qualities

Slope: 3 to 25 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 7.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R167XY001HI - Oxidic Dissected Lowland

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

ONE—Olinda loam, 20 to 40 percent slopes

Map Unit Setting

National map unit symbol: hqb4
Elevation: 2,500 to 5,000 feet
Mean annual precipitation: 40 to 60 inches
Mean annual air temperature: 59 to 64 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

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

Description of Olinda

Setting

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

Typical profile

H1 - 0 to 6 inches: loam
H2 - 6 to 28 inches: silty clay loam
H3 - 28 to 40 inches: very gravelly silty clay loam
H4 - 40 to 50 inches: bedrock

Properties and qualities

Slope: 20 to 40 percent
Depth to restrictive feature: 40 to 60 inches to lithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

W—Water > 40 acres

Map Unit Composition

Water > 40 acres: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

Island of Maui, Hawaii

rRR—Rough broken land

Map Unit Setting

National map unit symbol: hqcs
Elevation: 0 to 4,000 feet
Mean annual precipitation: 20 to 200 inches
Mean annual air temperature: 61 to 73 degrees F
Frost-free period: 365 days
Farmland classification: Not prime farmland

Map Unit Composition

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

Description of Rough Broken Land

Setting

Landform: Gulches
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank, side slope, rise
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Alluvium and colluvium

Typical profile

H1 - 0 to 8 inches: silty clay loam
H2 - 8 to 30 inches: silty clay loam
H3 - 30 to 60 inches: bedrock

Properties and qualities

Slope: 40 to 70 percent
Depth to restrictive feature: 20 to 55 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Low (about 4.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C

Hydric soil rating: No

Data Source Information

Soil Survey Area: Island of Maui, Hawaii
Survey Area Data: Version 22, Sep 11, 2024

FLORA AND FAUNA SURVEY
MAKAWAO FOREST RESERVE, MAUI

Prepared By:
FOREST & KIM STARR

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

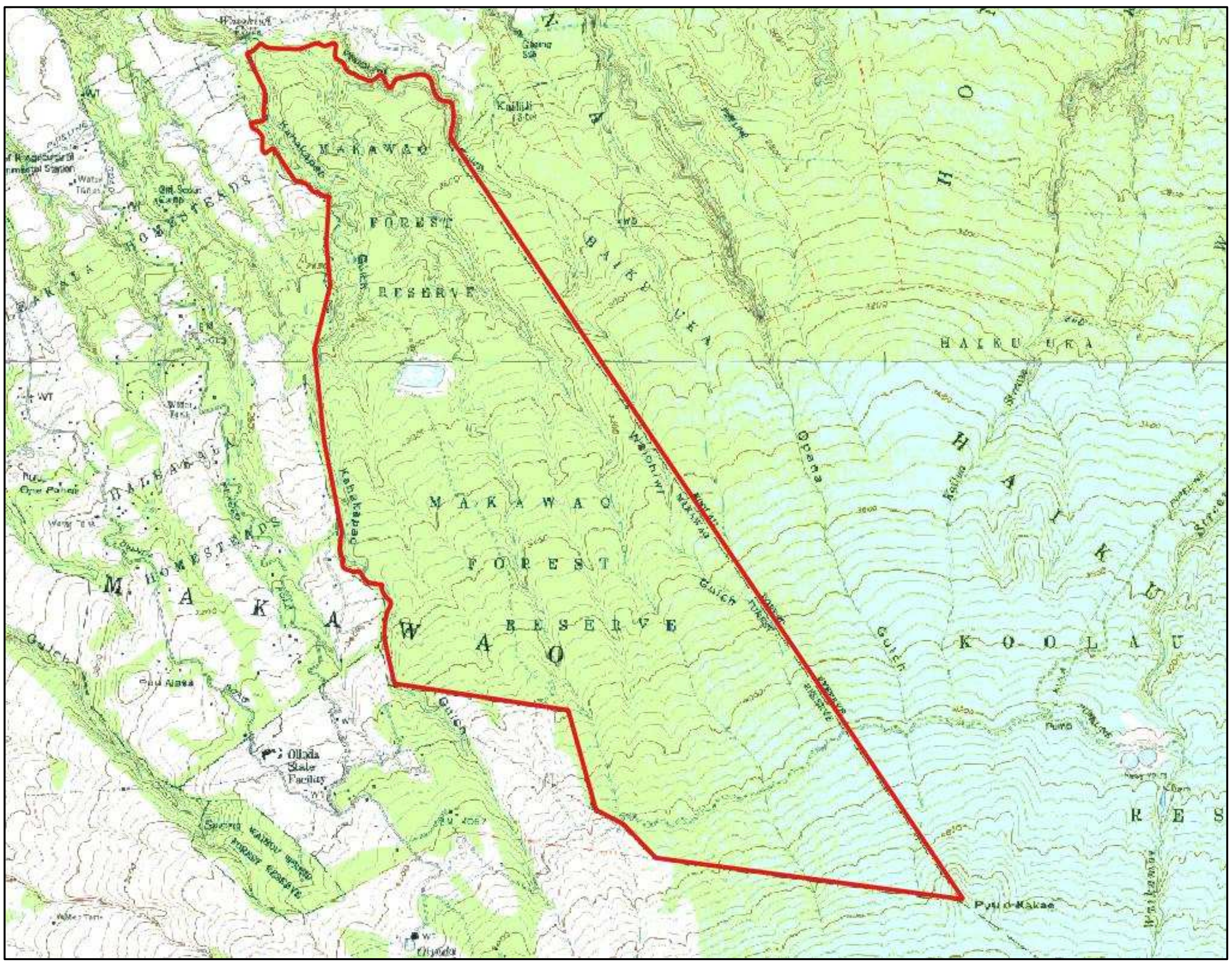
2022

INTRODUCTION

The Makawao Forest Reserve encompasses about 2,092 acres (TMK 240160020000) on the north slope of East Maui. 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 land is relatively steep, dissected by gulches. The bulk of the property is forested. Elevation ranges from 2,000 to 5,000 feet above sea level. Annual rainfall averages 100-160 inches. Annual air temperature averages 56-61 degrees Fahrenheit.



Project area, Makawao Forest Reserve, Maui.

SURVEY OBJECTIVES

The main objectives of the survey were to:

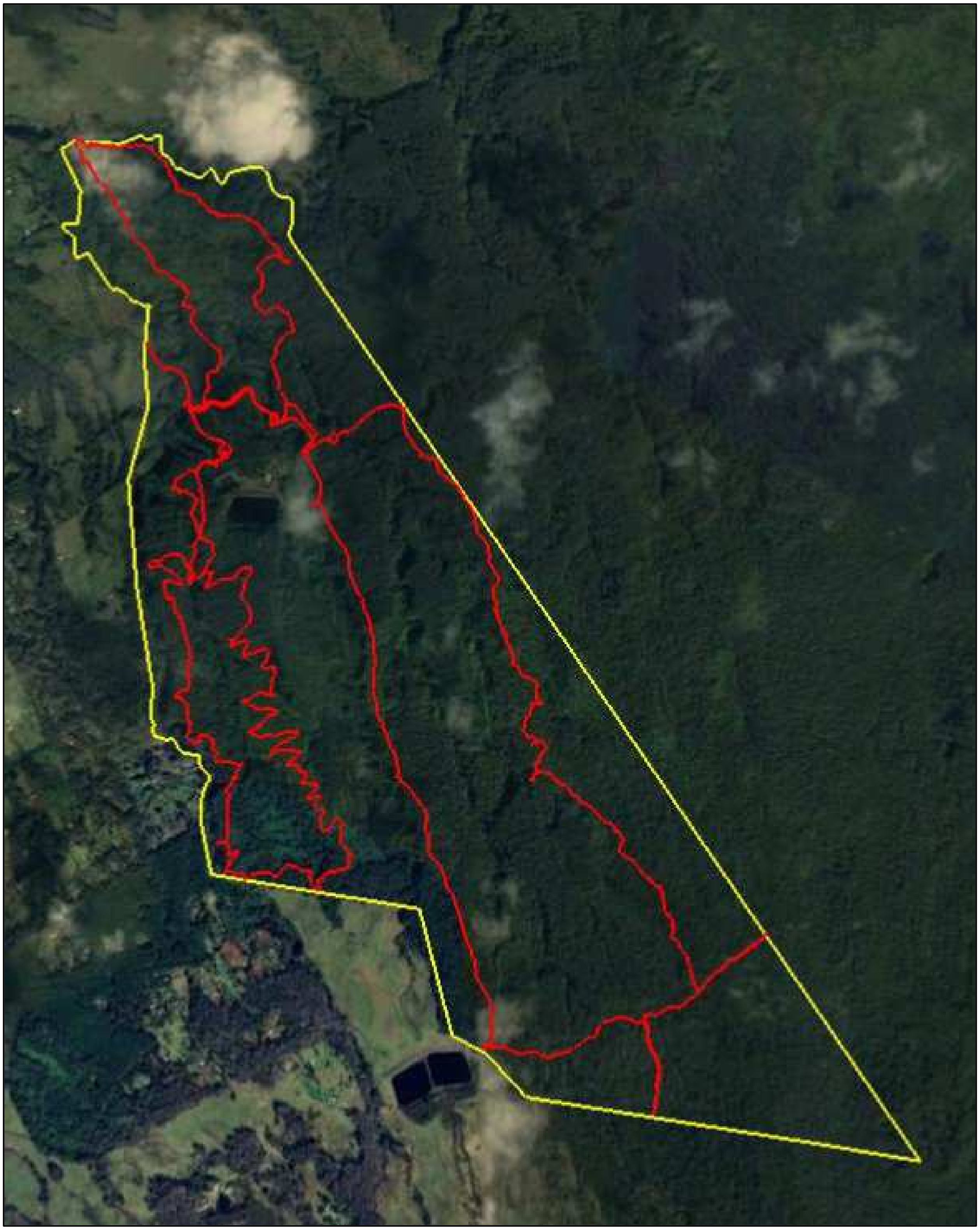
- Document what plant (terrestrial vascular flora) and animal (birds, bats, mammals, insects) species occur in the reserve or may likely occur in the existing habitat.

- 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.

SURVEY METHODS

A walk-through survey method was used over representative areas of the reserve in July 2022. Extra emphasis was placed on areas with potential for high diversity and areas where management was most likely. Notes were made on plant and animal species encountered. In addition, a sweep net was used to get closer looks at insects. And binoculars were used to get closer looks at birds. A helicopter overflight was also done to get a big picture overview, look at areas we didn't get to on foot, and get images for this report.

Taking notes on flora and fauna in the Makawao Forest Reserve.



Area surveyed (red lines).

RESULTS

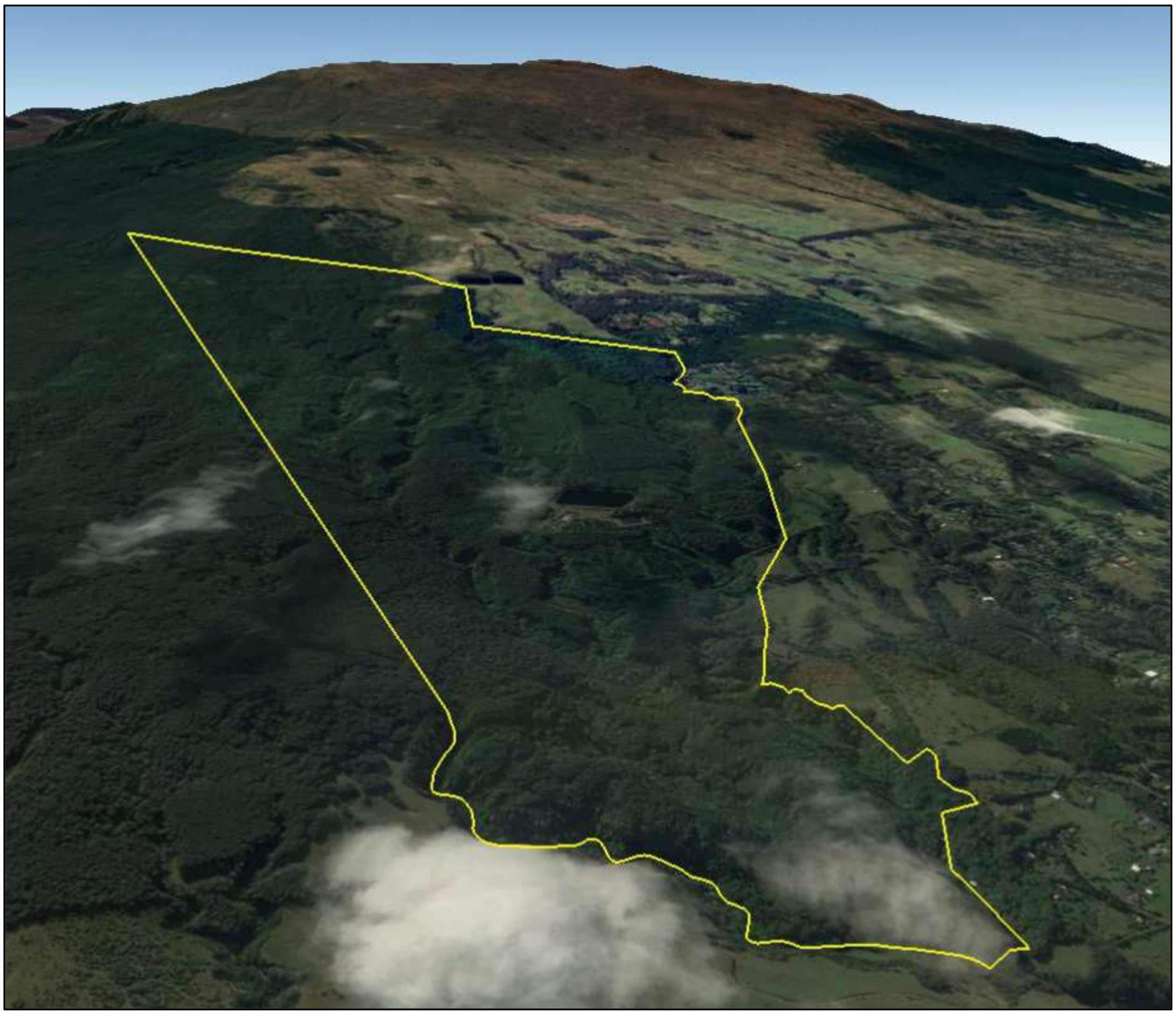
VEGETATION

There are a few main vegetation/habitat types in the Makawao Forest Reserve:

Plantation: The bulk of the reserve is dominated by non-native trees planted in large blocks.

Mesic Gulch: Most of the remnant native plants in the mid to lower part of the reserve are restricted to the steep gulches, where forestry plantings were not done.

Wet Forest: Much of the highest elevations of the reserve were also not planted with non-native trees, and are still dominated by a native wet forest.



Makawao Forest Reserve.

A key insight into the biological history of Makawao Forest Reserve is that in the 1960's, the bulk of the native forest on the ridges was bulldozed down and placed into contouring windrows. These areas were then planted with large blocks of non-native trees. In contrast, some of the more intact upland native forests, and steep gulches throughout the reserve, were not bulldozed. This general pattern of non-native plantation-like forests on the ridges, with native plants mostly restricted to the gulches and higher elevations remains in place today.

Aerial image of Makawao Forest Reserve in 1965 showing bulldozed native forest. Photo by USDA.

PLANTATION

A patchwork of plantation trees in the Kahakapao Loop Trail section of the Makawao Forest Reserve.

The bulk of the Makawao Forest Reserve is now dominated by non-native trees planted in large blocks, especially tropical ash (*Fraxinus uhdei*), eucalyptus (*Eucalyptus* spp.), pines (*Pinus* spp.), Australian red cedar (*Toona ciliata*), and brush box (*Lophostemon confertus*). There are also large blocks of native koa (*Acacia koa*) trees.

Beneath these large trees the understory is mostly barren in many areas, and in other areas is dominated by aggressive non-native plants, especially kahili ginger (*Hedychium gardnerianum*), strawberry guava (*Psidium cattleianum*), and quinine (*Cinchona pubescens*).

Some native trees and shrubs persist in the understory and on the edge of the plantations, such as koa (*Acacia koa*), ‘ōhi‘a (*Metrosideros polymorpha*), pilo (*Coprosma foliosa*), ‘a‘ali‘i (*Dodonaea viscosa*), manono (*Kadua affinis*), and pūkiawe (*Leptecophylla tameiameiae*).

Native ferns are also present in the understory of plantations, especially kupukupu (*Nephrolepis cordifolia*). Other less common native ferns include palapalai (*Microlepia strigosa*), ōkupukupu (*Doodia kunthiana*), *Dryopteris* spp., and *Asplenium* spp.

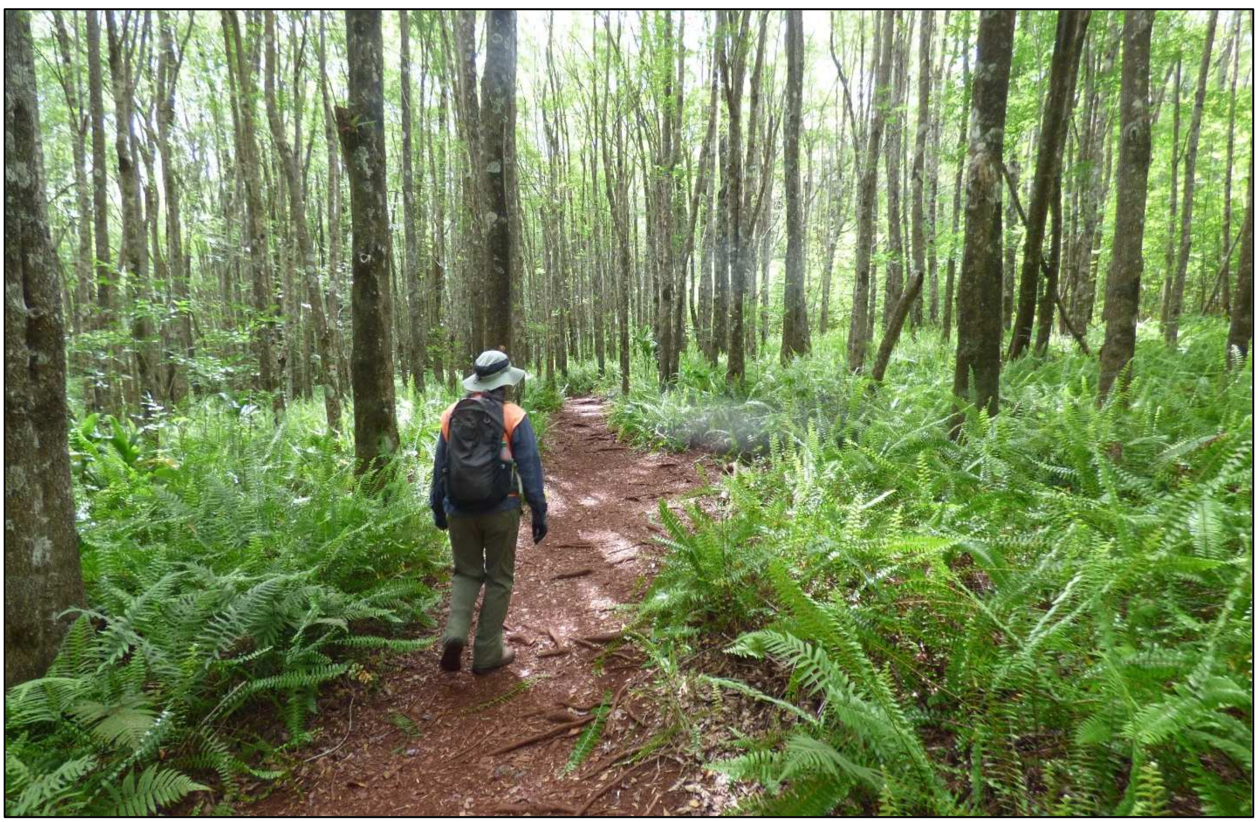
Non-native ferns encountered include rough maidenhair fern (*Adiantum hispidulum*), brake fern (*Pteris cretica*), and downy wood fern (*Cyclosorus*).

The native maile vine (*Alyxia stellata*) can be found in higher elevations, and koali ‘awa (*Ipomoea indica*) in lower elevations. Non-native passion vines (*Passiflora edulis*) are also encountered. And in some areas there are thickets of blackberry, mostly *Rubus argutus*.

The native sedge *Carex wahuensis* can be found in the understory of some plantations. Non-native palmgrass (*Setaria palmifolia*) is increasingly present in many areas.

Remnant koa tree (*Acacia koa*) in ash (*Fraxinus uhdei*) plantation, with mostly barren understory.

Tropical ash (*Fraxinus uhdei*) plantation starting to turn fall colors, Makawao Forest Reserve.



Tropical ash plantation with mixed fern understory, Kahakapao Loop Trail.

Eucalyptus plantations, Makawao Forest Reserve.

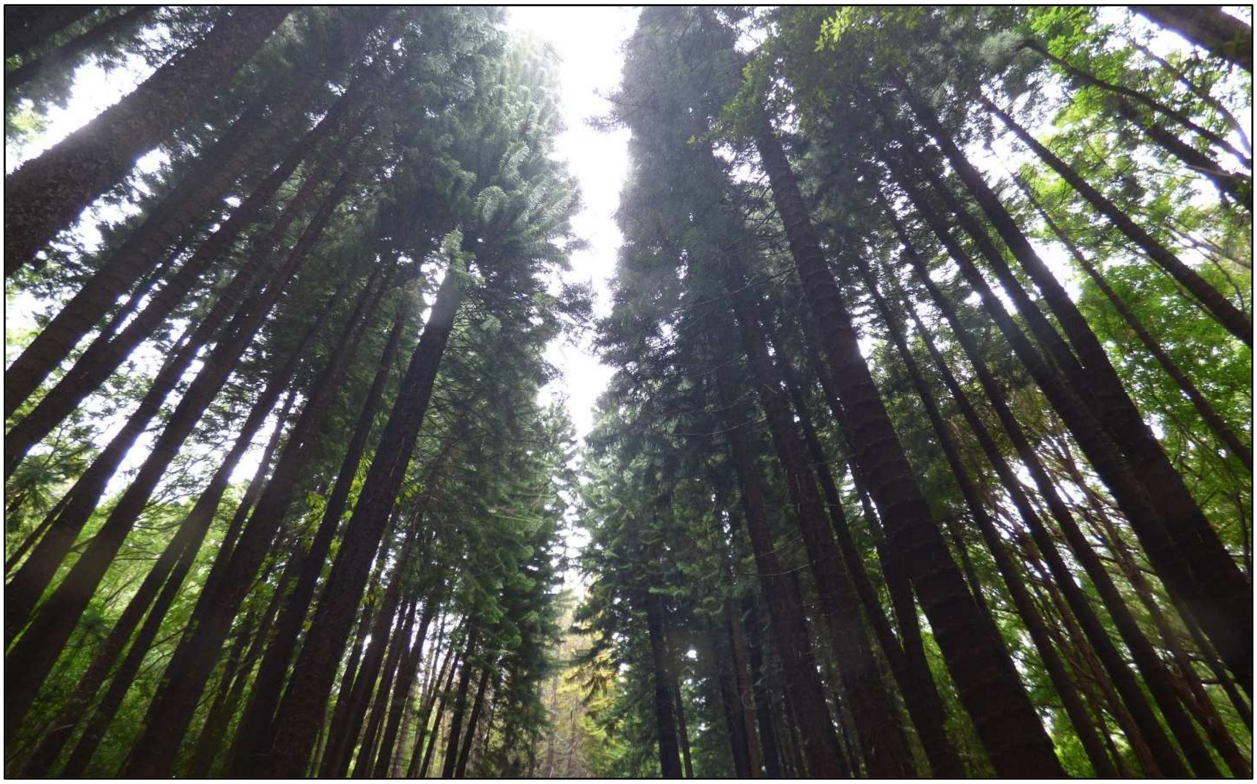
Many of the eucalyptus plantations have barren understories, especially on the western part of the reserve.

Some eucalyptus plantations have remnant native plants such as uluhe (*Dicranopteris*) in the understory.

Others are a tangle of invasive species, especially kahili ginger (*Hedychium*) and quinine (*Cinchona*).

Large areas of blue gum eucalyptus (*Eucalyptus globulus*) have recently died in the reserve. Similar stand level dieback is occurring over much of East Maui, presumably due to non-native insects and pathogens.

Dead and dying blue gum (*Eucalyptus globulus*) trees, Makawao Forest Reserve.



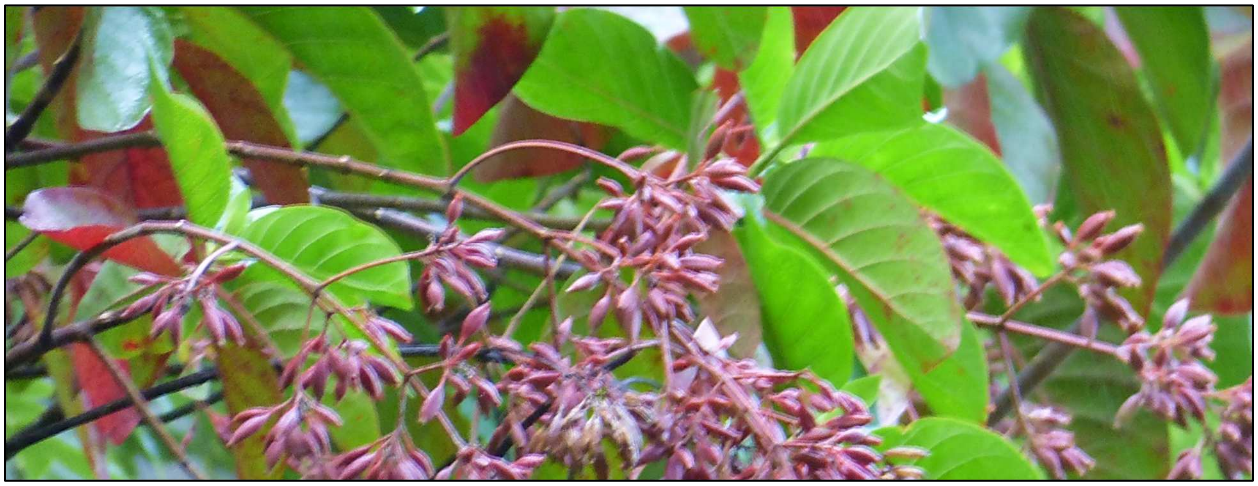
Other plantings of trees in the reserve include non-native cook pines (*Araucaria columnaris*).

And native koa trees (*Acacia koa*).

Pilo (*Coprosma foliosa*) is one of the few native shrubs able to survive in the understory of plantations.

Maile (*Alyxia stellata*) is also able to find open areas with enough sun to survive.

As is the native pūkiawe (*Leptecophylla tameiameiae*).



Quinine (*Cinchona pubescens*) is common in and near plantations.

Kahili ginger (*Hedychium gardnerianum*) dominates much of the understory in and near plantations.

Non-native passion vines (*Passiflora edulis*) are also occasionally encountered.

The native kupukupu fern (*Nephrolepis cordifolia*) is the most common fern on the Kahakapao Loop Trail.

Palapalai (*Microlepia strigosa*) is also found scattered about in small clumps.

As are *Asplenium* spp.

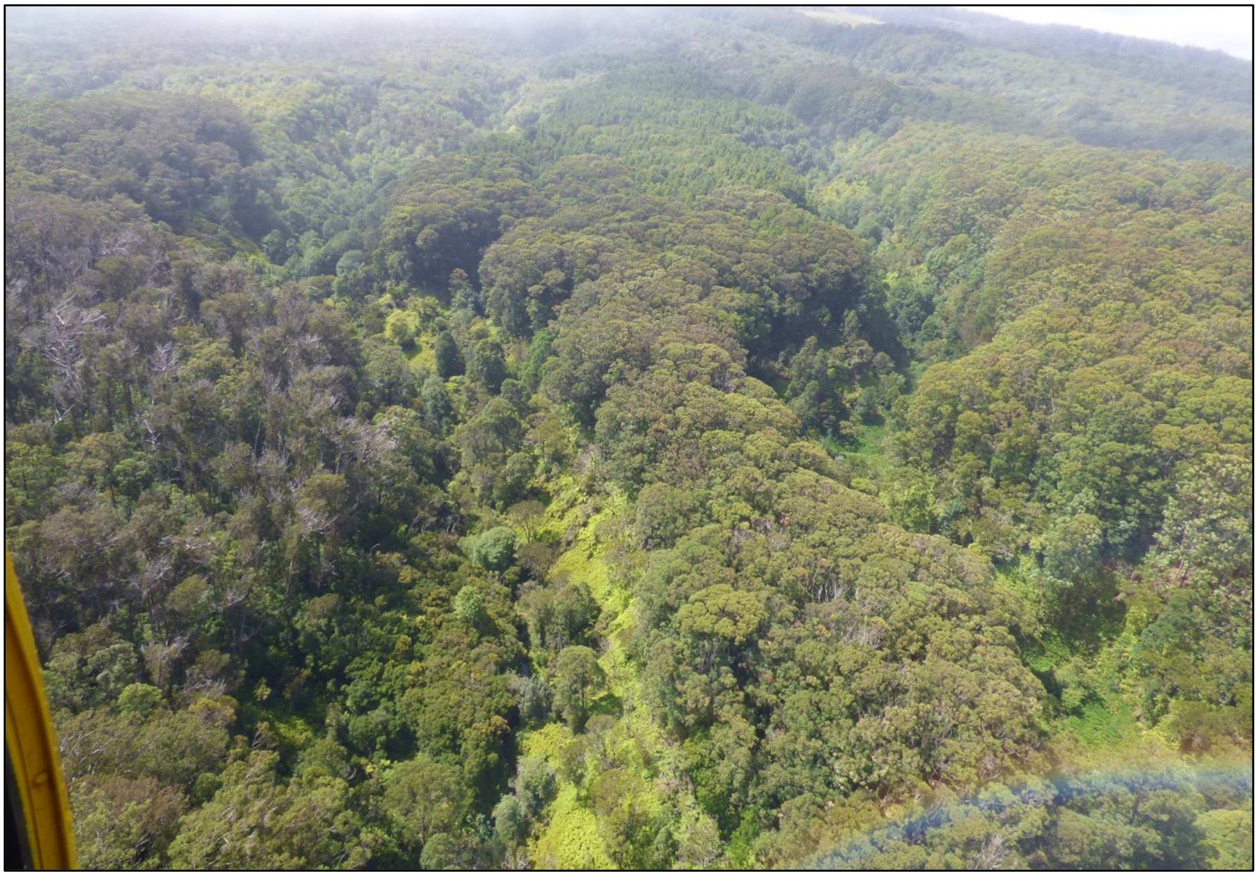

Remnant native ʻōhiʻa tree in a pine/eucalyptus plantation in the Makawao Forest Reserve.


Seeds of *Carex wahuensis*, one of the native sedges found scattered along the Kahakapao Loop Trail.


Non-native palmgrass (*Setaria palmifolia*) is becoming increasingly common in the reserve.

Plantation of large brush box (*Lophostemon confertus*) trees, Makawao Forest Reserve.

MESIC GULCHES



Remnant native plants in the gulches between non-native plantation trees on the ridges.

In contrast to the monotypic plantations on the ridges are the diverse gulches between the ridges. These areas harbor much of the remnant native plant richness in the lower portion of the reserve. Especially rich are the gulch walls.

Though there are many different native plant species in these gulches, their numbers are few and dwindling. The gulches are largest in the lowest portions of the reserve, and become almost indiscernible in the highest reaches of the reserve.

‘Ōhi‘a (*Metrosideros polymorpha*) is common throughout the gulches, more abundant up high, and sparse down low. Other native trees in the mesic gulches include dwarf koa (*Acacia koaia*), halapepe (*Pleomele auwahiensis*), olopua (*Nestegis sandwicensis*), kōlea (*Myrsine lessertiana*), hōlei (*Ochrosia haleakalae*), ‘āla‘a (*Pouteria sandwicensis*), and kāwa‘u (*Ilex anomala*).

Though not planted in the gulches, non-native trees are becoming increasingly common there as they spread from nearby plantings on the ridges. Most common is tropical ash (*Fraxinus uhdei*). Eucalyptus and pines are also spreading into the gulches. Shorter strawberry guava (*Psidium cattleianum*) covers large areas of the gulches, as does quinine (*Cinchona pubescens*).

Much of the understory along the river corridor has been converted to non-native plants, especially kahili ginger (*Hedychium gardnerianum*). Night blooming jasmine (*Cestrum nocturnum*) is also locally abundant.

Native māmaki shrubs (*Pipturus albidus*) still persist in areas not dominated by kahili ginger or forestry trees. As do the native vines maile (*Alyxia stellata*), huehue (*Cocculus orbiculatus*), and hoi kuahiwi (*Smilax melastomifolia*). Though more common in native dominated areas, ʻieʻie (*Freycinetia arborea*) can be found climbing up both native and non-native trees.

The more open remnant native areas often have an understory of uluhe fern (*Dicranopteris linearis*). Scattered hāpuʻu tree ferns (*Cibotium* spp.) still persist. And the non-native tree fern (*Sphaeropteris cooperi*) is becoming increasingly common in these areas.

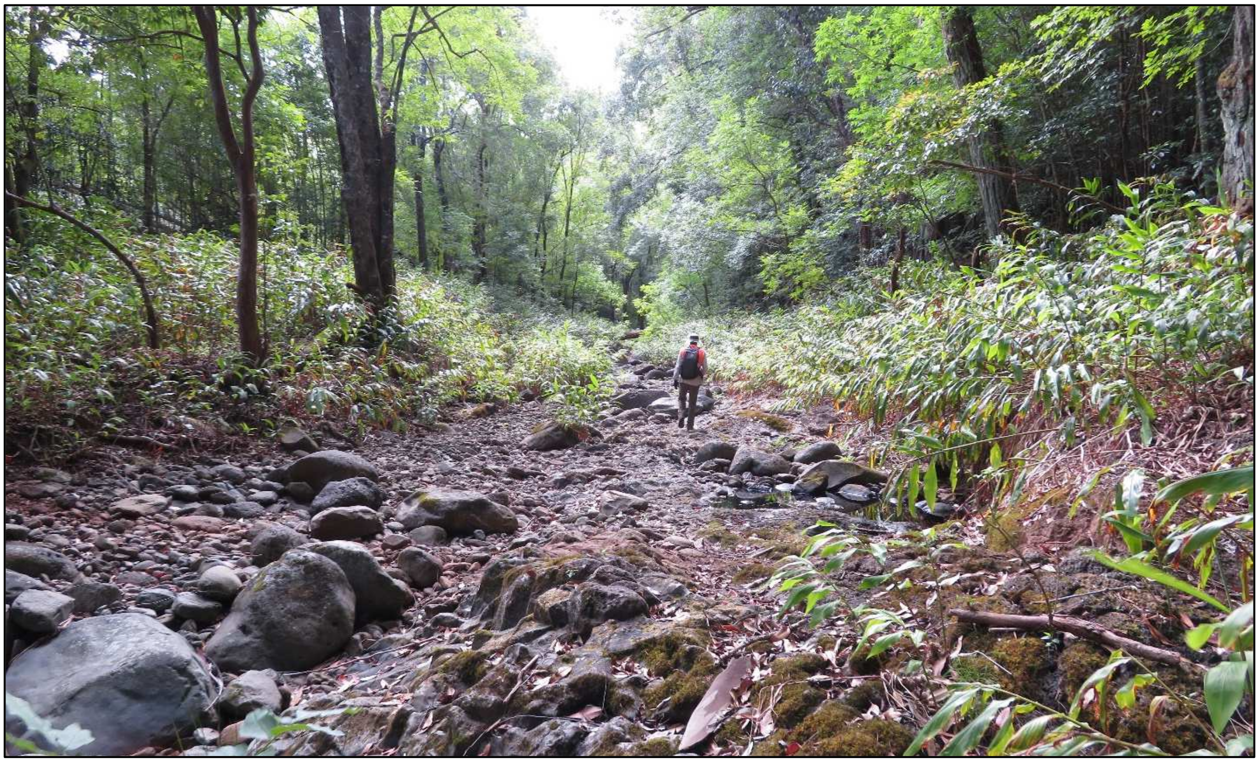
Diminutive native ʻalaʻala wai nui (*Peperomia* spp.) are present in the moister areas of the gulches, often on rocks, along with ferns, mosses, and other plants preferring that environment.

This remnant native gulch habitat type is relatively small in the reserve and is quickly going away, predominantly due to the spread of aggressive non-native plant species.

Remnant halapepe tree (*Pleomele auwahiensis*) and other native plants on a gulch edge along Kahakapao Loop Trail. These native remnants are being quickly overrun from above by more aggressive non-native trees spreading from nearby plantations. And from below by kahili ginger and other invasive understory plants.

Remnant native forest in a gulch in the mid section of the reserve.

Remnant native forest in a gulch in the lower portion of the reserve.



Open riverbed of Waiohiwi Stream flanked by ginger and forestry trees in the lowest portion of the reserve.

A more narrow and steeper gulch further up stream, vegetated with mostly non-native plants.

The intact native remnants in this section of gulch have been mostly overgrown by non-native trees.

Lower down the same gulch, remnant patches of native vegetation persist, but are being quickly overgrown.

Dwindling remnants of native mixed mesic forest in a gulch in the middle section of Makawao Forest Reserve.

Remnant gulch section with uluhe (*Dicranopteris*) understory in the mid to lower portion of the reserve. These areas house many of the rare plants found in the reserve, but are quickly being overrun by aggressive non-native species like tropical ash (*Fraxinus*), quinine (*Cinchona*), and kahili ginger (*Hedychium*).

Much of the lower section of reserve is dominated by non-native strawberry guava (*Psidium cattleianum*).

However, large sections of strawberry guava are also showing canopy dieback in the reserve. The same is occurring elsewhere on Maui, and no one knows exactly why.

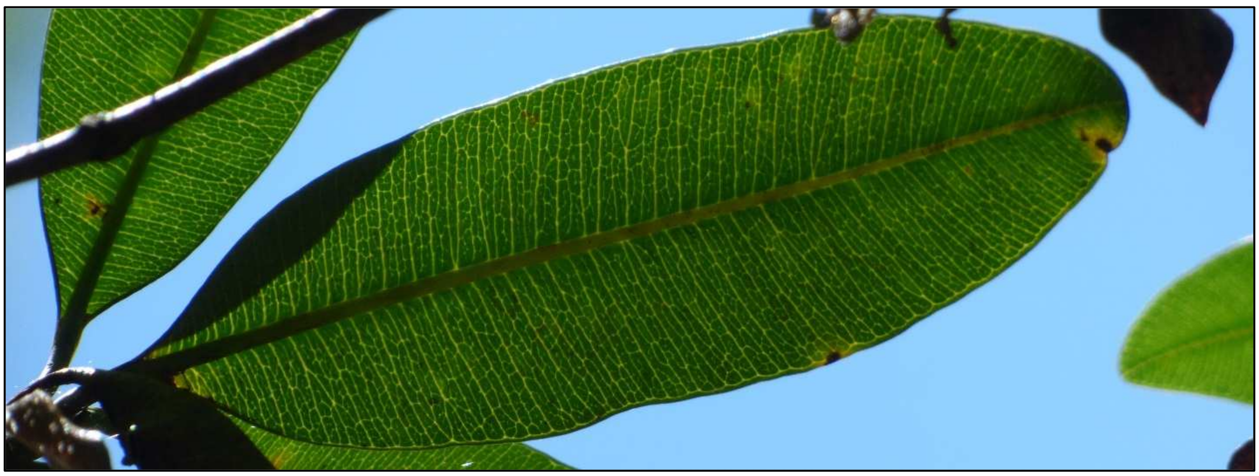
Strawberry guava canopy dieback, Makawao Forest Reserve.

ʻŌhiʻa (*Metrosideros polymorpha*) is the most common native tree in the mesic gulches.

Koaiʻa or dwarf koa (*Acacia koaia*) is present in the gulches in the lower section of reserve.

Kāwaʻu or Hawaiian holly (*Ilex anomala*) is found in the higher sections of the reserve.

Flower of the rare hōlei (*Ochrosia haleakalae*), a Hawaiian Plumeria, at Auwahi, Maui.



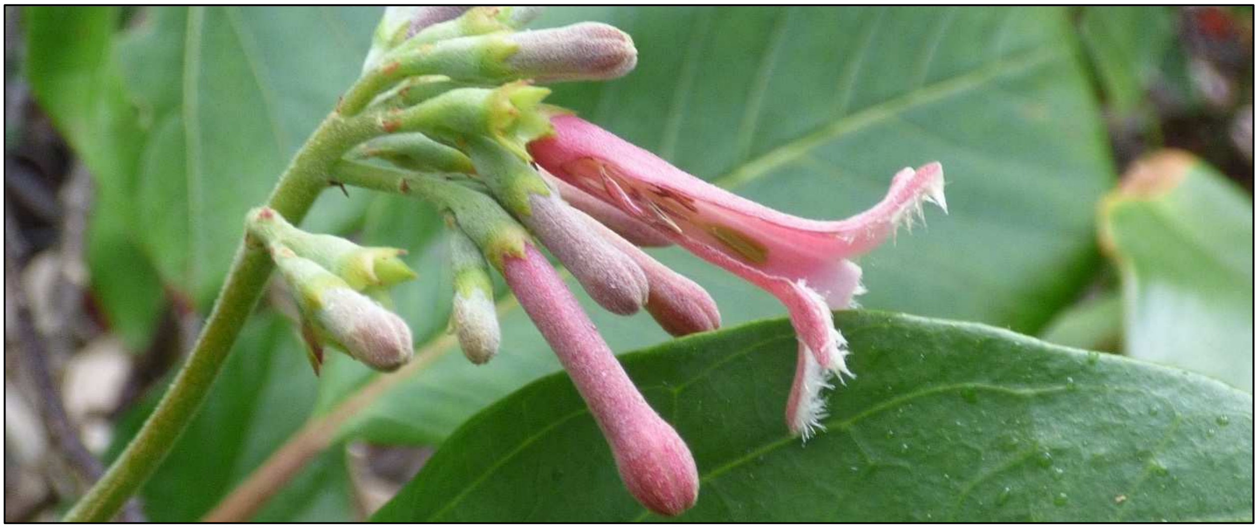
Close up of hōlei leaf, showing the characteristic venation, Makawao Forest Reserve.

Remnant hōlei tree on edge of gulch near the Kahakapao Loop Trail.

Native uluhe fern (*Dicranopteris linearis*) is often the dominant understory in the mesic gulches.

Māku‘e (*Elaphoglossum paleaceum*) is a less common native fern in the Makawao Forest Reserve.

‘Ala‘ala wai nui (*Peperomia cookiana*) on moist rock face, Makawao Forest Reserve.



Quinine (*Cinchona pubescens*) is spreading into many of the mesic gulches in the reserve.

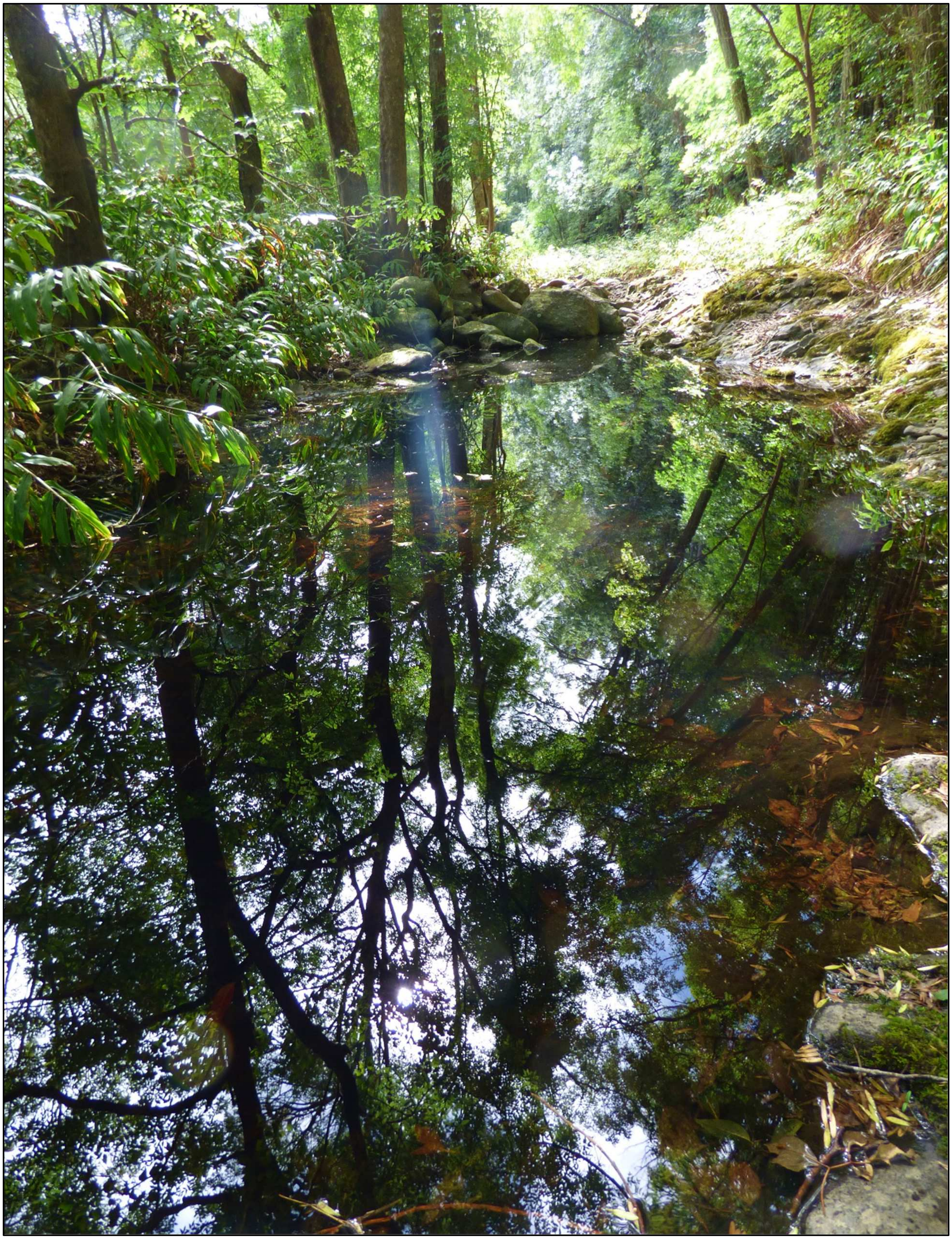
Quinine fruit.

Quinine foliage.

Yellow ginger (*Hedychium flavescens*) and kahili ginger (*H. gardnerianum*) dominate the gulch bottoms.

Non-native smooth senna (*Senna septemtrionalis*) can be found in open areas in the mesic gulches.

Australian tree fern (*Cyathea cooperi*) is becoming increasingly common.



Intermittent stream in the bottom of one of the many mesic gulches of Makawao Forest Reserve.

WET FOREST

Native wet forest beyond plantations in Makawao Forest Reserve.

The highest and wettest portions of the reserve are mostly dominated by native wet forest. ʻŌhiʻa (*Metrosideros polymorpha*) and koa (*Acacia koa*) make up the bulk of the native trees. Ōlapa (*Cheirodendron trigynum*), kōlea (*Myrsine*), alani (*Melicope*), and kāwaʻu (*Ilex anomala*) are also present in lower numbers.

In some sections non-native tropical ash (*Fraxinus uhdei*) and eucalyptus (*Eucalyptus* spp.) trees were planted in large blocks and are also spreading into nearby the native forest.

The native ʻōha wāi (*Clermontia* spp.) shrubs are scattered about the wet forest, as are naupaka kuahiwi (*Scaevola chamissoniana*), tree ʻōhelo (*Vaccinium calycinum*), ʻakala (*Rubus hawaiensis*), and kanawao (*Broussaisia arguta*).

The most dominant understory native is uluhe fern (*Dicranopteris linearis*). Tree ferns are also found in this area, both native (*Cibotium* spp.) and non-native (*Sphaeropteris cooperi*).

Many smaller native ferns are also found on the ground and on trees, such as ʻamaʻu (*Sadleria* spp.), uluhe lau nui (*Diplopterygium*), *Elaphoglossum*, palaʻā (*Odontosoria chinensis*), wahine noho mauna (*Adenophorus tamariscinus*), and ʻakōlea (*Athyrium microphyllum*).

By far the most dominant understory non-native is kahili ginger (*Hedychium gardnerianum*). This plant is beautiful and fragrant, but now covers vast areas of the wet forest portion of the reserve, pushing aside natives and making hiking arduous.

Also present, but in lower numbers, are palmgrass (*Setaria palmifolia*), strawberry guava (*Psidium cattleianum*), Koster's curse (*Clidemia hirta*) and cane tibouchina (*Tibouchina herbacea*). These species will all likely become more common in the future.

Many of the trees are adorned with native ʻieʻie vines (*Freycinetia arborea*), which twine up their trunks. Maile vines (*Alyxia stellata*) also sprawl about the wet forest.

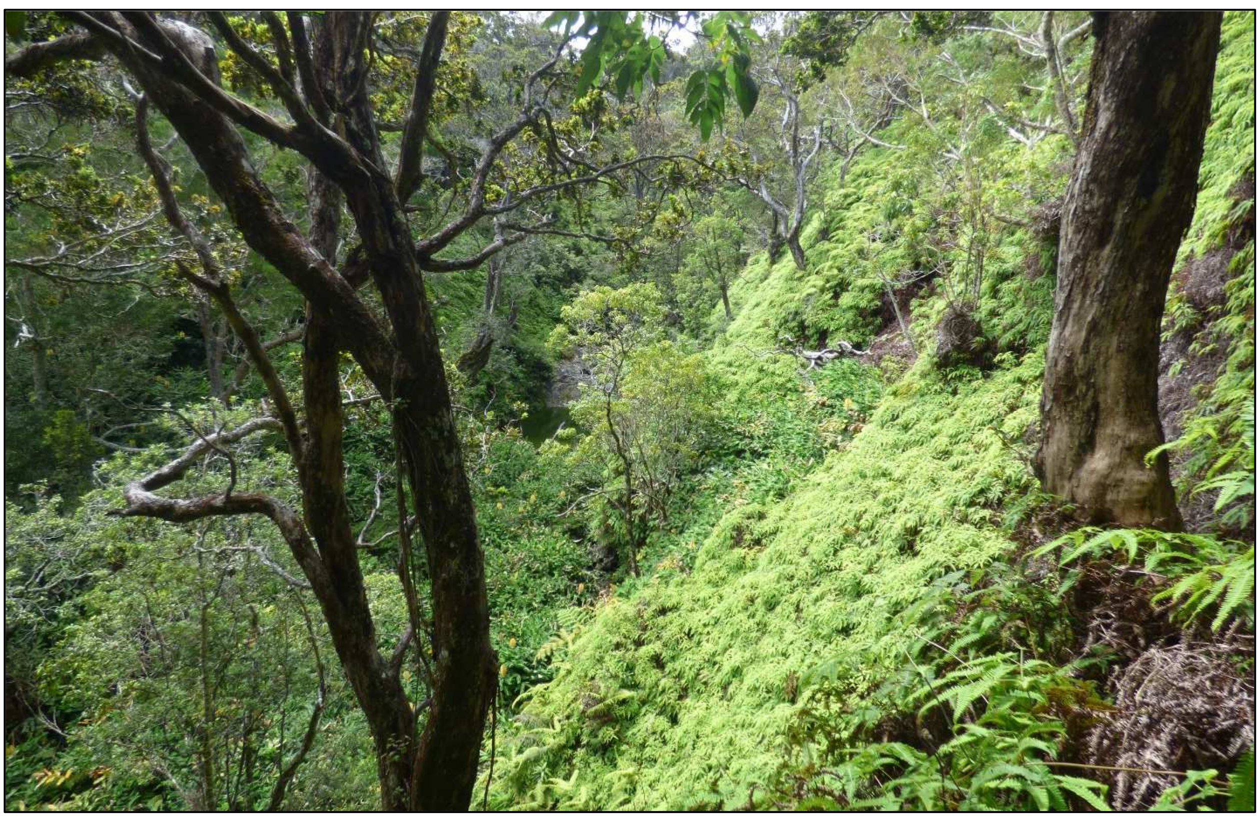
All in all, there is still some nice native wet forest left in the Makawao Forest Reserve, but there are also many aggressive non-native plants encroaching on what remains.

Native wet forest in upper reaches of Makawao Forest Reserve.

Remnant native wet forest near the eastern edge of the middle of the reserve. The canopy is mostly open.

Native wet forest in the highest elevations of the reserve, with a more closed canopy.

Much of the wet forest in the Makawao Forest Reserve occurs on broad ridges.



There are also a few steep gulches that become less deep in the upper elevations of the reserve.

Kahili ginger (*Hedychium gardnerianum*) dominates the understory of much of the wet forest in the reserve.

Kahili ginger understory in native ʻōhiʻa forest (*Metrosideros polymorpha*), Makawao Forest Reserve.

Ginger (*Hedychium*) on left, and dwindling wet forest remnants on right, along Waikamoi Flume Road.

Restoration site in the Makawao Forest Reserve. Ginger has been removed on the left. Into this now open area native plants have been planted including maile and other species that used to call this area home.

Nice section of native wet forest along Waiohiwi Stream, Makawao Forest Reserve.

Native ʻōha wāi nui (*Clermontia arborescens* subsp. *waihiae*) shrubs are scattered about the wet forest.

ʻŌha wāi (*Clermontia*) flowers co-evolved with Hawaiian honeycreepers to create a match for their long bills.

Native ʻākala berry (*Rubus hawaiensis*).

Methley plums (*Prunus cerasifera x salicina*) along the Waikamoi Flume Road.

Kanawao, the native Hydrangea (*Hydrangea arguta*).

Maile (*Alyxia stellata*).

Large patch of uluhe lau nui (*Diplopterygium pinnatum*).

ʻŌhiʻa tree covered in orange blossoms, with an understory of native uluhe and uluhe lau nui ferns.

Native ʻieʻie vine (*Freycinetia arborea*) twining up ʻōhiʻa tree in wet forest of Makawao Forest Reserve.

Tree ‘ōhelo (*Vaccinium calycinum*).

Naupaka kuahiwi (*Scaevola chamissoniana*).

Alani (*Melicope molokaiensis*).

Pakahakaha (*Lepisorus thunbergianus*).

Kīlau (*Dryopteris glabra*).

Wahine noho mauna (*Adenophorus tamariscinus*).

Sori on undersides of Australian tree fern (*Sphaeropteris cooperi*) fronds.

Non-native Australian tree ferns are becoming increasingly common in the reserve.

Australian tree ferns can be distinguished from native hāpuʻu ferns by rough scales at the base of the stipes.

Large koa tree (*Acacia koa*) in the wet forest section of Makawao Forest Reserve.

RARE PLANTS

The bulk of rare plants in the Makawao Forest Reserve occur in the mesic gulches that were not bulldozed in the 1960's. The nearby ridges planted in non-native trees hold the least rare plants. Most of these rare plants are found in highly degraded areas, often surrounded by aggressive non-native species. The list below, compiled by Hank Oppenheimer, includes species found in the reserve in recent decades. There are likely less of these plants in the reserve every year.

Acacia koaia (Koai‘a)
Alectryon macrococcus var. *micrococcus* (Mahoe)
Anoectochilus sandwicensis (Honohono)
Canavalia hawaiiensis (‘Āwikiwiki)
Cyanea asplenifolia (Hāhā)
Cyanea maritae (Hāhā)
Cyanea obtusa (Hāhā)
Dissochondrus biflorus (Hawaiian false bristle grass)
Dryopteris fusco-atra var. *lamoureuxii* (‘I‘i)
Dryopteris tetrapinnata (‘I‘i)
Labordia tinifolia var. *tinifolia* (Labordia)
Liparis hawaiensis (‘Awapuhi a Kanaloa)
Melicope hawaiensis (Mokihana kūkae moa)
Ochrosia haleakalae (Hōlei)
Peperomia subpetiolata (‘Ala‘ala wai nui)
Stenogyne calycosa (Stenogyne)
Zanthoxylum kauaense (A‘e)

Hāhā (*Cyanea asplenifolia*), Makawao Forest Reserve.

INCIPIENT PLANTS

Much of the Makawao Forest Reserve is already a rag-tag assemblage of Pantropical invasive species. However, despite the weedy nature of much of the reserve, there are other invasive species not yet present in the reserve, or only found in the reserve in low numbers. These incipient species would be good to control before they become widespread in the area.

Cortaderia spp. (Pampas grass)
Miconia calvescens (Miconia)
Myrica faya (Firetree)
Passiflora tarminiana (Banana poka)
Rubus glaucus (Andean raspberry)
Rubus niveus (Himalayan raspberry)

Though we did not encounter pampas grass (*Cortaderia*) this survey, we have encountered it in the reserve in the past. Pampas grass is able to invade a wide range of habitats, including remote wet forest.

Himalayan raspberry (*Rubus niveus*) is starting to get a foothold in the reserve. If left unchecked, this species could render areas of the reserve impassable due to the spiny stems that create impenetrable thickets.

PLANT SPECIES LIST

Following is a checklist of vascular plants encountered during the survey. Additional species are included from a list compiled by Hank Oppenheimer and Fern Duvall during a more intensive botanical survey in the mid-2000's. Also included are our previous sightings in the reserve.

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.
- Occasional = Scattered sparsely throughout the area or occurring in a few small patches.
- Rare = Only a few isolated individuals within the project area.
- Previous = Observed in the reserve in recent decades.

Kahili ginger (*Hedychium gardnerianum*), Makawao Forest Reserve.

Family	Scientific Name	Common Name	Nativity	Abundance
Fabaceae	*Acacia koa*	Koa	Endemic	Dominant
Fabaceae	*Acacia koaia*	Koaiʻa	Endemic	Occasional
Fabaceae	*Acacia mearnsii*	Black wattle	Non-native	Occasional
Fabaceae	*Acacia melanoxylon*	Australian blackwood	Non-native	Previous
Polypodiaceae	*Adenophorus hymenophylloides*	Pai, Palai huna	Endemic	Previous
Polypodiaceae	*Adenophorus pinnatifidus var. pinnatifidus*	Wahine noho mauna	Endemic	Previous
Polypodiaceae	*Adenophorus tamariscinus*	Wahine noho mauna	Endemic	Occasional
Polypodiaceae	*Adenophorus tripinnatifidus*	Wahine noho mauna	Endemic	Previous
Pteridaceae	*Adiantum hispidulum*	Rough maiden hair fern	Non-native	Occasional
Pteridaceae	*Adiantum raddianum*	Maiden hair fern	Non-native	Previous
Liliaceae	*Agapanthus praecox subsp. orientalis*	Lily of the Nile	Non-native	Rare

Family	Scientific Name	Common Name	Nativity	Abundance
Araucariaceae	*Agathis sp.*	Kauri	Non-native	Previous
Asteraceae	*Ageratina adenophora*	Maui pamakani	Non-native	Occasional
Asteraceae	*Ageratina riparia*	Hamakua pamakani	Non-native	Previous
Asteraceae	*Ageratum conyzoides*	Maile honohono	Non-native	Occasional
Sapindaceae	*Alectryon macrococcus var. macrococcus*	Mahoe	Endemic	Previous
Euphorbiaceae	*Aleurites moluccana*	Kukui	Non-native	Occasional
Betulaceae	*Alnus nepalensis*	Nepalese alder	Non-native	Previous
Apocynaceae	*Alyxia stellata*	Maile	Indigenous	Common
Thelypteridaceae	*Amauropelta globulifera*	Palapalai a Kamapuaʻa	Endemic	Previous
Poaceae	*Andropogon virginicus*	Broomsedge	Non-native	Occasional
Myrtaceae	*Angophora costata*	Gum myrtle	Non-native	Common
Poaceae	*Anthoxanthum odoratum*	Sweet vernalgrass	Non-native	Previous
Euphorbiaceae	*Antidesma platyphyllum var. platyphyllum*	Hame	Endemic	Previous
Araucariaceae	*Araucaria bidwillii*	Bunya pine	Non-native	Rare
Araucariaceae	*Araucaria columnaris*	Cook pine	Non-native	Common
Aspleniaceae	*Asplenium acuminatum*	Lola	Endemic	Occasional
Aspleniaceae	*Asplenium continguum*	Asplenium	Endemic	Occasional
Aspleniaceae	*Asplenium excisum*	Pāmoho	Indigenous	Previous
Aspleniaceae	*Asplenium horridum*	ʻIwa, ʻalae	Indigenous	Previous
Aspleniaceae	*Asplenium insiticium*	Piʻipiʻi lau manamana	Indigenous	Previous
Aspleniaceae	*Asplenium lobulatum*	Piʻipiʻi lau manamana	Indigenous	Previous
Aspleniaceae	*Asplenium macraei*	ʻIwaʻiwa lau liʻi	Endemic	Occasional
Aspleniaceae	*Asplenium normale*	Asplenium	Indigenous	Previous
Aspleniaceae	*Asplenium sphenotonum*	Asplenium	Endemic	Previous
Aspleniaceae	*Asplenium x waikamoi*	Asplenium	Endemic	Previous
Asteliaceae	*Astelia menziesiana*	Paʻiniu	Endemic	Occasional
Woodsiaceae	*Athyrium microphyllum*	ʻAkōlea	Endemic	Occasional
Poaceae	*Axonopus compressus*	Wide-leaved carpetgrass	Non-native	Occasional
Poaceae	*Axonopus fissifolius*	Narrow-leaved carpetgrass	Non-native	Occasional
Asteraceae	*Bidens pilosa*	Spanish needle	Non-native	Occasional
Blechnaceae	*Blechnum appendiculatum*	Blechnum	Non-native	Common
Urticaceae	*Boehmeria grandis*	ʻAkōlea	Endemic	Previous
Poaceae	*Briza maxima*	Big quaking grass	Non-native	Previous
Poaceae	*Briza minor*	Little quaking grass	Non-native	Previous
Hydrangeaceae	*Broussaisia arguta*	Kanawao	Endemic	Occasional
Hymenophyllaceae	*Callistopteris baldwinii*	Callistopteris	Endemic	Previous
Cupressaceae	*Callitris glauca*	White cypress	Non-native	Previous

Family	Scientific Name	Common Name	Nativity	Abundance
Fabaceae	*Canavalia hawaiiensis*	ʻĀwikiwiki	Endemic	Previous
Cannaceae	*Canna indica*	Canna, Indian shot	Non-native	Occasional
Cyperaceae	*Carex alligata*	Carex	Endemic	Occasional
Cyperaceae	*Carex meyenii*	Carex	Indigenous	Previous
Cyperaceae	*Carex wahuensis subsp. wahuensis*	Carex	Endemic	Occasional
Fabaceae	*Castanospermum australe*	Moreton Bay chestnut	Non-native	Occasional
Casuarinaceae	*Casuarina equisetifolia*	Ironwood	Non-native	Occasional
Poaceae	*Cenchrus clandestinus*	Kikuyu grass	Non-native	Occasional
Poaceae	*Cenchrus purpureus*	Cane grass	Non-native	Occasional
Apiaceae	*Centella asiatica*	Pennywort	Non-native	Occasional
Solanaceae	*Cestrum nocturnum*	Night blooming jasmine	Non-native	Occasional
Fabaceae	*Chamaecrista nictitans*	Partridge pea	Non-native	Previous
Cupressaceae	*Chamaecyparis lawsoniana*	Port Orford cedar	Non-native	Previous
Amaranthaceae	*Charpentiera obovata*	Pāpala	Endemic	Previous
Araliaceae	*Cheirodendron trigynum subsp. trigynum*	ʻŌlapa	Endemic	Common
Thelypteridaceae	*Christella cyatheoides*	Kikawaiō	Endemic	Previous
Poaceae	*Chrysopogon aciculatus*	Mānienie ʻula, golden beardgrass	Non-native	Occasional
Cibotiaceae	*Cibotium glaucum*	Hāpuʻu pulu	Endemic	Common
Cibotiaceae	*Cibotium menziesii*	Hāpuʻu iʻi	Endemic	Common
Rubiaceae	*Cinchona calisaya*	Ledger quinine	Non-native	Previous
Rubiaceae	*Cinchona pubescens*	Quinine	Non-native	Common
Lauraceae	*Cinnamomum camphora*	Camphor tree	Non-native	Occasional
Campanulaceae	*Clermontia arborescens subsp. waihiae*	ʻŌhā wai nui	Endemic	Occasional
Campanulaceae	*Clermontia kakeana*	ʻŌhā wai, hāhā	Endemic	Occasional
Melastomataceae	*Clidemia hirta*	Koster's curse	Non-native	Occasional
Menispermaceae	*Cocculus orbiculatus*	Huehue	Indigenous	Occasional
Pteridaceae	*Coniogramme pilosa*	Loʻulu	Endemic	Occasional
Asteraceae	*Conyza bonariensis*	Hairy horseweed	Non-native	Occasional
Asteraceae	*Conyza canadensis*	Horseweed	Non-native	Previous
Rubiaceae	*Coprosma foliosa*	Pilo	Endemic	Common
Rubiaceae	*Coprosma granadensis*	Mākole, pilo	Indigenous	Previous
Rubiaceae	*Coprosma pubens*	Pilo	Endemic	Previous
Asparagaceae	*Cordyline fruticosa*	Ti leaf	Non-native	Occasional
Poaceae	*Cortaderia jubata*	Pampas grass	Non-native	Previous
Asteraceae	*Crassocephalum crepidioides*	Crassocephalum	Non-native	Previous
Cupressaceae	*Cryptomeria japonica*	Sugi pine	Non-native	Occasional
Lythraceae	*Cuphea carthagenensis*	Tarweed	Non-native	Occasional

Family	Scientific Name	Common Name	Nativity	Abundance
Cupressaceae	*Cupressus macrocarpa*	Monterey cypress	Non-native	Occasional
Campanulaceae	*Cyanea asplenifolia*	Hāhā	Endemic	Previous
Campanulaceae	*Cyanea elliptica*	Hāhā	Endemic	Previous
Campanulaceae	*Cyanea maritae*	Hāhā	Endemic	Previous
Campanulaceae	*Cyanea mceldowneyi*	Hāhā	Endemic	Previous
Campanulaceae	*Cyanea obtusa*	Hāhā	Endemic	Previous
Thelypteridaceae	*Cyclosorus dentatus*	Downy wood fern	Non-native	Previous
Thelypteridaceae	*Cyclosorus parasiticus*	Downy wood fern	Non-native	Common
Cyperaceae	*Cyperus gracilis*	McCoy grass	Non-native	Occasional
Cyperaceae	*Cyperus hypochlorus var. hypochlorus*	Ahuʻawa	Endemic	Previous
Cyperaceae	*Cyperus polystachyos*	Pycreus	Indigenous	Occasional
Gesneriaceae	*Cyrtandra grayi*	Cyrtandra	Endemic	Previous
Gesneriaceae	*Cyrtandra hashimotoi*	Cyrtandra	Endemic	Previous
Gesneriaceae	*Cyrtandra hawaiensis*	Cyrtandra	Endemic	Previous
Gesneriaceae	*Cyrtandra platyphylla*	ʻIliahi	Endemic	Rare
Dryopteridaceae	*Cyrtomium caryotideum*	Kaʻapeʻape	Indigenous	Common
Dryopteridaceae	*Cyrtomium falcatum*	Holly fern	Non-native	Previous
Poaceae	*Dactylis glomerata*	Cocksfoot	Non-native	Previous
Woodsiaceae	*Deparia petersenii*	Deparia	Non-native	Previous
Woodsiaceae	*Deparia prolifera*	Deparia	Endemic	Previous
Poaceae	*Deschampsia nubigena*	Hairgrass	Endemic	Previous
Fabaceae	*Desmodium incanum*	Spanish clover	Non-native	Previous
Fabaceae	*Desmodium tortuosum*	Florida beggarweed	Non-native	Previous
Liliaceae	*Dianella sandwicensis*	ʻUkiʻuki	Endemic	Previous
Gleicheniaceae	*Dicranopteris linearis f. emarginata*	Uluhe	Endemic	Previous
Gleicheniaceae	*Dicranopteris linearis f. linearis*	Uluhe	Indigenous	Dominant
Poaceae	*Digitaria ciliaris*	Henry's crab grass	Non-native	Previous
Woodsiaceae	*Diplazium arnottii*	Hōʻiʻo, pohole	Endemic	Previous
Athyriaceae	*Diplazium sandwichianum*	Hōʻiʻo, pohole	Endemic	Occasional
Gleicheniaceae	*Diplopterygium pinnatum*	Uluhe lau nui	Endemic	Occasional
Poaceae	*Dissochondrus biflorus*	Hawaiʻi false bristle grass	Endemic	Previous
Sapindaceae	*Dodonaea viscosa*	ʻAʻaliʻi	Indigenous	Rare
Blechnaceae	*Doodia kunthiana*	ʻŌkupukupu	Endemic	Occasional
Blechnaceae	*Doodia lyonii*	ʻŌkupukupu	Endemic	Previous
Caryophyllaceae	*Drymaria cordata var. pacifica*	Pilipili	Non-native	Occasional
Dryopteridaceae	*Dryopteris fusco-atra var. fusco*	ʻIʻi	Endemic	Occasional
Dryopteridaceae	*Dryopteris fusco-atra var. lamoureuxii*	ʻIʻi	Endemic	Previous

Family	Scientific Name	Common Name	Nativity	Abundance
Dryopteridaceae	*Dryopteris glabra var. glabra*	Kīlau	Endemic	Occasional
Dryopteridaceae	*Dryopteris hawaiiensis*	‘I‘i	Endemic	Previous
Dryopteridaceae	*Dryopteris mauiensis*	‘I‘i	Endemic	Previous
Dryopteridaceae	*Dryopteris rubiginosa*	Nothoperanema	Endemic	Previous
Dryopteridaceae	*Dryopteris tetrapinnata*	‘I‘i	Endemic	Previous
Dryopteridaceae	*Dryopteris unidentata var. paleacea*	‘I‘i	Endemic	Previous
Dryopteridaceae	*Dryopteris wallichiana*	‘I‘o nui, laukahi	Indigenous	Occasional
Asteraceae	*Dubautia plantaginea subsp. plantaginea*	Kupaoa	Endemic	Previous
Poaceae	*Ehrharta erecta*	Panic veldt grass	Non-native	Occasional
Poaceae	*Ehrharta stipoides*	Meadow rice grass	Non-native	Previous
Dryopteridaceae	*Elaphoglossum crassifolium*	Hoe a Māui	Endemic	Occasional
Dryopteridaceae	*Elaphoglossum paleaceum*	Māku‘e	Indigenous	Occasional
Dryopteridaceae	*Elaphoglossum parvisquaminium*	Hoe a Māui	Endemic	Previous
Dryopteridaceae	*Elaphoglossum wawrae*	Laukahi	Endemic	Previous
Asteraceae	*Elephantopus mollis*	Soft elephants foot	Non-native	Rare
Myrsinaceae	*Embelia pacifica*	Kilioe	Endemic	Previous
Asteraceae	*Erechtites valerianifolia*	Fireweed	Non-native	Occasional
Rosaceae	*Eriobotrya japonica*	Loquat	Non-native	Occasional
Myrtaceae	*Eucalyptus botryoides*	Bangalay	Non-native	Previous
Myrtaceae	*Eucalyptus globulus*	Blue gum eucalyptus	Non-native	Dominant
Myrtaceae	*Eucalyptus microcarpa*	Grey box	Non-native	Previous
Myrtaceae	*Eucalyptus paniculata*	Gray ironbark	Non-native	Previous
Myrtaceae	*Eucalyptus pilularis*	Blackbutt	Non-native	Previous
Myrtaceae	*Eucalyptus punctata*	Grey gum	Non-native	Previous
Myrtaceae	*Eucalyptus robusta*	Swamp mahogany	Non-native	Common
Myrtaceae	*Eucalyptus saligna*	Sydney blue gum	Non-native	Previous
Myrtaceae	*Eucalyptus* spp.	Eucalyptus	Non-native	Dominant
Myrtaceae	*Eucalyptus tereticornis*	Forest red gum	Non-native	Previous
Myrtaceae	*Eugenia uniflora*	Surinam cherry	Non-native	Rare
Euphorbiaceae	*Euphorbia hirta*	Hairy spurge	Non-native	Occasional
Oleaceae	*Fraxinus americana*	American ash	Non-native	Previous
Oleaceae	*Fraxinus griffithii*	Himalayan ash	Non-native	Occasional
Oleaceae	*Fraxinus uhdei*	Tropical ash	Non-native	Dominant
Pandanaceae	*Freycinetia arborea*	‘Ie‘ie	Indigenous	Occasional
Grammitidaceae	*Grammitis hookeri*	Māku‘e lau li‘i	Indigenous	Previous
Grammitidaceae	*Grammitis tenella*	Kolokolo	Endemic	Previous
Proteaceae	*Grevillea robusta*	Silky oak	Non-native	Occasional

Family	Scientific Name	Common Name	Nativity	Abundance
Zingiberaceae	*Hedychium coronarium*	White ginger	Non-native	Common
Zingiberaceae	*Hedychium flavescens*	Yellow ginger	Non-native	Common
Zingiberaceae	*Hedychium gardnerianum*	Kahili ginger	Non-native	Dominant
Poaceae	*Holcus lanatus*	Yorkshire fog	Non-native	Occasional
Lycopodiaceae	*Huperzia erosa*	Huperzia	Endemic	Previous
Hypericaceae	*Hypericum mutilum*	St. John's wort	Non-native	Occasional
Asteraceae	*Hypochoeris radicata*	Hairy cat's ear	Non-native	Occasional
Dennstaedtiaceae	*Hypolepis hawaiiensis var. hawaiiensis*	Olua	Endemic	Previous
Aquifoliaceae	*Ilex anomala*	Kāwaʻu	Indigenous	Occasional
Balsaminaceae	*Impatiens walleriana*	Impatiens	Non-native	Previous
Convolvulaceae	*Ipomoea indica*	Koaliʻawa	Indigenous	Occasional
Bignoniaceae	*Jacaranda mimosifolia*	Jacaranda	Non-native	Previous
Juncaceae	*Juncus acuminatus*	Tapertip rush	Non-native	Occasional
Juncaceae	*Juncus polyanthemos*	Mayflower rush	Non-native	Occasional
Rubiaceae	*Kadua acuminata*	Au, pilo	Endemic	Previous
Rubiaceae	*Kadua affinis*	Manono	Endemic	Common
Rubiaceae	*Kadua centranthoides*	Manono	Endemic	Previous
Rubiaceae	*Kadua hillebrandii*	Manono	Endemic	Previous
Rubiaceae	*Kadua schlechtendahliana* var. *schlechtendahliana*	Kopa	Endemic	Previous
Rubiaceae	*Kadua terminalis*	Manono	Endemic	Previous
Santalaceae	*Korthalsella complanata*	Hulumoa	Indigenous	Previous
Santalaceae	*Korthalsella platycaula*	Hulumoa	Indigenous	Rare
Loganiaceae	*Labordia tinifolia* var. *tinifolia*	Labordia	Endemic	Previous
Verbenaceae	*Lantana camara*	Lantana	Non-native	Occasional
Asteraceae	*Lapsana communis*	Nipplewort	Non-native	Previous
Polypodiaceae	*Lepisorus thunbergianus*	Pākahakaha	Indigenous	Occasional
Ericaceae	*Leptecophylla tameiameiae*	Pūkiawe	Indigenous	Occasional
Fabaceae	*Leucaena leucocephala*	Haole koa	Non-native	Occasional
Orchidaceae	*Liparis hawaiiensis*	ʻAwapuhi a Kanaloa	Endemic	Previous
Myrtaceae	*Lophostemon confertus*	Brush box	Non-native	Common
Fabaceae	*Lotus subbiflorus*	Hairy bird's foot trefoil	Non-native	Occasional
Fabaceae	*Lotus uliginosus*	Greater bird's foot trefoil	Non-native	Occasional
Lycopodiaceae	*Lycopodium venustulum* var. *venustulum*	Lycopodium	Indigenous	Previous
Lythraceae	*Lythrum maritimum*	Lythrum	Non-native	Occasional
Cyperaceae	*Machaerina mariscoides* subsp. *meyenii*	ʻAhaniu, ʻuki	Indigenous	Previous
Thelypteridaceae	*Macrothelypteris toressiana*	Sword fern	Non-native	Previous
Marattiaceae	*Marattia douglasii*	Pala, kapuaʻilio	Endemic	Previous

Family	Scientific Name	Common Name	Nativity	Abundance
Hymenophyllaceae	*Mecodium recurvum*	ʻŌhiʻa kū	Endemic	Previous
Poaceae	*Megathyrsus maximus*	Guinea grass	Non-native	Occasional
Myrtaceae	*Melaleuca quinquenervia*	Paper bark	Non-native	Occasional
Rutaceae	*Melicope clusiifolia*	Kūkaemoa	Endemic	Occasional
Rutaceae	*Melicope hawaiensis*	Mokihana kūkae moa	Endemic	Previous
Rutaceae	*Melicope molokaiensis*	Alani	Endemic	Occasional
Rutaceae	*Melicope peduncularis*	Alani	Endemic	Previous
Poaceae	*Melinis minutiflora*	Molasses grass	Non-native	Occasional
Myrtaceae	*Metrosideros polymorpha*	ʻŌhiʻa	Endemic	Dominant
Dennstaedtiaceae	*Microlepia strigosa*	Palapalai	Indigenous	Occasional
Myrsinaceae	*Myrsine lanaiensis*	Kōlea	Endemic	Previous
Primulaceae	*Myrsine lessertiana*	Kōlea lau nui	Endemic	Common
Myrsinaceae	*Myrsine sandwicensis*	Kōlea lau liʻi	Endemic	Previous
Nephrolepidaceae	*Nephrolepis brownii*	Asian sword fern	Non-native	Occasional
Nephrolepidaceae	*Nephrolepis cordifolia*	Kupukupu	Indigenous	Dominant
Dryopteridaceae	*Nephrolepis exaltata* subsp. *hawaiiensis*	Niʻaniʻau, ōkupukupu	Endemic	Previous
Oleaceae	*Nestegis sandwicensis*	Olopua	Endemic	Occasional
Solanaceae	*Nothocestrum longifolium*	ʻAiea	Endemic	Previous
Apocynaceae	*Ochrosia haleakalae*	Hōlei	Endemic	Occasional
Lindsaeaceae	*Odontosoria chinensis*	Palaʻā	Indigenous	Occasional
Oleaceae	*Olea europaea subsp. cuspidata*	African olive	Non-native	Occasional
Ophioglossaceae	*Ophioderma pendula* f. *falcata*	Puapua moa	Indigenous	Previous
Poaceae	*Oplismenus hirtellus*	Bamboo grass	Non-native	Occasional
Oxalidaceae	*Oxalis corniculata*	Yellow wood sorrel	Non-native	Occasional
Oxalidaceae	*Oxalis debilis* var. *corymbosa*	Pink wood sorrel	Non-native	Occasional
Lycopodiaceae	*Palhinhaea cernua*	Wāwaeʻiole	Indigenous	Occasional
Poaceae	*Panicum nephelophilum*	Konakona	Endemic	Previous
Poaceae	*Paspalum conjugatum*	Hilo grass	Non-native	Occasional
Poaceae	*Paspalum urvillei*	Vasey grass	Non-native	Occasional
Passifloraceae	*Passiflora edulis*	Passion vine	Non-native	Occasional
Passifloraceae	*Passiflora subpeltata*	White passion flower	Non-native	Occasional
Piperaceae	*Peperomia cookiana*	ʻAlaʻala wai nui	Endemic	Occasional
Piperaceae	*Peperomia hirtipetiola*	ʻAlaʻala wai nui	Endemic	Previous
Piperaceae	*Peperomia latifolia*	ʻAlaʻala wai nui	Endemic	Previous
Piperaceae	*Peperomia obovatilimba*	ʻAlaʻala wai nui	Endemic	Previous
Piperaceae	*Peperomia subpetiolata*	ʻAlaʻala wai nui	Endemic	Previous
Piperaceae	*Peperomia tetraphylla*	ʻAlaʻala wai nui	Indigenous	Previous
Dipentodontaceae	*Perrottetia sandwicensis*	Olomea	Endemic	Occasional

Family	Scientific Name	Common Name	Nativity	Abundance
Lauraceae	*Persea americana*	Avocado	Non-native	Occasional
Polygonaceae	*Persicaria capitata*	Pink-head knotweed	Non-native	Occasional
Polygonaceae	*Persicaria glabra*	Denseflower Knotweed	Non-native	Previous
Orchidaceae	*Phaius tankervilleae*	Chinese ground orchid	Non-native	Previous
Polypodiaceae	*Phlebodium aureum*	Lauae haole	Non-native	Occasional
Lycopodiaceae	*Phlegmariurus phyllanthus*	Wāwaeʻiole	Indigenous	Previous
Lamiaceae	*Phyllostegia ambigua*	Phyllostegia	Endemic	Previous
Lamiaceae	*Phyllostegia bracteata*	Phyllostegia	Endemic	Previous
Solanaceae	*Physalis peruviana*	Poha	Non-native	Occasional
Phytolaccaceae	*Phytolacca octandra*	Pokeweed	Non-native	Previous
Phytolaccaceae	*Phytolacca sandwicensis*	Pōpolo kū mai	Endemic	Previous
Pinaceae	*Pinus caribaea* var. *hondurensis*	Caribbean pine	Non-native	Previous
Pinaceae	*Pinus* sp.	Pines	Non-native	Common
Urticaceae	*Pipturus albidus*	Mamaki	Endemic	Occasional
Nyctaginaceae	*Pisonia brunoniana*	Papala kepau	Indigenous	Occasional
Pittosporaceae	*Pittosporum glabrum*	Hoawa	Endemic	Previous
Plantaginaceae	*Plantago lanceolata*	Narrow-leaved plantain	Non-native	Occasional
Plantaginaceae	*Plantago major*	Broad-leaved plantain	Non-native	Occasional
Asparagaceae	*Pleomele auwahiensis*	Halapepe	Endemic	Occasional
Polygalaceae	*Polygala paniculata*	Milkwort, root beer plant	Non-native	Occasional
Polypodiaceae	*Polypodium pellucidum* var. *pellucidum*	ʻAe	Endemic	Previous
Sapotaceae	*Pouteria sandwicensis*	ʻĀlaʻa	Endemic	Occasional
Lamiaceae	*Prunella vulgaris*	Selfheal	Non-native	Occasional
Rosaceae	*Prunus cerasifera x salicina*	Methley plum	Non-native	Occasional
Rosaceae	*Prunus persica*	Peach	Non-native	Previous
Thelypteridaceae	*Pseudophegopteris keraudreniana*	Waimakanui	Endemic	Previous
Myrtaceae	*Psidium cattleianum*	Strawberry guava	Non-native	Dominant
Myrtaceae	*Psidium guajava*	Guava	Non-native	Occasional
Psilotaceae	*Psilotum complanatum*	Moa nahele	Indigenous	Occasional
Psilotaceae	*Psilotum nudum*	Moa	Indigenous	Occasional
Rubiaceae	*Psychotria kaduana*	Kōpiko kea	Endemic	Previous
Rubiaceae	*Psychotria mariniana*	Kōpiko	Endemic	Occasional
Rubiaceae	*Psydrax odorata*	Alaheʻe	Indigenous	Previous
Hypolepidaceae	*Pteridium aquilinum* subsp. *decompositum*	Kīlau, bracken fern	Indigenous	Rare
Pteridaceae	*Pteris cretica*	ʻŌali, cretan brake	Indigenous	Occasional
Pteridaceae	*Pteris excelsa*	Waimakanui	Indigenous	Previous
Pteridaceae	*Pteris hillebrandii*	Pteris	Endemic	Previous

Family	Scientific Name	Common Name	Nativity	Abundance
Euphorbiaceae	*Ricinus communis*	Castor bean	Non-native	Occasional
Rosaceae	*Rubus argutus*	Blackberry	Non-native	Occasional
Rosaceae	*Rubus hawaiensis*	ʻĀkala	Endemic	Occasional
Rosaceae	*Rubus niveus* f. *a*	Mysore raspberry	Non-native	Rare
Rosaceae	*Rubus rosifolius*	Thimbleberry	Non-native	Occasional
Poaceae	*Sacciolepis indica*	Glenwood grass	Non-native	Occasional
Blechnaceae	*Sadleria cyatheoides*	ʻAmaʻu	Endemic	Occasional
Blechnaceae	*Sadleria pallida*	ʻAmaʻu	Endemic	Occasional
Blechnaceae	*Sadleria souleyetiana*	ʻAmaʻu	Endemic	Occasional
Blechnaceae	*Sadleria squarrosa*	ʻAmaʻu	Endemic	Previous
Goodeniaceae	*Scaevola chamissoniana*	Naupaka kuahiwi	Endemic	Occasional
Araliaceae	*Schefflera arboricola*	Dwarf umbrella plant	Non-native	Occasional
Anacardiaceae	*Schinus terebinthifolius*	Christmasberry	Non-native	Previous
Selaginellaceae	*Selaginella arbuscula*	Lepelepe a moa	Endemic	Occasional
Selaginellaceae	*Selaginella kraussiana*	Spreading selaginella	Non-native	Previous
Asteraceae	*Senecio madagascariensis*	Fireweed	Non-native	Occasional
Fabaceae	*Senna semptemtrionalis*	Senna	Non-native	Occasional
Poaceae	*Setaria palmifolia*	Palmgrass	Non-native	Common
Poaceae	*Setaria parviflora*	Yellow foxtail	Non-native	Occasional
Smilacaceae	*Smilax melastomifolia*	Hoi kuahiwi	Endemic	Occasional
Solanaceae	*Solanum americanum*	Glossy nightshade	Indigenous	Occasional
Solanaceae	*Solanum pseudocapsicum*	Jerusalem cherry	Non-native	Previous
Asteraceae	*Sonchus oleraceus*	Sow thistle	Non-native	Occasional
Fabaceae	*Sophora chrysophylla*	Māmane	Endemic	Rare
Orchidaceae	*Spathoglottis plicata*	Philippine ground orchid	Non-native	Previous
Hymenophyllaceae	*Sphaerocionium lanceolatum*	Palai hinahina	Endemic	Previous
Cyatheaceae	*Sphaeropteris cooperi*	Australian tree fern	Non-native	Common
Lindsaeaceae	*Sphenomeris chinensis*	Palaʻā	Indigenous	Previous
Poaceae	*Sporobolus indicus*	Smutgrass	Non-native	Occasional
Verbenaceae	*Stachytarpheta jamaicensis*	Jamaica vervain	Non-native	Previous
Lamiaceae	*Stenogyne calycosa*	Stenogyne	Endemic	Previous
Lamiaceae	*Stenogyne kamehamehae*	Stenogyne	Endemic	Previous
Gleicheniaceae	*Sticherus owhyhensis*	Uluhe	Endemic	Previous
Moraceae	*Streblus pendulinus*	Aʻiaʻi	Indigenous	Occasional
Myrtaceae	*Syncarpia glomulifera*	Turpentine tree	Non-native	Common
Myrtaceae	*Syzygium sandwicensis*	ʻŌhiʻa ʻai	Endemic	Previous
Dryopteridaceae	*Tectaria gaudichaudii*	ʻIwaʻiwa lau nui	Endemic	Occasional
Acanthaceae	*Thunbergia alata*	Black-eyed susan vine	Non-native	Previous

Family	Scientific Name	Common Name	Nativity	Abundance
Melastomataceae	*Tibouchina herbacea*	Cane tibouchina	Non-native	Occasional
Meliaceae	*Toona ciliata*	Australian red cedar	Non-native	Dominant
Urticaceae	*Touchardia latifolia*	Olonā	Endemic	Previous
Urticaceae	*Touchardia oahuensis*	Ōpuhe	Endemic	Previous
Fabaceae	*Trifolium repens*	White clover	Non-native	Occasional
Fabaceae	*Ulex europaeus*	Gorse	Non-native	Occasional
Arecaceae	Unknown	Palm	Non-native	Rare
Ericaceae	*Vaccinium calycinum*	Tree ʻōhelo	Endemic	Occasional
Ericaceae	*Vaccinium dentatum*	ʻŌhelo	Endemic	Previous
Hymenophyllaceae	*Vandenboschia cyrtotheca*	Vandenboschia	Endemic	Previous
Hymenophyllaceae	*Vandenboschia davallioides*	Palai hihi	Endemic	Occasional
Verbenaceae	*Verbena litoralis*	Vervain	Non-native	Occasional
Scrophulariaceae	*Veronica serpyllifolia*	Thyme-leaved speedwell	Non-native	Previous
Thymelaeaceae	*Wikstroemia oahuensis var. oahuensis*	ʻĀkia	Endemic	Previous
Flacourtiaceae	*Xylosma hawaiiense*	Maua	Endemic	Previous
Asteraceae	*Youngia japonica*	Oriental hawksbeard	Non-native	Occasional
Rutaceae	*Zanthoxylum kauaense*	Aʻe	Endemic	Previous

ʻIeʻie (*Freycinetia arborea*), Makawao Forest Reserve.

BATS

We did not specifically survey for Hawaiian Hoary Bats or ʻŌpeʻapeʻa (*Aeorestes semotus*). But bats are present over all of East Maui, and some of their highest numbers occur in forested sections of the mid-elevations.

Bats often forage in and near gulches. Groves of trees are also utilized for foraging, even non-native, especially the leeward sides out of the weather where insects would seek refuge. Hawaiian Hoary Bats generally roost and raise their young in large trees in sheltered locations.

Surprisingly little is known about this nocturnal native, but many Hawaiian Hoary Bats likely call Makawao Forest Reserve home.

Hawaiian Hoary Bat or ʻŌpeʻapeʻa (*Aeorestes semotus*), Olinda.

NON-NATIVE MAMMALS

One of the many uses of the Makawao Forest Reserve is as a game hunting area. The main ungulates hunted in the reserve are Wild Pigs (*Sus scrofa*). Though we did not directly observe pigs, we did see signs (scat, wallows, rubbings, tracks) over much of the reserve, especially in areas farthest from human activity. We also saw signs (scat, rubbings) that appeared to be from Axis Deer (*Axis axis*), but we did not see actual deer.

Another use of the reserve is for equestrians. No horses (*Equus ferus caballus*) were observed during the survey. Also not observed, but potentially entering the reserve are cows (*Bos taurus*) that could wander in from nearby ranches.

Dogs (*Canis lupus familiaris*) were regularly observed with people on the main trails. Other mammals likely to utilize the reserve, but which were not encountered include rats (*Rattus* spp.), mice (*Mus domesticus*), cats (*Felis domesticus*), and mongooses (*Herpestes javanicus*).

Pig wallow, Makawao Forest Reserve.


Likely Axis Deer (*Axis axis*) rubbings on tree, Makawao Forest Reserve.


Likely Axis Deer scat, Makawao Forest Reserve.

REPTILES

Though we didn't do targeted surveys for reptiles, we did come across a Jackson's Chameleon (*Trioceros jacksonii*) in the upper wet forest section of the reserve. It was crawling through a thicket of uluhe ferns (*Dicranopteris linearis*).

Jackson's Chameleons were introduced to Hawai‘i from Africa in 1972, escaped from the pet trade into the wild, and are now found in remote locations over much of the state.

Prey items include anything they can fit in their mouths, such as native insects, spiders, and snails, many of which are becoming increasingly rare.

On O'ahu, where predator-free snail enclosures have been constructed in the wild, Jackson's Chameleons must be removed from the enclosures before the native snails can flourish.

Jackson's Chameleon (*Trioceros jacksonii*) in the upper reaches of Makawao Forest Reserve.

BIRDS

46 travelling counts of variable time and length were done across a range of habitat types and elevations. The average distance travelled for each count was 500 meters, and the average duration was 26 minutes. All birds observed or heard for an unlimited distance were recorded.

Looking and listening for birds, Makawao Forest Reserve.

Red-billed Leiothrix (*Leiothrix lutea*) is the most common bird in the Makawao Forest Reserve.

Maui ʻAmakihi (*Chlorodrepanis virens* var. *wilsoni*) foraging in Kahakapao Loop Trail parking lot.

There are a variety of habitats and elevational range in the reserve, resulting in a variety of birds. Open, diverse areas had the most birds. Monotypic plantation areas had the least birds.

Of the native birds, Maui ʻAmakihi (*Chlorodrepanis virens* var. *wilsoni*) is the most common. It was encountered over the entire reserve, from 2,000-5,000 ft.. It was most abundant in and near the more native dominated areas, but was also in the Kahakapao Loop Trail parking lot.

ʻApapane (*Himatione sanguinea*) are less common, we only encountered them in the higher, more native dominated areas above 3,200 ft. ʻIʻiwi (*Vestiaria coccinea*) were even less common, found about 3,500 ft., again preferring higher elevation, more native dominated areas.

The Maui Creeper or ʻAlauahio (*Paroreomyza montana*) was not observed, but likely occurs in the reserve. Less likely, but not impossible would be the sporadic occurrence in the highest elevations of the reserve of Kiwikiu or Maui Parrotbill (*Pseudonestor xanthophrys*) or ʻĀkohekohe or Crested Honeycreeper (*Palmeria dolei*).

A lone Black-crowned Night-Heron (*Nycticorax nycticorax*) flushed from the side of a small pool in Waiohiwi Stream.

Though not encountered, Hawaiian Owls or Pueo (*Asio flammeus sandwichensis*), Hawaiian Geese or Nēnē (*Branta sandvicensis*), and Pacific Golden-Plovers or Kōlea (*Pluvialis fulva*) likely also occur in the reserve at times.

Native seabirds, such as the ʻUaʻu or Hawaiian Petrel (*Pterodroma sandwichensis*) and perhaps ʻAʻo or Newell's Shearwater (*Puffinus newelli*) seasonally fly over the reserve at night.

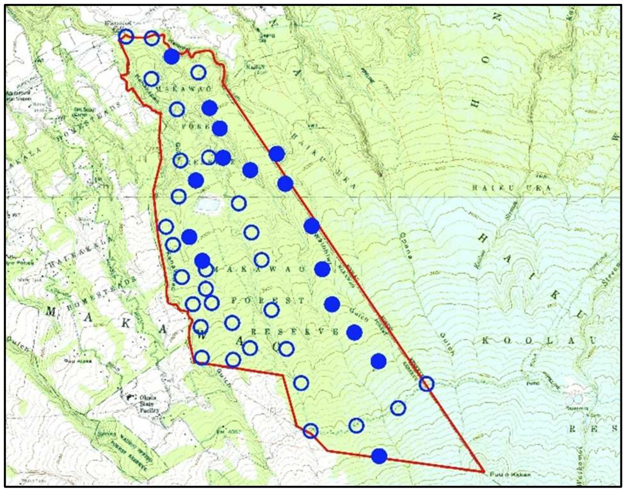
The most common bird in the reserve is the non-native Red-billed Leiothrix (*Leiothrix lutea*). It was heard and observed over the entire reserve. In areas most frequented by humans, like the Kahakapao Loop Trail, it has taken to panhandling, coming right up to us begging for treats.

Other non-native passerines encountered include, Japanese Bush-warbler (*Cettia diphone*), Warbling White-eye (*Zosterops japonicus*), House Finch (*Haemorhous mexicanus*), House Sparrow (*Passer domesticus*), Northern Cardinal (*Cardinalis cardinalis*), Red-crested Cardinal (*Paroaria coronata*), and Mannikins (*Lonchura* sp.).

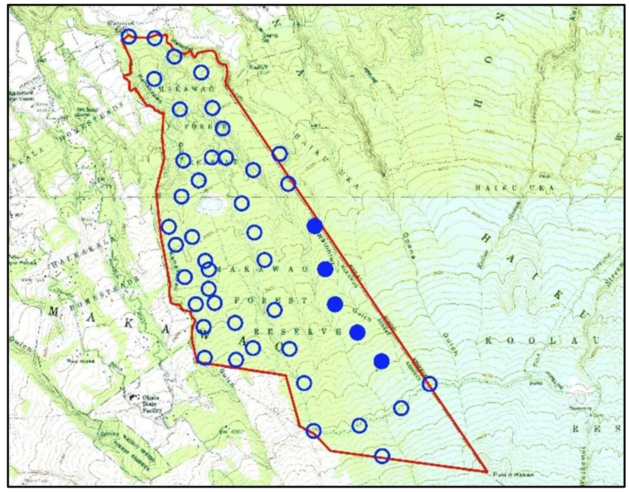
The only game or dove like birds encountered were Zebra Doves (*Geopelia striata*). Ring-necked Pheasant (*Phasianus colchicus*) likely occur in the reserve at times as well.

BIRD COUNT MAPS

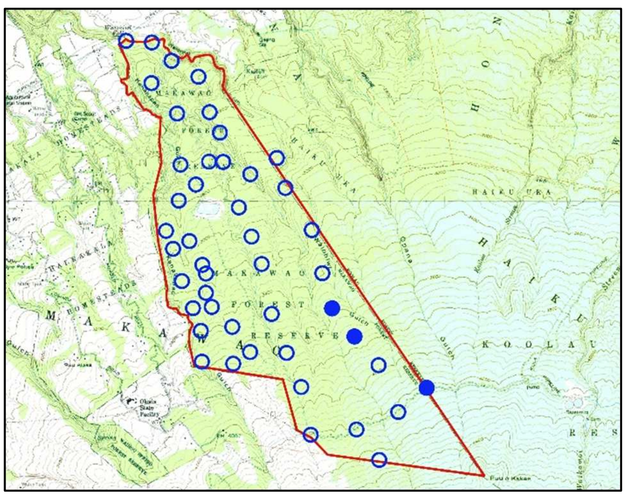
Solid blue circles indicate detection, open blue circles indicate no detection.



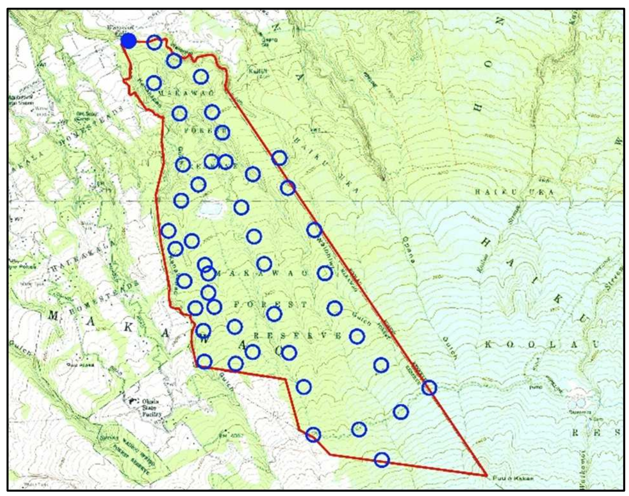
Maui ‘Amakihi



‘Apapane

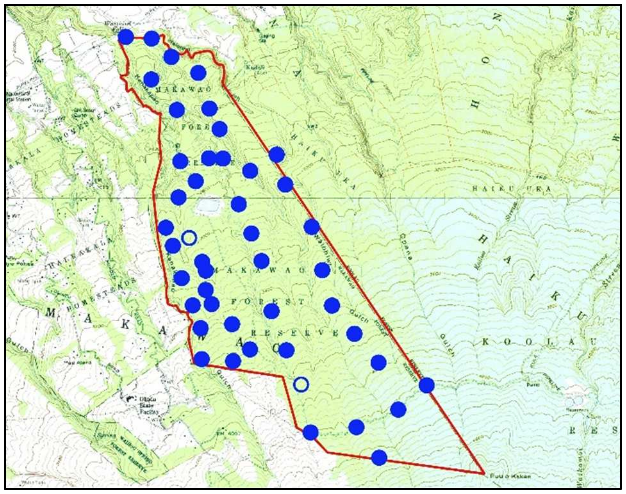


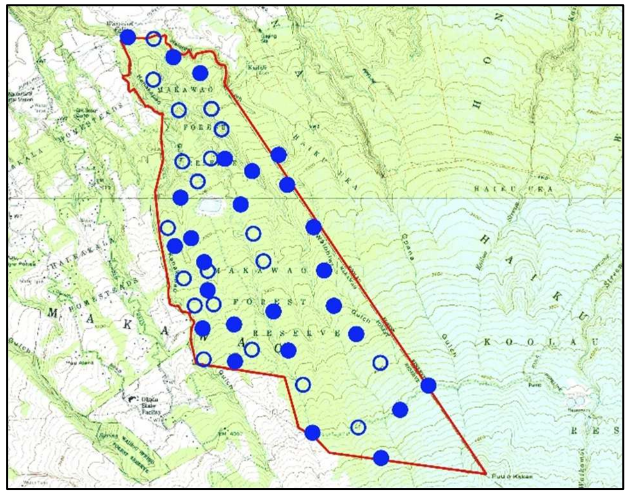
‘I‘iwi



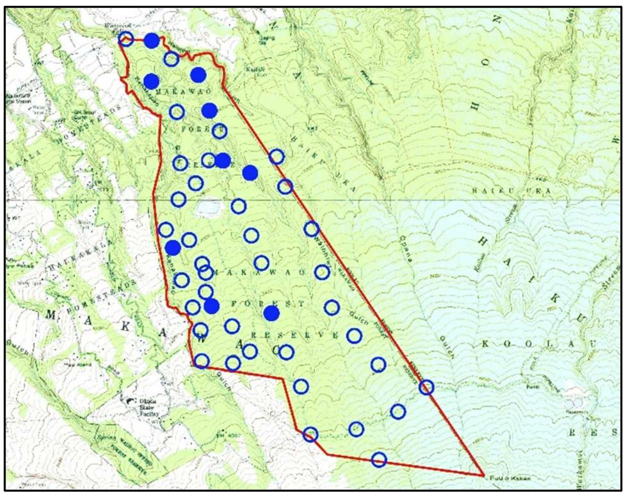
Black-crowned Night-Heron

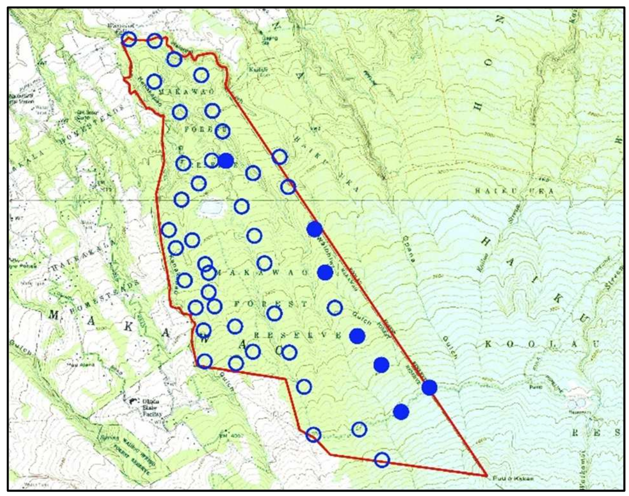
‘Apapane calling in ‘ōhi‘a canopy, Kahikinui Forest Reserve.





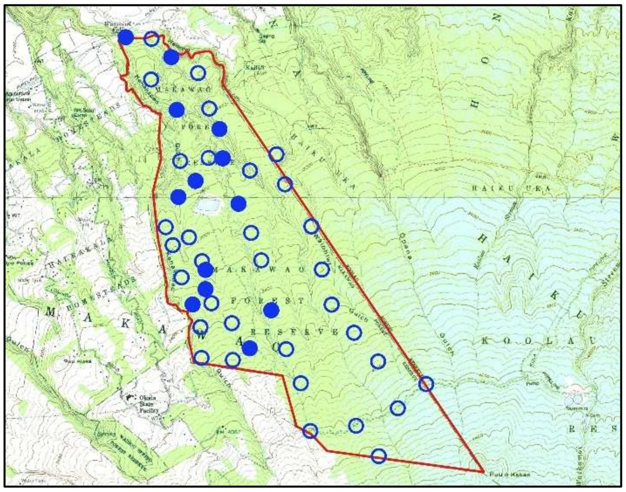
Red-billed Leiothrix **Warbling White-eye**

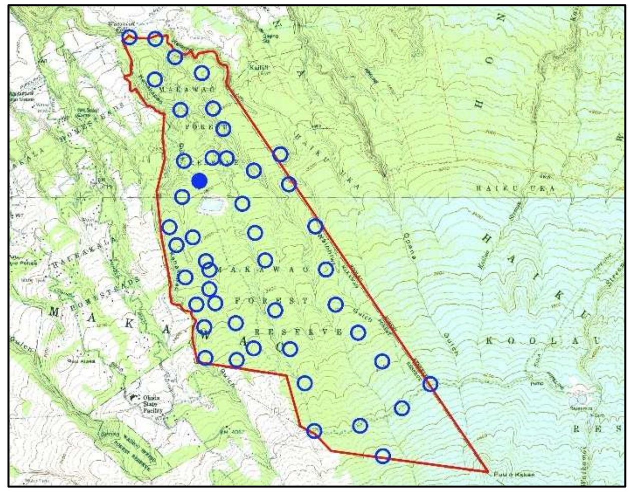




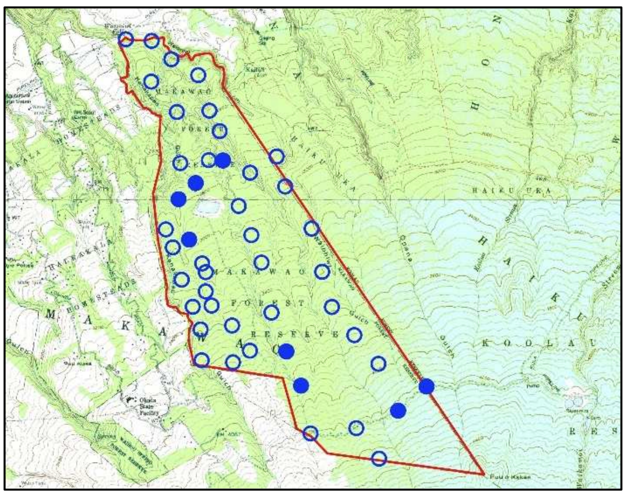
Chinese Hwamei **Japanese Bush-Warbler**

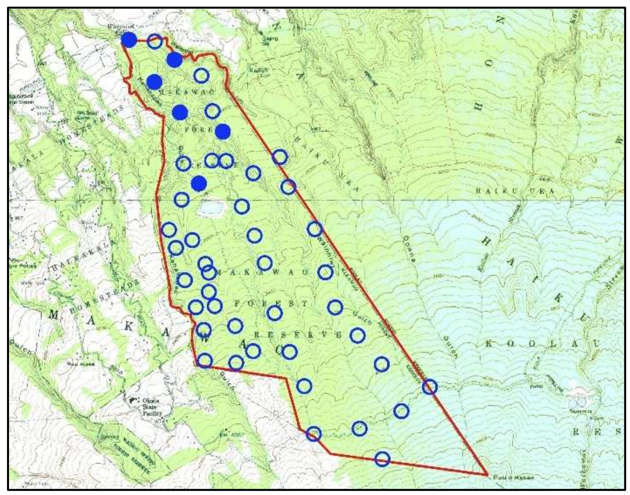
Red-billed Leiothrix looking for a handout in the Makawao Forest Reserve.





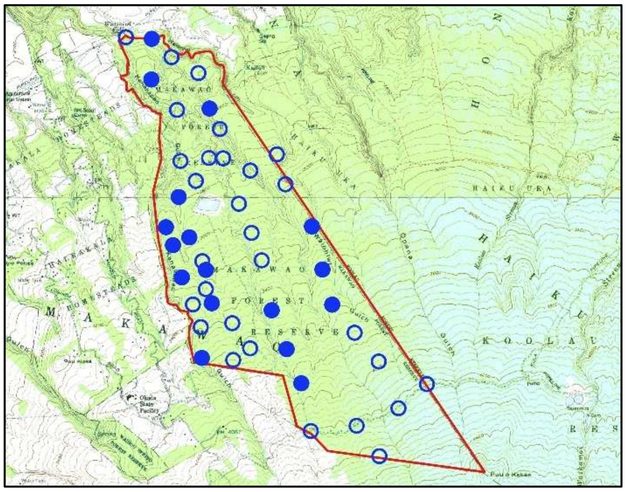
Northern Cardinal | **Red-crested Cardinal**



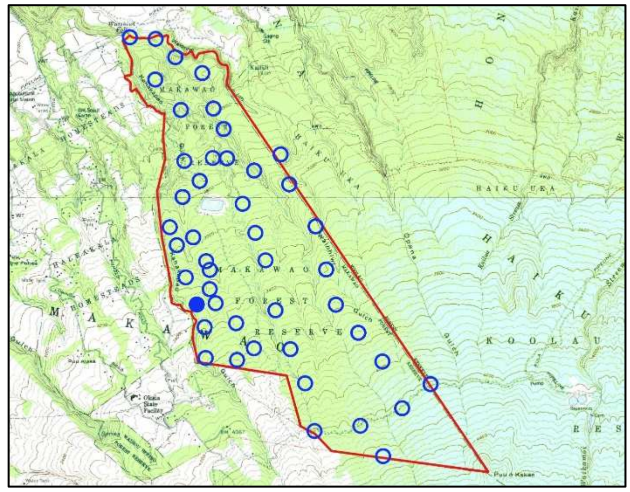


Ricebird (*Lonchura*) | **Zebra Dove**

Northern Cardinal in the Makawao Forest Reserve.



House Finch



House Sparrow

BIRD SPECIES LIST

Following is a checklist of the bird species inventoried during the field work.

- Abundant = Many flocks or individuals seen throughout area at all times of day.
- Common = A few flocks or well scattered individuals throughout the area.
- Occasional = 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	Occasional
Black-crowned Night-Heron	*Nycticorax nycticorax*	Indigenous	Rare
House Finch	*Haemorhous mexicanus*	Non-native	Common
House Sparrow	*Passer domesticus*	Non-native	Rare
Hwamei	*Garrulax canorus*	Non-native	Occasional
‘I‘iwi	*Drepanis coccinea*	Endemic	Rare
Japanese Bush-Warbler	*Horornis diphone*	Non-native	Occasional
Mannikin/Munia	*Lonchura* sp.	Non-native	Occasional
Maui ‘Amakihi	*Chlorodrepanis virens wilsoni*	Endemic	Common
Northern Cardinal	*Cardinalis cardinalis*	Non-native	Common
Red-billed Leiothrix	*Leiothrix lutea*	Non-native	Abundant
Red-crested Cardinal	*Paroaria coronata*	Non-native	Rare
Warbling White-eye	*Zosterops japonicus*	Non-native	Common
Zebra Dove	*Geopelia striata*	Non-native	Occasional

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. There has been previous, more comprehensive, work done on insects in the reserve by Will Haines. Will's list of species encountered comprises the bulk of the insects in the species list for this report.

Some of the more conspicuous and noteworthy insects we came across are noted below. There is still much to be discovered in the Makawao Forest Reserve, including new undescribed species.

Looking for native *Hyposmocoma* moths and other insects along Waiohiwi Stream.

Sweeping for insects at Kahakapao Loop trailhead.

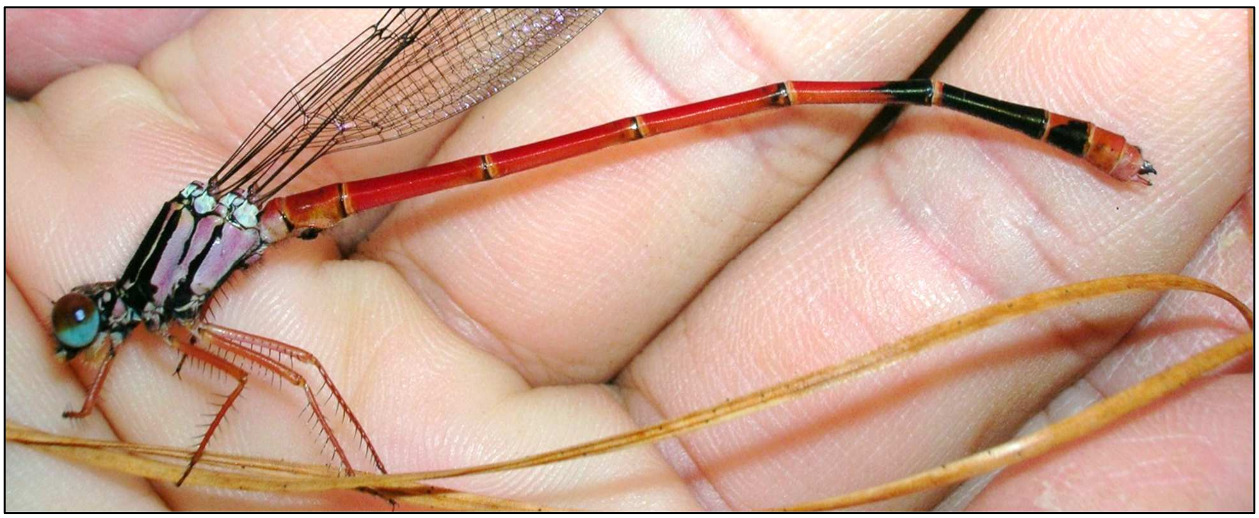
DAMSELFLIES & DRAGONFLIES

Native damselflies or Pinao ‘Ula (*Megalagrion*) and dragonflies or Pinao (*Anax*) were observed in the reserve (Odonata: Coenagrionidae and Aeshnidae). These native damselflies are predators on insects. The larvae live in streams or ponds, feeding on a variety of aquatic insects. The adults are strong flyers and patrol for insects along stream corridors, wetland areas, ridges, and gulches.

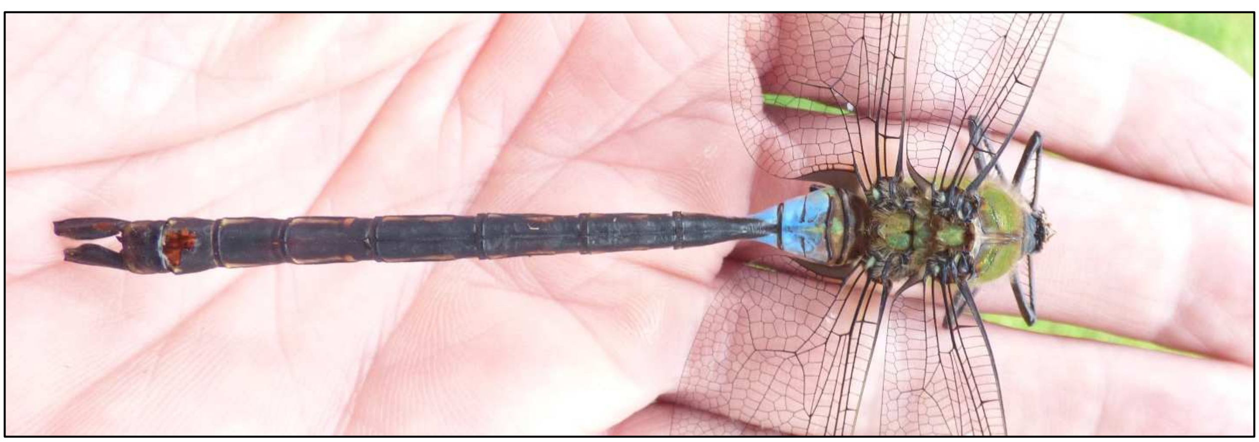
Multiple individuals of what appeared to be *Megalagrion calliphya* were observed resting on uluhe ferns in the upper reaches of the reserve. While building the Kahakapao Loop Trail in 2005 we came across a dead individual of *M. blackburni* in the pine forest, image below.

We also encountered a lone Pinao or Giant Hawaiian Darner (*Anax strenuus*) that was hawking for insects along the Waikamoi Flume Road.

Other species of *Megalagrion* could potentially occur in the reserve, including *M. hawaiiense*, *M. nigrohamatum*, and *M. pacificum*.



Native damselfly or Pinao ‘Ula (*Megalagrion blackburni*), Makawao Forest Reserve.



Native Giant Hawaiian Darner or Pinao (*Anax strenuus*), Olinda.

FANCY-CASED MOTHS

Able to survive in some of the least hospitable areas of Hawai‘i, native fancy-cased moths (*Hyposmocoma* spp.) (Lepidoptera: Cosmopterigidae) are present in the Makawao Forest Reserve. Most prevalent to our eyes were the "burrito" and "cone" shaped larvae/pupae occurring in sheltered areas on large stones and cliff faces. We also came across cases of the "carnivorous/snail eater", "candy wrapper", and "purse" types.

Larvae of "burrito" moths 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. Adults emerge as small moths. The "carnivorous" larvae eat snails or possibly other *Hyposmocoma*.

The discovery of the snail eating *H. molluscivora* occurred in the Makawao Forest Reserve. This native moth attaches a snail to a leaf with silk and then eats it alive. Other *Hyposmocoma* moths encountered in the reserve could also be new undescribed native species, there is still much to learn about these small native moths hidden in plain view.

Diverse selection of *Hyposmocoma* "burrito" cases in Makawao Forest Reserve.

Looking for native *Hyposmocoma* moths along Kahakapao Loop Trail.

This rock outcrop along the Kahakapao Loop Trail houses many different types of *Hyposmocoma* moths.

Various case types of native fancy-cased moths (*Hyposmocoma* spp.) found in Makawao Forest Reserve.

‘ŌHI‘A PSYLLIDS

Some ‘ōhi‘a trees in the Makawao Forest Reserve have galls on their leaves created by native psyllids or jumping plant lice (*Pariaconus* spp.) (Hemiptera: Psyllidae).

The "closed gall" psyllids create galls that look like little bumps on leaves of ‘ōhi‘a. There are other *Pariaconus* species that create "open galls" and "stem/flower" galls on ‘ōhi‘a which were not observed in the reserve, but may occur there as well.

"Closed galls" on ‘ōhi‘a leaves created by native psyllids (*Pariaconus* sp.). These galls are old, the adult psyllid has already left the galls.

These galls are still active, with native psyllids living inside the ‘ōhi‘a leaf. One psyllid per gall.

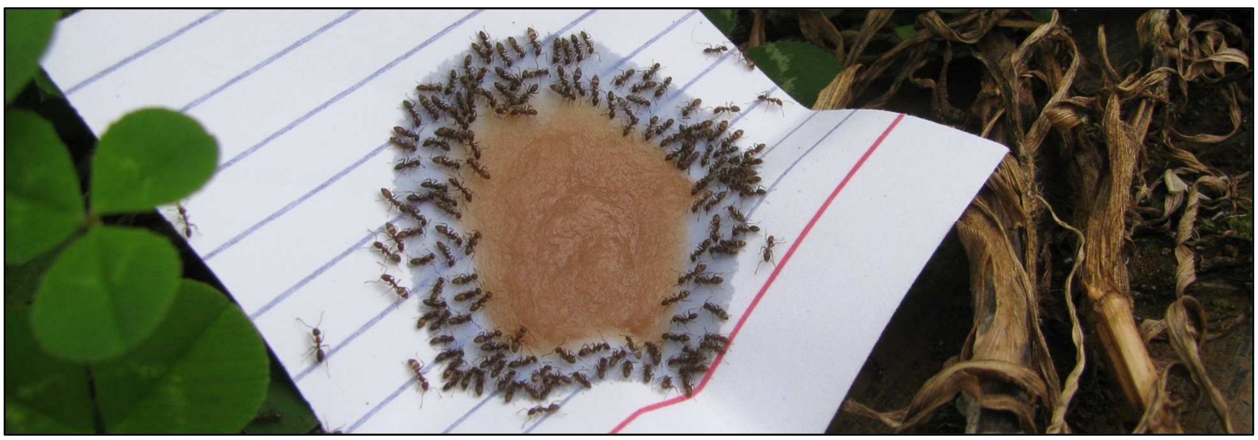
ANTS

Hawaiʻi has no native ants (Hymenoptera: Formicidae). Detailed ant surveys were not done for this project. But anecdotally, the reserve appears to have vast areas mostly devoid of invasive tramp ants, which bodes well for the native insects, which can be heavily impacted by ants.

Only one ant was encountered during this survey, a Thief Ant (*Solenopsis papuana*). These ants are common over much of the wettest portions of windward East Maui.

Will Haines did a more detailed arthropod survey of the reserve and also found few ants. Species he collected include a few specimens of *Cardiocondyla* and *Hypoponera*. Will also noted the Argentine Ant (*Linepithema humile*) was present along paved roads in and adjacent to the reserve, and within localized sites within the reserve, but is not widespread.

The presumed inability of invasive ants to broadly occupy the reserve bodes well for the native insects that call the area home. Dedicated ant surveys would better assess the true situation.



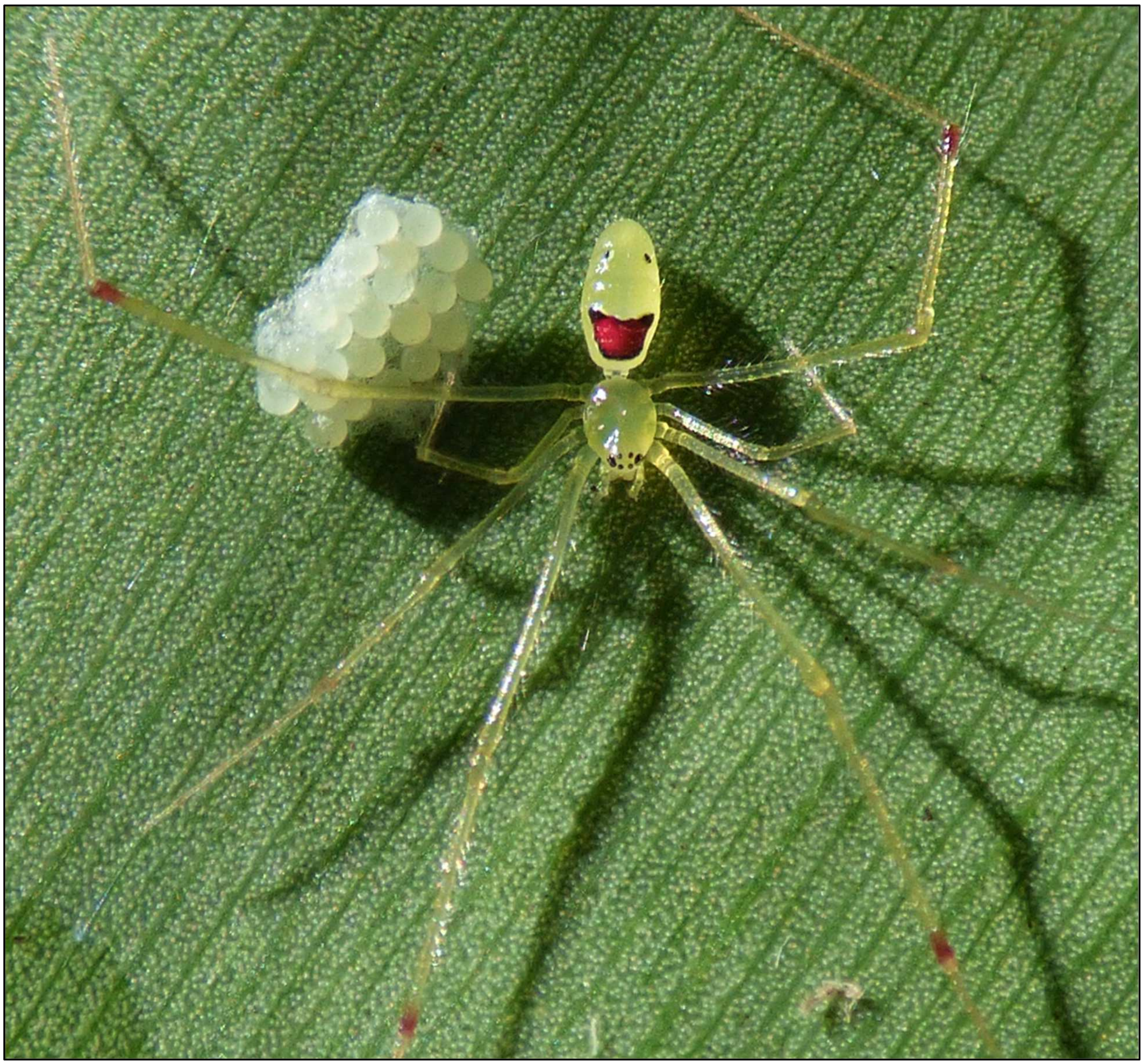
Argentine ants (*Linepithema humile*) at bait card, Waipoli Rd.

Thief ant (*Solenopsis papuana*), Makawao Forest Reserve

HAPPY-FACE SPIDERS

Native Happy-Face Spiders (*Theridion grallator*) (Araneae: Theriidae) are locally abundant in the Makawao Forest Reserve. This relatively well known native spider seeks shelter and lives out its life on the undersides of leaves.

Generally found in the higher and wetter parts of the reserve, this spider appears to not distinguish between native and non-native vegetation. This works to this spider's advantage, as it is often found on the undersides of the invasive kahili ginger (*Hedychium gardnerianum*), an aggressive non-native plant taking over vast areas of the reserve.



Native Happy-face Spider with eggs, Makawao Forest Reserve.

A different patterned Happy-face Spider, Makawao Forest Reserve.

Baby Happy-face Spiders, Makawao Forest Reserve.

ALANI GALLS

We're not sure what's causing these galls occasionally present on native alani trees (*Melicope*) in the reserve. At first we thought an Eriophyid Mite, as they create similar galls on other species.

But after a bit of research, it appears to potentially be a native rust, possibly *Puccinia rutainsulara* or a similar species, perhaps even undescribed. If you figure it out, let us know.

Galling on undersides of Alani (*Melicope*) leaves, Makawao Forest Reserve.

Galls on Alani (*Melicope*), perhaps caused by a native rust fungus, Makawao Forest Reserve.

PILO GALLS

Another mystery we can't find the answer to is what creates the large woody galls on pilo (*Coprosma*) in the reserve. Again Eriophyid Mites or some other insects could be a potential causal agent, as could a native pathogen of some sort. But we can't find any reference to what is causing the conspicuous damage, despite coming across similar galls in many areas of Maui, from Kipahulu to West Maui. If you figure it out, please let us know.

Galls on dead pilo (*Coprosma*) tree along Waikamoi Flume Road.

Gall on live pilo (*Coprosma*) tree with hand for scale, Waikamoi Flume Road.

INSECT SPECIES LIST

Most of the insects in this checklist are from a much more detailed arthropod survey of the Makawao Forest Reserve by Will Haines et al. Also included are a few additional insects we observed during this survey and while doing work in the reserve in the mid-2000's. Further surveys would undoubtedly turn up many more arthropod species, some new to science.

Koa butterfly (*Udara blackburni*).

Order	Family	Species	Nativity
Araneae	Theridiidae	*Theridion grallator*	Native
Coleoptera	Carabidae	*Metacolpodes buchanani*	Non-native
Coleoptera	Carabidae	*Notiobia purpurascens*	Non-native
Coleoptera	Chrysomelidae	*Chaetocnema confinis*	Non-native
Coleoptera	Cucujidae	*Cryptamorpha desjardinsi*	Non-native
Coleoptera	Cucujidae	*Psammoechus insularis*	Non-native
Coleoptera	Curculionidae	*Dryopthorus sp.*	Native
Coleoptera	Curculionidae	*Listroderes dificilis*	Non-native
Coleoptera	Curculionidae	*Oodemas sp.*	Native
Coleoptera	Curculionidae	*Rhyncogonus sp.*	Native
Coleoptera	Nitidulidae	*Eupetinus impressus*	Native
Coleoptera	Nitidulidae	*Prosopeus concolor*	Native
Coleoptera	Nitidulidae	*Prosopeus similis*	Native
Coleoptera	Nitidulidae	*Stelidota geminata*	Non-native
Coleoptera	Scarabaeidae	*Adoretus sinicus*	Non-native
Coleoptera	Scarabaeidae	*Aphodius lividus*	Non-native
Coleoptera	Scarabaeidae	*Copris incertus*	Non-native
Coleoptera	Scolytidae	*Xylosandrus morigerus*	Non-native

Order	Family	Species	Nativity
Coleoptera	Staphylinidae	*Philonthus turbidus*	Non-native
Diptera	Calliphoridae	*Dyscritomyia hawaiiensis*	Native
Diptera	Calliphoridae	*Dyscritomyia sp.*	Native
Diptera	Calliphoridae	*Eucalliphora latifrons*	Non-native
Diptera	Calliphoridae	*Sarcophaga peregrina*	Non-native
Diptera	Ceratopogonidae	*Atrichopogon jacobsoni*	Non-native
Diptera	Ceratopogonidae	*Forcipomya hardyi*	Native
Diptera	Chloropidae	*Meijerella flavisetosa*	Non-native
Diptera	Chloropidae	*Neoloxotaenia gracilis*	Non-native
Diptera	Chloropidae	*Rhodesiella elegantula*	Non-native
Diptera	Culicidae	Unknown	Non-native
Diptera	Dolichopodidae	*Campsicnemus capitulatus*	Native
Diptera	Dolichopodidae	*Campsicnemus distinctus*	Native
Diptera	Dolichopodidae	*Campsicnemus fumipennis*	Native
Diptera	Dolichopodidae	*Campsicnemus perplexus*	Native
Diptera	Dolichopodidae	*Campsicnemus spp.*	Native
Diptera	Dolichopodidae	*Chrysotus longipalpus*	Non-native
Diptera	Dolichopodidae	*Dolichopus exsul*	Non-native
Diptera	Drosophilidae	*Drosophila spp.*	Unknown
Diptera	Heleomyzidae	*Tephrochlamys sp.*	Native
Diptera	Keroplatidae	*Leia sp.*	Native
Diptera	Keroplatidae	*Tylparua insularis*	Native
Diptera	Lauxaniidae	*Homoneura unguiculata*	Non-native
Diptera	Lonchaeidae	*Lonchaea polita*	Non-native
Diptera	Muscidae	*Lispe sp.*	Unknown
Diptera	Muscidae	*Lispocephala carita*	Native
Diptera	Muscidae	*Lispocephala confluens*	Native
Diptera	Muscidae	*Lispocephala indecisa*	Native
Diptera	Muscidae	*Lispocephala ingens*	Native
Diptera	Muscidae	*Lispocephala longipes*	Native
Diptera	Muscidae	*Lispocephala mauiensis*	Native
Diptera	Muscidae	*Lispocephala planifemorata*	Native
Diptera	Muscidae	*Muscina levida*	Non-native
Diptera	Otitidae	*Euxesta annonae*	Non-native
Diptera	Phoridae	*Diplonevra peregrina*	Non-native
Diptera	Sciaridae	*Ctenosciara hawaiiensis*	Native
Diptera	Sphaeroceridae	*Leptocera abdominiseta*	Non-native
Diptera	Sphaeroceridae	*Poecilosomella punctipennis*	Non-native
Diptera	Sphaeroceridae	*Pterogramma brevivenosum*	Native
Diptera	Stratiomyidae	*Exaireta spinigera*	Non-native

Order	Family	Species	Nativity
Diptera	Syrphidae	*Allograpta obliqua*	Non-native
Diptera	Tephriditae	*Tetreuaresta obscuriventri*	Non-native
Diptera	Tipulidae	*Limonia hawaiiensis*	Native
Diptera	Tipulidae	*Limonia perkinsi*	Non-native
Diptera	Tipulidae	*Limonia stygipennis*	Native
Diptera	Tipulidae	*Limonia swezeyi*	Native
Hemiptera	Cicadellidae	*Sophonia rufofascia*	Non-native
Hemiptera	Delphacidae	*Sardia rostrata*	Non-native
Hemiptera	Flatidae	*Siphanta acuta*	Non-native
Hemiptera	Lygaeidae	*Botocudo marianensis*	Non-native
Hemiptera	Lygaeidae	*Nesoclimacias lanaiensis*	Native
Hemiptera	Miridae	*Nesiomiris sp.*	Native
Hemiptera	Miridae	*Pseudoclerada kilaueae*	Native
Hemiptera	Miridae	*Taylorilygus apicalis*	Non-native
Hemiptera	Pentatomidae	*Nezara viridula*	Non-native
Hemiptera	Psyllidae	*Pariaconus spp.*	Native
Hemiptera	Reduviidae	*Oncocephalus pacifica*	Non-native
Hymenoptera	Apidae	*Apis mellifera*	Non-native
Hymenoptera	Blaniulidae	*Proteroiulus fuscus*	Non-native
Hymenoptera	Braconidae	*Meteorus laphygmae*	Non-native
Hymenoptera	Formicidae	*Cardiocondyla sp.*	Non-native
Hymenoptera	Formicidae	*Hypoponera sp.*	Non-native
Hymenoptera	Formicidae	*Linepithema humile*	Non-native
Hymenoptera	Formicidae	*Solenopsis papuana*	Non-native
Hymenoptera	Ichneumonidae	*Enicospilus blackburni*	Native
Hymenoptera	Ichneumonidae	*Enicospilus dispilus*	Native
Hymenoptera	Ichneumonidae	*Enicospilus kaalae*	Native
Hymenoptera	Ichneumonidae	*Enicospilus lineatus*	Native
Hymenoptera	Ichneumonidae	*Enicospilus orbitalis*	Native
Hymenoptera	Ichneumonidae	*Pimpla punicipes*	Non-native
Hymenoptera	Ichneumonidae	*Trathala flavoorbitalis*	Non-native
Hymenoptera	Tenthredinidae	*Priophorus morio*	Non-native
Hymenoptera	Vespidae	*Vespula pensylvanica*	Non-native
Isopoda	Unknown	Unknown	Non-native
Julidae	Julidae	*Cylindroiulus latestriatus*	Non-native
Lepidoptera	Cosmopterigidae	*Hyposmocoma* spp.	Native
Lepidoptera	Crambidae	*Glyphodes cyanomichla*	Native
Lepidoptera	Crambidae	*Herpetogramma licarsisalis*	Non-native
Lepidoptera	Crambidae	*Maruca vitrata*	Non-native
Lepidoptera	Crambidae	*Nomophila noctuella*	Non-native

Order	Family	Species	Nativity
Lepidoptera	Crambidae	*Omiodes accepta*	Native
Lepidoptera	Crambidae	*Omiodes anastrepta*	Native
Lepidoptera	Crambidae	*Omiodes continuatalis*	Native
Lepidoptera	Crambidae	*Omiodes localis*	Native
Lepidoptera	Crambidae	*Omiodes monogona*	Native
Lepidoptera	Crambidae	*Salbia haemorrhoidalis*	Non-native
Lepidoptera	Crambidae	*Spoladea recurvalis*	Non-native
Lepidoptera	Crambidae	*Udea sp*	Native
Lepidoptera	Crambidae	*Uresiphita polygonalis*	Native?
Lepidoptera	Geometridae	*Macaria abydata*	Non-native
Lepidoptera	Geometridae	*Prognostola cremnopis*	Native
Lepidoptera	Geometridae	*Scotorythra arboricolens*	Native
Lepidoptera	Geometridae	*Scotorythra corticea*	Native
Lepidoptera	Geometridae	*Scotorythra gomphias*	Native
Lepidoptera	Geometridae	*Scotorythra nephelosticta*	Native
Lepidoptera	Geometridae	*Scotorythra ortharcha*	Native
Lepidoptera	Geometridae	*Scotorythra rara*	Native
Lepidoptera	Geometridae	*Scotorythra trapezias*	Native
Lepidoptera	Lycaenidae	*Udara blackburni*	Native
Lepidoptera	Noctuidae	*Agrotis ipsilon*	Non-native
Lepidoptera	Noctuidae	*Amyna sp.*	Non-native
Lepidoptera	Noctuidae	*Athetis thoracica*	Non-native
Lepidoptera	Noctuidae	*Aumakua omaomao*	Native
Lepidoptera	Noctuidae	*Chrysodeixis eriosoma*	Non-native
Lepidoptera	Noctuidae	*Ctenoplusia albostriata*	Non-native
Lepidoptera	Noctuidae	*Elaphria nucicolora*	Non-native
Lepidoptera	Noctuidae	*Eublemma accedens*	Non-native
Lepidoptera	Noctuidae	*Haliophyle ferruginea*	Native
Lepidoptera	Noctuidae	*Hypena laceratalis*	Non-native
Lepidoptera	Noctuidae	*Leucania loreyimima*	Non-native
Lepidoptera	Noctuidae	*Lophoplusia pterylota*	Native
Lepidoptera	Noctuidae	*Lophoplusia sp.*	Native
Lepidoptera	Noctuidae	*Lycophotia porphyrea*	Non-native
Lepidoptera	Noctuidae	*Megalographa biloba*	Non-native
Lepidoptera	Noctuidae	*Melipotis indomita*	Non-native
Lepidoptera	Noctuidae	*Peridroma sp.*	Native
Lepidoptera	Noctuidae	*Pseudaletia unipunctata*	Non-native
Lepidoptera	Schreckensteiniidae	*Schreckensteinia festaliella*	Non-native
Lepidoptera	Sphingidae	*Agrius cingulata*	Non-native
Lepidoptera	Sphingidae	*Hyles wilsoni perkinsi*	Native

Order	Family	Species	Nativity
Lepidoptera	Sphingidae	*Hyles wilsoni wilsoni*	Native
Lepidoptera	Tineidae	*Opogona omoscopa*	Non-native
Lepidoptera	Tineidae	*Opogona sacchari*	Non-native
Lepidoptera	Tortricidae	*Amorbia emigratella*	Non-native
Lepidoptera	Tortricidae	*Cryptophlebia illepida*	Non-native
Lepidoptera	Tortricidae	*Epinotia lantana*	Non-native
Lepidoptera	Tortricidae	*Epiphyas postvittana*	Non-native
Odonata	Aeshnidae	*Anax strenuus*	Native
Odonata	Coenagrionidae	*Megalagrion blackburni*	Native
Odonata	Coenagrionidae	*Megalagrion calliphya*	Native
Orthoptera	Tettigoniidae	*Conocephalus saltator*	Non-native
Pulmonata	Zonitidae	*Oxychilus alliarius*	Non-native
Trichoptera	Hydropsychidae	*Cheumatopsyche pettiti*	Non-native

Native fancy-cased moth larva (*Hyposmocoma*), Makawao Forest Reserve.

MOLLUSKS

Targeted snail surveys were not done for this project, but snails were encountered.

The most common snail encountered was the non-native garlic snail (*Oxychilus alliarius*). This snail is a predator of other snails, and impacts native snail communities where introduced.

A cluster of native tornatellid snails was found under a stone. They were identified by Keahi Bustamante and Bishop Museum as *Tornatellides terebra* (Gastropoda: Achatinellidae).

This genus of snails is found in a variety of habitats from the Northwestern Hawaiian Islands to the main Hawaiian Islands. Tornatellid snails are known to be eaten in the reserve by native *Hyposmocoma molluscivora* moths, which capture snails with silk and eat them alive.

In previous years we also encountered native *Auriculella* snails. Further surveys would undoubtedly turn up more species of snails in the reserve.

Non-native Garlic Snail (*Oxychilus alliarius*) crawling along moss in Makawao Forest Reserve.

Native *Tornatellides terebra* snails hanging out under a stone in the Makawao Forest Reserve.

Native *Auriculella* snails on underside of ‘ie‘ie leaves (*Freycinetia arborea*), Makawao Forest Reserve.

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Koa leaves and reflected trees in a puddle along the Waikamoi Flume Road.
"Hahai nō ka ua i ka ululāʻau" **- The rain follows the forest.**

Photo: DOFAW

Forest Birds

ʻĀkohekohe or Crested honeycreeper

Palmeria dolei

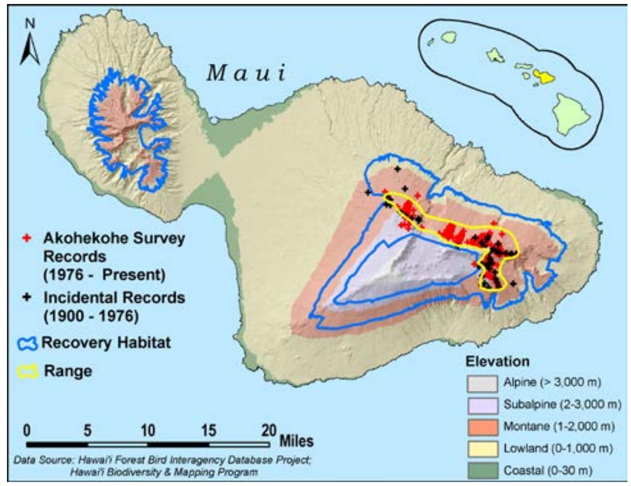
SPECIES STATUS:
Federally Listed as Endangered
State Listed as Endangered
State Recognized as Endemic
NatureServe Heritage Rank G1—Critically Imperiled
IUCN Red List Ranking—Critically Endangered
Revised Recovery Plan for Hawaiian Forest Birds—USFWS 2006

SPECIES INFORMATION: The ʻākohekohe, or crested honeycreeper (Family: Fringillidae), is the largest extant honeycreeper on Maui Nui (Lānaʻi, Molokaʻi, Maui, and Kahoʻolawe). Although primarily black, the plumage of the ʻākohekohe is striking. Depending on their location, feathers are tipped with orange-yellow, gray, silver, or white. Orange feathers surround the eyes and extend over the nape, orange or yellow-white feathers cover the thighs, the epaulettes are white with orange tips, and there is a distinctive plume of white feathers that curl forward over the bill. They do not sing, but produce a random series of buzzes, croaks, and whistles. They are primarily nectarivorous, feeding mainly on ʻōhiʻa (*Metrosideros polymorpha*), but also from the flowers of other trees and shrubs. Like ʻapapane (*Himatione sanguinea*) and iʻiwi (*Vestiaria coccinea*), ʻākohekohe are strong fliers and will move from low to high elevations in search of blooming ʻōhiʻa. Arthropods, mainly gleaned from ʻōhiʻa, are also part of the species' diet. They spend up to 70 percent of the day foraging. They aggressively defend feeding and nesting territories year-round. Females build open-cup nests primarily in ʻōhiʻa, incubate the clutch of one or two eggs, and brood nestlings; male feeds female on nest. Fledglings can forage independently 10 to 14 days after leaving the nest. Pairs successfully fledge two to three broods per season.

DISTRIBUTION: Restricted to a 58 square kilometer (22 square mile) area on the northeastern slope of Haleakalā at 1,100 to 2,300 meters (3,600 – 7,550 feet). Subfossil evidence indicates they once occurred in Maui's lowland dry forests, and they also once occurred eastern Molokaʻi. They currently occupy 5 percent of the historical range.

ABUNDANCE: The Hawaiian Forest Bird Survey (1980) estimated the population at 3,800 ± 700 (95% confidence interval) individuals. Surveys in 1992 and 1995-97 indicated similar densities across the same range.

LOCATION AND CONDITION OF KEY HABITAT: Wet and mesic montane forests dominated by ʻōhiʻa and ʻōlapa (*Cheirodendron trigynum*); koa (*Acacia koa*) and kāwaʻu (*Ilex anomala*) occur at lower densities. Nearly all birds occur in forest between 1,500 and 2,100 meters (5,000 – 6,000 feet) elevation in rugged, steep terrain with a dense understory. The entire known range of the species occurs within State (e.g., Forest Reserve and Natural Area Reserve) or Federally (e.g., National Park) managed lands.



THREATS: ʻĀkohekohe 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 ʻākohekohe, the following are of particular concern:

- Disease. Similar to ʻapapane and ʻiʻiwi, movements between low- and high-elevation foraging sites may increase these birds' exposure to mosquito-borne diseases.
- Habitat degradation. Feral pig (*Sus scrofa*) damage to understory vegetation may reduce the availability of nectar-producing plants important to ʻākohekohe, especially those flowering when ʻōhiʻa nectar is less available.
- Population size. Small populations are plagued by a variety of potentially irreversible problems that fall into three categories: demographic, stochastic, and genetic; the former are usually most problematic. Demographic factors include skewed sex ratios and stochastic factors include natural disasters. Habitat fragmentation exacerbates demographic and genetic problems.

CONSERVATION ACTIONS: Captive propagation of ʻākohekohe has been attempted, but to date has been unsuccessful. ʻĀkohekohe likely benefited from actions to conserve endangered forest bird species on the northeastern slope of Haleakalā, including fencing, ungulate and small mammal control, forest restoration, habitat monitoring, and studies of disease and disease vectors. In addition to these efforts, future actions specific to ʻākohekohe may include the following:

- Establish a second population to reduce the chances that a catastrophe could result in the species' extinction. Potential re-introduction sites (e.g., west Maui and Molokaʻi) are limited because of the presence of mosquitoes.
- Continue attempts at establishing a captive population, especially if a second wild population cannot be establish.
- Implement additional fencing and feral pig control to improve understory conditions in occupied habitat and potentially facilitate expansion of ʻākohekohe populations.
- Conduct public outreach and education.
- 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 and feral cats in native forests, determining the ecological requirements of *Culex* mosquitoes at mid- and high-elevation forests, and developing methods to control mosquito populations. Research priorities specific to ʻākohekohe include the following:

- Determine if disease-resistant individuals exist, and if so, if resistance is passed to offspring. Disease-resistant individuals could be used to establish new populations.
- Determine the role of ʻākohekohe in transmitting disease between high- and low-elevation habitats.

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Photo: Brenda Zaun, USFWS

ʻAʻo or Newell's shearwater

Puffinus auricularis newelli

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

SPECIES INFORMATION: The ʻaʻo or Newell's shearwater (Family: Procellaridae) is highly pelagic year-round, and is endemic to the Hawaiian Islands. Adult males and females are dark, sooty brown above, with white throat and underparts, and have a dark bill with a hooked tip. Flight is direct, fast and usually low over water, powered by rapid wing beats interspersed with glides; wing loading is higher than in more aerial shearwaters due to the species' foraging method (see below). Often forages in large, mixed species flocks associated with schools of large, predatory fishes, which drive prey to the surface. ʻAʻo feed mainly by pursuit-plunging; individuals dive into water and swim using their partly folded wings for propulsion. Diet is not well known, but likely consists of fish and squid. ʻAʻo are colonial and nest on steep mountain slopes, with variable amounts of vegetation, where they lay a single egg in cavities and burrows, often located at the base of a tree. Breeding is highly synchronous, and eggs are laid in early June, and most young fledge by November. Both parents incubate the egg, and brood and feed the nestling. Parents forage hundreds of kilometers offshore and return to colony at night to feed chick. No post-fledging care is provided. Age at first breeding is six to seven years.

DISTRIBUTION: ʻAʻo nest on Kauaʻi, Hawaiʻi, Molokaʻi, and Lehua, and may also nest on Oʻahu, Maui, and Lānaʻi, but not confirmed. Nesting colonies do not occur outside of Hawaiʻi. At-sea distribution includes the eastern and central subtropical Pacific Ocean.

ABUNDANCE: Apparently abundant prior to the arrival of Polynesians, hunting and predation by introduced species resulted in declines of ʻaʻo, and the species was thought to be extinct by 1908. The species was rediscovered at sea in 1947 and breeding birds were found on Kauaʻi in 1967. Abundance is difficult to estimate because of the remoteness and terrain of colonies. In the early 1990s, the population was estimated at 84,000 birds based on at-sea surveys (included adults and non-breeding birds); the population in the subsequent decade (1998-2011) was estimated at roughly 27,000 birds based on revised population estimates using at-sea survey data and are broadly validated by radar detections. Due to differences in sampling methods it is unknown whether these lower estimates reflect a population decline or a difference in the proportion of the total population sampled. The breeding population was estimated at 14,600 pairs, 75-90 percent of which nest on Kauaʻi, based on demographic data.

The population is in serious decline; radar detections on Kauaʻi declined by approximately 75 percent from 1993 to 2008, and three colonies reported as active between 1980 and 1994 were abandoned.

LOCATION AND CONDITION OF KEY HABITAT: On Kauaʻi, most colonies occur between 160 and 1,200 meters (525 - 3,936 feet) elevation on steep, densely vegetated mountains, however, birds also nest on the dry, sparsely vegetated cliffs of the Nā Pali coast and on Lehua. On the island of Hawaiʻi, they nest within forested cinder cones. Colonies are usually located in areas of open native forest dominated by ʻōhiʻa (*Metrosideros polymorpha*) with a dense understory of ʻuluhe fern (*Dicranopteris linearis*).

THREATS:

- Historical hunting. Subsistence hunting by Polynesians likely reduced populations, and the species was likely captured using methods described for ʻuaʻu or Hawaiian petrel (e.g., artificial nests, nets, and smoke from fires).
- Introduced predators. Adults, eggs, and chicks are taken by introduced predators, including dogs (*Canis familiaris*), pigs (*Sus scrofa*), and rats (*Rattus exulans*). Europeans added barn owls (*Tyto alba*), additional rat species, feral cats (*Felis silvestris*), and the small Indian mongoose (*Herpestes auropunctatus*), which is the main factor behind population decline. The largest colonies are on Kauaʻi, the only Main Hawaiian Island besides Lānaʻi where the small Indian mongoose is not established.
- Habitat loss and degradation. Kauaʻi has lost about 75 percent of its forest in the last 150 years, and much of the remaining forest is being degraded by non-native plant species and feral ungulates
- 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, thousands are killed annually by cars, cats, and dogs or die of starvation or dehydration. On Kauaʻi, approximately 350 fledglings were recovered annually from fallout in 1999 to 2010, far fewer than the thousands found per year in the late 1970s when the Save Our Shearwaters (SOS) program began; an unknown number are never found.
- Collisions. Adults and fledglings are susceptible to mortality from collisions with obstacles such as communication towers, overhead utility lines, and wind farm structures while commuting between inland nest sites and the ocean at night.
- Overfishing. Because ʻaʻo rely on predatory fish to drive prey to the surface, overfishing may be affecting the population.
- Colony locations. Remoteness of colonies, as well as the habitat they occur in (e.g., steep terrain or dense forest) complicates predator and ungulate eradication or control.
- Catastrophes. Given that a large proportion of the population breeds on Kauaʻi, catastrophic events like hurricanes could lead to extirpation.

CONSERVATION ACTIONS: Past and current actions include the SOS program which has recovered and released more than 31,000 downed fledgling shearwaters on Kauaʻi since 1978; presently all streetlights and some other types of lighting have been shielded on Kauaʻi; however, fallout still occurs and it is unknown whether these actions have improved survival. Fallout also occurs on Mauʻi. Current and future conservation efforts on Kauaʻi to benefit the ʻaʻo, ʻuaʻu (Hawaiian petrel), and ʻakēʻakē (band-rumped storm-petrel) include efforts to reduce and shield lighting, control predators and invasive species, and conduct surveys to locate additional colonies. In addition to these efforts, future actions specific to ʻaʻo should include the following:

- Continue predator and ungulate control at key colonies on Kauaʻi and the island of Hawaiʻi, and initiate predator control at other known and potential colony sites.
- Continue to support the initiatives of the SOS program, particularly its public outreach about light fallout and rescue and rehabilitation program, and maintain and strengthen similar programs on other islands where needed.
- Continue to identify areas where high fallout occurs, accurately estimate flight collision risk, and develop improved methods to minimize and mitigate the effects of powerlines and artificial lights.
- Eradicate or control invasive plants from current and potential colony sites.
- Prioritize restoration projects at occupied and unoccupied nesting areas based on likelihood of success and existing threats at each site.
- Develop methods, test, and implement social attraction and translocation in order to create safe, managed colonies.
- Develop partnerships with private landowners to assist conservation measures.

MONITORING: Conduct at-sea and terrestrial surveys in known and likely habitats to evaluate the population size and status. 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 standard survey and monitoring protocols that allow changes in population size and structure to be evident.
- Expand and refine radar studies to monitor population trends, locate colonies, and evaluate the effectiveness of conservation measures.
- Evaluate diet and at-sea distribution to determine the potential effects of fishing and food web changes related to climate and oceanographic factors, and provide input on spatial planning for marine protected areas.
- Expand long-term demographic studies to determine reproductive success, survival rates, and factors affecting the population.

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Photo: Eric Nishibayashi

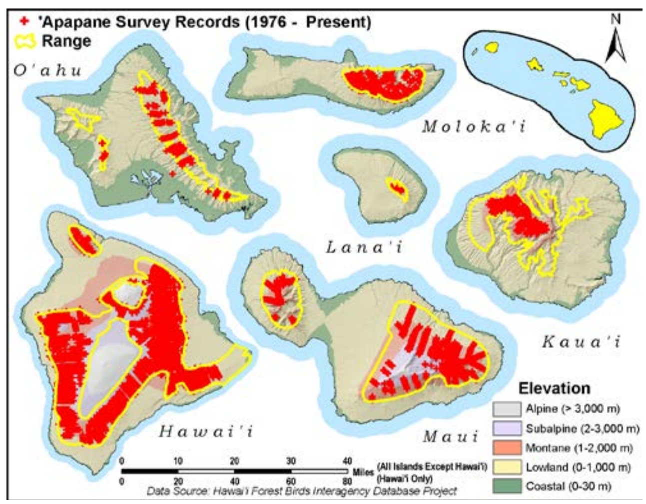
Forest Birds

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 hapuʻu 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 Hawaiʻi, Maui, and Kauaʻi, 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 ʻapapane the following is of particular concern:

- <u>Disease</u>. Of Hawaii's native forest birds, ʻapapane 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. ʻApapane breed in mid-elevation forests, which suggests some disease resistance.

CONSERVATION ACTIONS: ʻApapane likely benefited from actions to conserve other endangered forest birds on northeastern Haleakalā, Hakalau Forest National Wildlife Refuge, Hawaiʻi Volcanoes National Park, the ʻŌlaʻa/Kīlauea Watershed Partnership, and Alakaʻi 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 ʻapapane 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 ʻapapane 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 ʻapapane 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

Forest Birds

ʻIʻiwi

Vestiaria coccinea

SPECIES STATUS:
State Listed as Endangered on Oʻahu, Molokaʻi, Lānaʻi
State Recognized as Endemic
NatureServe Heritage Rank G4/T1/TH—Apparently Secure/
Critically Imperiled Globally on Oʻahu and Molokaʻi/Possibly Extinct on Lānaʻi
IUCN Red List Ranking—Vulnerable

SPECIES INFORMATION: The ʻiʻiwi is one of the most beautiful of the extant Hawaiian honeycreepers (Family: Fringillidae). Both males and females are vermillion red, with a black tail and wings, and a long, decurved pink bill. Native Hawaiians created feather capes using hundreds of thousands of ʻiʻiwi feathers; such capes signified power and prestige. Like ʻapapane (*Himatione sanguinea*), ʻiʻiwi often fly long distances in search of flowering ʻōhiʻa (*Metrosideros polymorpha*) trees and are important ʻōhiʻa pollinators. Their diet consists primarily of nectar from a variety of native and non-native flowers and the presence of non-native flowers may have contributed to increases in some populations. In addition to nectar, ʻiʻiwi also eat small arthropods. Both sexes defend small nesting territories and may defend important nectar resources. Courtship chases and feeding may precede breeding. Nest sites are in terminal branches of ʻōhiʻa trees and both sexes build the open-cup nest. Only females incubate eggs (typically two) and brood young. Young are mostly provisioned by female; males feed females off the nest. Despite their widespread distribution, little is known about their life history.

DISTRIBUTION: Occurs above 1,250 meters (4,100 feet) elevation on the islands of Hawaiʻi, Maui, and Kauaʻi; and may occur at reduced densities below. Relict populations occur on Oʻahu and Molokaʻi. Historically, ʻiʻiwi were common down to low elevations on all the Main Hawaiian Islands.

ABUNDANCE: The following island population estimates are based on Paxton et al. (2013): 543,009 ± 26,697 (95% confidence interval) birds on island of Hawaiʻi, 59,859 ± 5,290 on east Maui, 176 on west Maui, 80 on Molokaʻi, and 2,551 ± 617 on Kauaʻi. Oʻahu supports a population of less than 50 birds. The population is probably declining, but the species' wide-ranging foraging complicates population estimates and the determination of long-term trends.

LOCATION AND CONDITION OF KEY HABITAT: Mesic and wet forest dominated by ʻōhiʻa and koa (*Acacia koa*). Loss and degradation of habitat and high densities of cold-intolerant *Culex* mosquitoes, an important disease vector, in lowland areas restrict most birds to elevations above 1,250 meters (4,100 feet). Habitats with the highest ʻiʻiwi densities also support kōlea (*Myrsine lessertiana*), naio (*Myoporum sandwicense*), and hapuʻu 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 quality and habitat protection and restoration varies considerably.

THREATS: Although populations appear stable on the islands of Hawai'i and Maui, 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 'i'iwi, the following is of particular concern:

- Disease. 'I'iwi are very susceptible to avian malaria and avian pox. Nine of ten individuals died within 37 days after receiving a single bite from mosquitoes infected with *Plasmodium*. Individuals infected with pox also are more likely to be infected with malaria. Because the highest points on Moloka'i and O'ahu are below 1,250 meters (4,100 feet), this susceptibility likely explains the severe population declines noted on these islands. Foraging movements may increase their exposure to disease.

CONSERVATION ACTIONS: **'**I'iwi likely have benefited from actions to conserve other endangered forest birds on northeastern Haleakalā, Hakalau Forest National Wildlife Refuge, Alaka'i Wilderness Preserve and surrounding areas, Hawai'i Volcanoes National Park, and the 'Ōla'a/Kīlauea Watershed Partnership. 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 'i'iwi 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 (*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. Research priorities specific to 'i'iwi include the following:

- Determine if disease-resistant birds exist, and if so, determine if resistance is passed to offspring. Disease-resistant birds could be used to establish new populations.
- Determine the role of 'i'iwi in transmitting disease between low and high elevations.
- 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: Robby Kohley

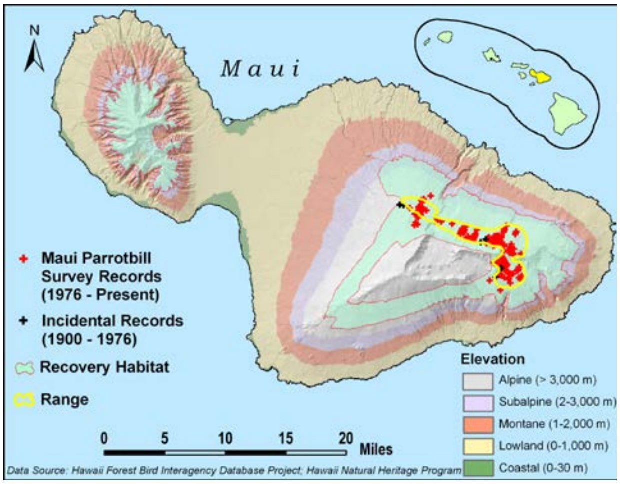
Forest Birds

Kiwikiu or Maui parrotbill

Pseudonestor xanthophrys

SPECIES STATUS:
Federally Listed as Endangered
State Listed as Endangered
State Recognized as Endemic
NatureServe Heritage Rank G1—Critically Imperiled
IUCN Red List Ranking— Critically Endangered
Revised Recovery Plan for Hawaiian Forest Birds—USFWS 2006

SPECIES INFORMATION: The kiwikiu or Maui parrotbill is stocky, bull-headed Hawaiian honeycreeper endemic to Maui, with a short tail and a relatively large, parrot-like bill. Adults are mostly olive-green above with a yellow breast, belly and cheeks, and a bright yellow line above their eyes (i.e., supercilium). Males are typically brighter than females, although individuals are variable. Males are larger than females with a larger bill. They feed on a variety of shrubs and small trees, especially ʻakala (*Rubus hawaiensis*), kanawao (*Broussaisia arguta*), ʻōhiʻa (*Metrosideros polymorpha*), and koa (*Acacia koa*) where it gleans prey from moss-covered branches or uses its bill to chisel, crack, crush, dig, and tear bark and softer wood in search of beetle and Lepidoptera larvae and pupae. Also opens fruit in search of insects. Pairs defend relatively large (6-8 hectare), year-round home ranges. Females build nests, incubate eggs, and brood young. Clutch size is usually one, and females feed nestlings with food delivered by males. Males feed fledglings. They will renest after a nest failure, but are not known to attempt another nest if the first is successful. Development of bill and acquisition of foraging techniques is prolonged and young remain with parents for 5 to 18 months. Because of this long period of dependency, kiwikiu are often seen in small groups and males can be seen provisioning juveniles from current and previous years.



DISTRIBUTION: Restricted to a ~50 square kilometer (19 square mile) on the northeastern slopes of Haleakalā between 1,230 and 2,370 meters (4,000 – 7,700 feet). Subfossils indicate they once occurred island-wide including at low elevations and leeward (southeastern) forests and on the island of Molokaʻi.

ABUNDANCE: The Hawaiian Forest Bird Survey (1980) estimated the population at 502 ± 116 (95% confidence interval) birds. More recent surveys reported densities similar to those from the 1980 survey.

LOCATION AND CONDITION OF KEY HABITAT: Mid-to-upper-elevation montane wet forests dominated by ʻōhiʻa, and in a few mesic areas dominated by ʻōhiʻa and koa (*Acacia koa*), with a dense, diverse native understory and subcanopy of ferns, sedges, epiphytes, shrubs, and small to medium trees. Most of the range is managed by the National Park Service, State of Hawaiʻi, The Nature Conservancy (TNC), and the East Maui Watershed Partnership.

THREATS:

- Low reproduction. Unlike many Hawaiian honeycreepers, kiwikiu have low annual fledgling production. This results from a low reproductive potential (one fledgling per year) coupled with low reproductive success due to habitat limitations and weather. This life history characteristic may be related to their very specialized foraging strategy. Regardless, the species is susceptible to factors that reduce population size.
- Disease. Despite the availability of seemingly suitable habitat below 1,350 meters (4,500 feet), kiwikiu are not found in these areas, suggesting that disease may be restricting populations to higher elevations.
- Predation. Predation on adults and nests by rats (*Rattus* spp.), cats (*Felis silvestris*), the small Indian mongoose (*Herpestes auropunctatus*), and owls (*Asio flammeus sandwichensis, Tyto alba*) may limit the species. High rat densities have been reported in the Hanawī area, which also supports a large proportion of the kiw The rare Maui Parrotbill— Photo by Eric Nishibayasl
- Habitat loss. Historical accounts suggest that kiwikiu f and ranching has resulted in the loss of large areas of mesic koa forest, and their current range is restricted to wet forests where koa density is relatively low. Thus like many endangered Hawaiian forest birds, kiwikiu may be restricted to suboptimal habitat.
- Habitat degradation. Damage to understory vegetation by feral pigs (*Sus scrofa*) likely reduces habitat suitability and may contribute to reduced food availability and low reproductive success. Habitat degradation also may increase exposure of nests to inclement weather.
- Population size. Small populations are plagued by a variety of potentially irreversible problems that fall into three categories: demographic, stochastic, and genetic; the former are usually most problematic. Demographic factors include skewed sex ratios and stochastic factors include natural disasters. Habitat fragmentation exacerbates demographic and genetic problems.

CONSERVATION ACTIONS: In 1997, a captive breeding program was initiated. As of 2015, 14 kiwikiu are in captivity at the Maui Bird Conservation Center. The kiwikiu also benefits from management efforts to conserve other endangered forest birds on northeastern Haleakalā, such as the establishment of the 3,000 hectare (7,500 acre) Hanawī Natural Area Reserve in 1986, the formation of East Maui Watershed Partnership and Maui Forest Bird Recovery Project, fencing, ungulate and small mammal control, forest restoration, habitat monitoring, and studies of disease and disease vectors. Future actions specific to the recovery of the kiwikiu may include the following:

- Protect and restore habitat in high-elevation disease-free areas.
- Implement fencing and ungulate control in low-elevation habitat from the Hanawī Natural Area Reserve to TNC's Waikamoi Preserve, to facilitate the recovery of the understory and subcanopy vegetation and eventually result in high-quality kiwikiu habitat.
- Establish a continuous corridor of suitable habitat around Haleakalā by connecting conservation lands on the southern and western parts of the mountain. Restoration of koa forests to this area would be a key element to this effort.
- Restore, fence, and eradicate ungulates from the remnant mesic koa forests on the State Forest Reserve and Department of Hawaiian Home Lands in the Kahikinui region of southern Haleakalā. Restoration of this area would be a cost-effective starting point to providing the kiwikiu with high-quality habitat.
- Conduct public outreach and education about the importance of invasive species control and forest restoration.
- 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, mongooses, and feral cats in native forests, determining ecological requirements of *Culex* mosquitoes at mid- and high-elevation forests, and developing methods to control mosquitoes. Research priorities specific to the kiwikiu include the following:

- Evaluate the effect of predator control on reproduction and survival of kiwikiu.
- Further refine captive breeding techniques and evaluate experimental reintroduction sites. Evaluation should include mosquito surveys and determination of disease prevalence in lower elevation sites.
- Investigate habitat use in forests that kiwikiu do not currently inhabit to design and implement large-scale restoration.

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Photo: Jack Jeffrey

Maui ʻalauahio or Maui creeper

Paroreomyza montana

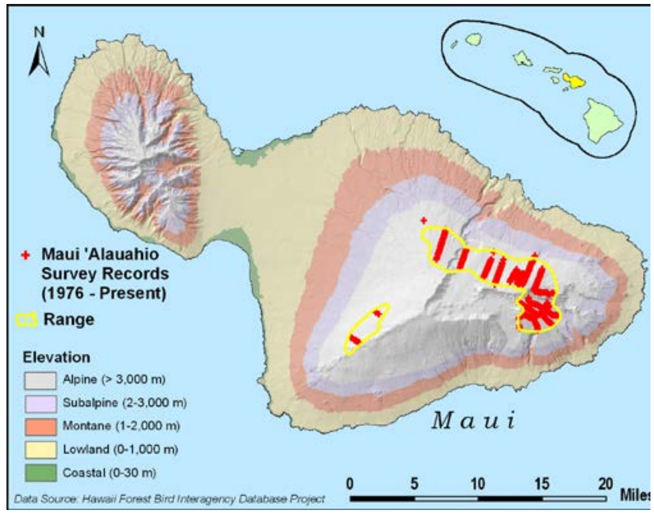
SPECIES STATUS:
State Recognized as Endemic
NatureServe Heritage Rank G4—Apparently Secure
IUCN Red List Ranking—Endangered

SPECIES INFORMATION: The Maui ʻalauahio, or Maui creeper, is a small insectivorous Hawaiian honeycreeper (Family: Fringillidae) endemic to Maui. The species also occurred on Lānaʻi but was last seen in 1937 and is presumed extinct. Adult males are predominantly olive-green above and have a bright yellow face, throat, and belly; the amount and intensity of yellow varies among individuals. Adult females are similar, but generally not as bright; both have short, fine straight bills. Adult plumage is not attained for several years. The Maui ʻalauahio gleans invertebrates from woody and leafy parts of a variety of plants. Adults defend 1 to 2 hectare (2.5 – 5 acre) home ranges against conspecifics year round and will chase ʻapapane (*Himantione sanguinea*) and Japanese white-eyes (*Zosterops japnicus*) from the vicinity of their nests. They are socially monogamous and pair for life, although extra-pair copulations have been confirmed through genetic analysis. Females choose the nest site and build open-cup nests. Clutch size is two, and birds will renest after a failure, although double brooding has not been documented. Only females incubate eggs and brood nestlings. They do not breed until their third year, and young birds (i.e., helpers) associate with breeding pairs. Helpers are usually offspring from the previous year and feed the female, nestlings, and fledglings. Fledglings are fed for two to three months, and young remain with their parents in family groups for 18 - 20 months.

DISTRIBUTION: Above 900 meters (3,000 feet) on the slopes of Haleakalā. Historically common in west Maui and on Lānaʻi; these populations are now extirpated. Fossil evidence suggests they were common across the south side of the island and in lowland forests.

ABUNDANCE: The Hawaiian Forest Bird Survey (1980) estimated the population at 35,000 ± 5,000 (95% confidence interval) birds. Surveys conducted in 1995-1997 found similar numbers, but densities decreased below 1,600 meters (5,250 feet) and the range appears to have contracted.

LOCATION AND CONDITION OF KEY HABITAT: Primarily wet and mesic montane forests dominated by ʻōhiʻa (*Metrosideros polymorpha*), although they also occur in subalpine māmane scrub (*Sophora chrysophylla*), and in dry and mesic forests dominated by pine (*Pinus* spp.) and eucalyptus (*Eucalyptus* spp.; e.g., Polipoli State Park and Hosmer Grove); all populations occur above 900 meters (2,925 feet) elevation. Habitat conditions vary greatly across the species' range. The northeastern part of the species' range is actively managed by the State of Hawaiʻi, (i.e., Forest Reserve and Natural Area Reserve), the National Park Service, and private landowners including the Nature Conservancy. All entities are current members of the East Maui Watershed Partnership. The remainder of the species' range occurs on State and Federally owned lands, where management efforts vary considerably.



THREATS:

- Predation. Rats (*Rattus* spp.) have been observed depredating nests and females. Female behavior of begging near nests may make them particularly susceptible to rats.
- Disease. Susceptibility to avian malaria has been documented, and likely prevents the establishment of populations in lowland areas. In Kahikinui, few individuals show signs of avian pox, although it is prevalent in ʻamakihi (*Hemignathus virens*) and ʻapapane (*Himatione sanguinea*). These data are equivocal, indicating low transmission rates, possible resistance, or very high mortality for this species.
- Habitat degradation. Current fencing around protected areas is not effective in excluding axis deer (*Axis axis*). Currently, deer populations on Maui are growing and threaten to further degrade forests occupied by the ʻalauahio.

CONSERVATION ACTIONS: Maui ʻalauahio likely have benefited from actions to conserve endangered forest birds on northeastern Haleakalā including fencing, ungulate and small mammal control, forest restoration, habitat monitoring, and studies on disease and disease vectors. In addition, ongoing fencing and ungulate control on Department of Hawaiian Home Lands at Kahikinui will likely benefit the small population there. In general, actions should include continued protection and management of wildlife sanctuaries and refuges.

MONITORING: Continue forest bird surveys and habitat monitoring.

RESEARCH PRIORITIES: Research priorities for Hawaiian forest birds include improving methods for controlling rats and feral cats (*Felis silvestris*) in native forests, determining ecological requirements of *Culex* mosquitoes at mid- and high-elevation forests, and developing methods to control mosquitoes. Research priorities specific to Maui ʻalauahio include development of a translocation protocol to facilitate reintroduction into restored high-elevation forests.

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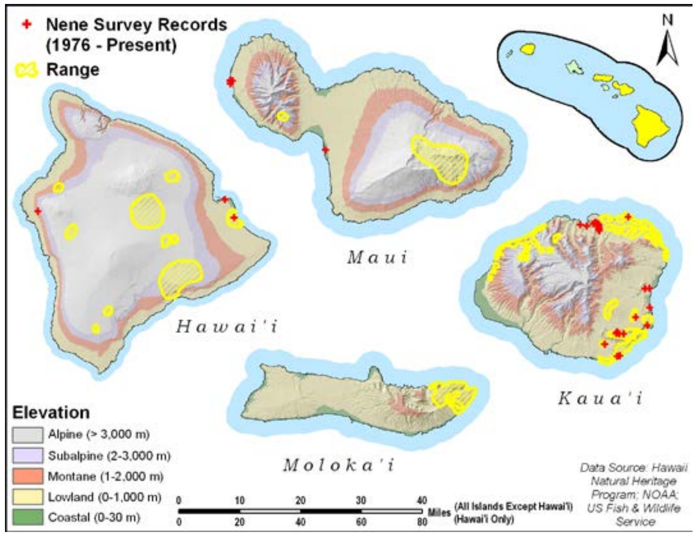
Photo: Jack Jeffery

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 Hawaiʻi; 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 Hawaiʻi, Maui, Kauaʻi, and Molokaʻi, and a single pair was reported on Oʻahu 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 Hawaiʻi, 400 on Maui, 1,500 on Kauaʻi, 80 on Molokaʻi, and a single nesting pair reported on Oʻahu in 2014. During 2005-2010, about 224 nēnē were removed from near the Kauaʻi 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 Kauaʻi nēnē population prompted the removal of an additional 600 nēnē from the vicinity of the Kauaʻi Airport and which were released into the wild on Hawaiʻi 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 Hawaiʻi and Maui, most nests are built under native vegetation, such as pūkiawe (*Styphelia tameiameiae*), ʻaʻaliʻi (*Dondonaea viscose*), and ʻōhiʻa (*Metrosideros polymorpha*). On Kauaʻi, 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 Hawaiʻi 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 Kauaʻi.

- 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

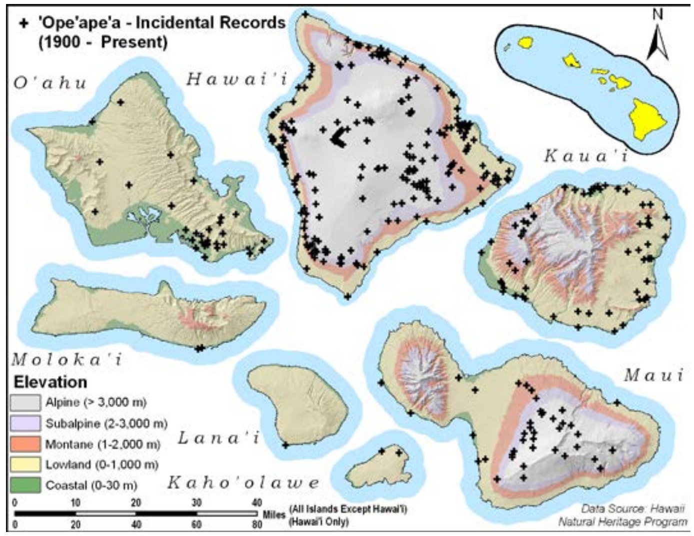
Lasiurus cinereus semotus

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: 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 ʻW-patternʼ 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, Hawaiʻi; around 1,600 pairs occur on Kauaʻi; several thousand birds occur on Lānaʻi; and potentially around 50 pairs nest on Molokaʻi.

LOCATION AND CONDITION OF KEY HABITAT: Nests in a variety of remote, inland habitats. On the islands of Hawaiʻi 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 Kauaʻi and Lānaʻi, and West Maui colonies occur in lower-elevation forests dominated by ʻōhiʻa (*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 ʻaʻo (Newell's shearwater [*Puffinus auricularis*]) have often benefited ʻuaʻu 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 Kauaʻi 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 ʻuaʻu on Maui, Lānaʻi and Kauaʻi; 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

BLACK WATTLE (*Acacia mearnsii*)

Hawai'i Pacific Weed Risk Assessment: 15 (High Risk)
Weed Fire Risk Score: 0.46 (This species is likely a high fire risk in Hawai'i)
Regulatory Status: Hawai'i Noxious Weed List
Prevention and Control Category: N/A

Description

- Fast-growing tree completely covered in fine hairs
- Hairs of new growth are golden in color
- Leaves are dark olive-green, bipinnate, leaflets short (1.5 – 4mm), and crowded
- Raised glands occur at and between the junctions of pinnae pairs
- Flowers form in large globular clusters and are pale yellow or cream-colored.
- Fruits are dark brown pods

Impacts

- It threatens native habitats by competing with indigenous vegetation, replacing grass communities, and reducing native biodiversity
- Increases water loss from riparian zones due to high transpiration rates
- Long lived seeds readily germinate after fire

Distribution

- Native to south-eastern Australia
- Distribution in Hawaii is currently unknown

MAUI PAMAKANI (*Ageratina adenophora*)

Hawai'i Pacific Weed Risk Assessment: None
Regulatory Status: None
Prevention and Control Category: N/A

Description

- Semi-woody, erect shrub that is up to 5 feet tall
- Stems typically purple and covered in hairs
- Leaves simple, diamond or triangular-shaped, up to 6 inches long by 3 inches wide
- Flowers are white and in clusters
- Seeds reddish brown

Impacts

- Prolific seeder that displaces native species in the understory
- Seeds wind dispersed
- Grows in a wide range, from sea level to 3,600 feet in elevation in Hawai'i
- Toxic to horses

Distribution

- Native to Mexico and the West Indies
- Currently known on O'ahu, Lāna'i, Moloka'i, and Maui

HAMAKUA PAMAKANI (*Ageratina riparia*)

Hawai'i Pacific Weed Risk Assessment: None
Regulatory Status: None
Prevention and Control Category: N/A

Description

- Sprawling herb that grows 15.7-24 inches in height
- Stems typically purple
- Leaves opposite, simple, lanceolate to elliptic-shaped, toothed margins, and 1.2-4.7 inches long by 0.3-1.2 inches wide
- Flowers are white and in clusters
- Seeds reddish brown

Impacts

- Prolific seeder that displaces native species in the understory
- Seeds dispersed by wind or attachment to animals or humans
- Grows in a wide range, from 9.8 to 3,900 feet in elevation in Hawai'i
- Toxic to livestock

Distribution

- Native to Mexico
- Currently known on all the main Hawaiian islands, except Kaho'olawe

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

BROOMSEDGE (*Andropogon virginicus*)

Hawai'i Pacific Weed Risk Assessment: 22 (High Risk)
Weed Fire Risk Score: 0.79 (This species is likely a high fire risk in Hawaiʻi)
Regulatory Status: Hawai'i Noxious Weed List (HAR 68)
Prevention and Control Category: N/A

Description

- Perennial grass that grows in dense tufts
- Yellowish at base; culms erect, 50-100 cm tall, branching freely from the middle and upper nodes, internodes compressed, up to 4 mm in diameter, hollow but partially pithy, glabrous.
- Leaves primarily basal; blades up to 35 cm long
- Inflorescence branches several from each of the middle and upper nodes, slender and wiry, erect or ascending
- Caryopsis brown, ovoid, 1.9-2.4 mm long.

Impacts

- Forms continuous cover in boggy, open mesic and dry habitats.
- Releases highly persistent allelopathic substances.
- Dead material provides fuel for fires. Increases fire intensity and area burned.

- Fire-stimulated; cover increases dramatically with each fire.
- It is dormant during the rainy season, which leads to increased erosion in some areas.
- Seeds dispersed by wind.

Distribution

- Native to eastern North America, now extending into Central America.
- Currently known on all the main Hawaiian islands, except Kahoʻolawe
    - Common and often dominant along roadsides and in disturbed dry to mesic forests and shrublands, especially on ridges,165-3,940 feet in elevation

QUININE (*Cinchona pubescens*)

Hawai'i Pacific Weed Risk Assessment: 9 (High Risk)
Regulatory Status: Hawai'i Noxious Weed List (HAR 68)
Prevention and Control Category: N/A

Description

- Tree that grows up to 10 m tall. Leaves are opposite, ovate, younger leaves with upper surface shiny green that turns red with age. Inflorescence densely pubescent with pink to purple corolla and a paler base. Seeds have "wings", enabling airborne movement and distribution.

Impacts

- Seeds are wind-dispersed, allowing for travel and establishment over wide ranges
- Forms dense thickets and outcompetes native plant species
- Seeds viable for more than one year

Distribution

- Distribution in Hawai'i is currently unknown

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

PAMPAS GRASS (*Cortaderia jubata*)

Hawai'i Pacific Weed Risk Assessment: 26 (High Risk)
Weed Fire Risk Score: 0.72 (This species is likely a high fire risk in Hawaiʻi)
Regulatory Status: Hawai'i Noxious Weed List (HAR 68)
Prevention and Control Category: KISC Target Species. OISC Target Species. MISC Target Species. BIISC Target Species

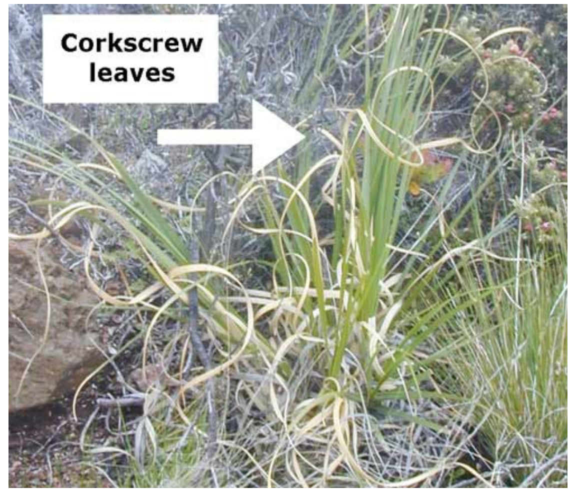
REPORT INVASIVE SPECIES
643-PEST
643pest.org
CALL OR CLICK TO PROTECT HAWAII

Description

- An erect giant bunch grass with long, slender, bright green, saw-toothed leaves
- At its base are dried, corkscrew-shaped leaves
- Inflorescences are large and showy, extending 2-3 feet beyond the foliage.
- Reaches heights of 9-10 feet and has loosely clumped pinkish-white seed heads.
- Flowers from July through November
- Spent flower stalks are sometimes persistent for several years

Impacts

- Grows rapidly and produces thousands of seeds per flower plume
- Creates and accumulates large amounts of fire prone biomass
- Seeds are viable for 4-6 months, but field evidence from Hawaii suggests viability could be longer
- Can crowd out native species, impede access, degrade grazing lands, and create fire hazards.



Distribution

- Native to South America,
- Currently known on Maui and O'ahu

What you can do

It is important NOT to pull and move the plant, as proper removal and disposal are essential to prevent spreading seeds and re-sprouting.

Look-alike Species

- **Sugarcane (*Saccharum officinarum*):** is a Polynesian introduced plant that has a similar seed plume as pampas but the plume is not as dense and sugarcane does not have corkscrew leaves.
- **Native Hawaiian sedges (*Cyperaceae sp.*):** These can be confused with young pampas grass. They do not produce corkscrew leaves, tall flowering stalks, or large showy seed plumes. Most Hawaiian sedge leaves are not as sharp.

SILKY OAK (*Grevillea robusta*)

Hawai'i Pacific Weed Risk Assessment: 8 (High Risk)
Weed Fire Risk Score: 0.55 (This species is likely a high fire risk in Hawaiʻi)
Regulatory Status: none
Prevention and Control Category: none

Description

- A large tree, reaching a height of 75 feet or more
- Canopy has a pyramidal shape and a 25 foot for spread
- Horizontal limbs and a thick trunk
- Fern-like green leaves are divided into many lobes
- Produces large clusters of brilliant yellow flowers
- Black, leathery seed capsules follow the flowers

Impacts

- Adaptable- grows in a wide range of habitat types and elevation
- Seeds dispersed by wind and water

- Produces large density of seeds
- Forms dense stands and outcompetes native species

Distribution

- Native to Australia
- First imported to Hawaii in 1851 and widely planted over 50 years for forestry
- Currently found on all the main Hawaiian islands

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

HIMALAYAN (KAHILI) GINGER (*Hedychium gardnerianum*)

Hawai'i Pacific Weed Risk Assessment: 16 (High Risk)
Regulatory Status: Hawai'i Noxious Weed List (HAR 68)
Prevention and Control Category: Report if seen on Molokaʻi

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

Description

- A coarse ginger with leafy shoots growing up to 6 feet tall
- Leaves (7-17 inches long by 4-6 inhes wide) clasping the tall shoots in an alternate pattern
- Yellow flowers with long red centers grow in spiked cylindrical clusters
- Seeds spread by birds, root fragments will also regrow

Impacts

- Forms dense mats of rhizomes that smoother forest floor
- Thickets shade and dominate native understory species and prevent native recruitment

Distribution

- Native to the Himalayas
- Currently found on all the main Hawaiian islands, except Kahoʻolawe

LANTANA (*Lantana camara*)

Hawai'i Pacific Weed Risk Assessment: 32 (High Risk)
Weed Fire Risk Score: 0.40 (This species is likely a high fire risk in Hawaiʻi)
Regulatory Status: none
Prevention and Control Category: none

Description

- A woody branched shrub up to 10 feet tall
- Prickly stems and serrated leaves (2.5 in long by 2 inches wide) emits a strong aroma
- Flower heads are 1 inch across and are comprised of numerous brightly colored (pink, orange, yellow) smaller flowers
- Fruit resembles a blackberry and contains numerous seeds within
- Seeds are spread by non-native birds

Impacts

- Forms dense impenetrable strands in forest understory and pastures
- Lantana can make children, pets, and livestock sick, its foliage and unripe berries are toxic
- Outcompetes with more desirable species
- Mechanical removal is difficult due to its many thorns

Distribution

- Native to Central America
- Currently found on all the main Hawaiian islands

GUINEA GRASS (*Megathyrsus maximus*)

Hawai'i Pacific Weed Risk Assessment: none
Weed Fire Risk Score: 0.89 (This species is likely a high fire risk in Hawai‘i)
Regulatory Status: none
Prevention and Control Category: none

Description

- Robust perennial grass that grows 2-10 feet tall
- Blades are wide and flat, bright green, 5.9-35 inches9 long, and have dense hairs at the base
- Inflorescences are 3.5-23.6 inches long

Impacts

- Fast-growing grass that can dominate disturbed areas
- Outcompetes native vegetation
- Dried foliage extremely flammable, increasing risk for wild fires

Distribution

- Native to Africa
- Currently known on all the main Hawaiian islands

KOSTER'S CURSE (*Miconia crenata*)

Hawai'i Pacific Weed Risk Assessment: 28
Weed Fire Risk Score: 0.25 (This species is likely a low fire risk in Hawai'i)
Regulatory Status: none
Prevention and Control Category: none

Description

- An evergreen branched shrub growing up to 9 feet tall (3.5 feet more commonly) and densely covered in hair
- Leaves are light green in color, are arranged opposite each other, and are finely toothed on the edges
- Leaves have 5 prominent longitudinal veins, a descriptor for the Melastomataceae family, along with horizontal veins give a scalloped appearance in the leaves
- The upper leaf is sparsely covered in pink hair, fold a leaf and look closely to observe
- Flowers are born from a cup, are densely covered in hair, are white, have 5 petals along with 5 stamens, are not showy, and are born at the nodes or branch tips
- Fruit is dark blue/purple in color, also covered in small hairs and with a persistent calyx
- Each fruit contains 200 to 900 small seeds, fruit comes in numerous bunches, and is also covered in hair.
- Seeds are spread by fruit eating birds

Impacts

- Grows and thrives in a wide variety of habitats and elevations
- Possibly toxic to browsing animals

- Forms dense thickets and prevents native plant regeneration
- Spreads by seeds and vegetative cuttings
- Seed bank lasts at least 4 years
- Seeds spread by birds, water, and unintentionally by humans
- Able to resprout after cutting to the base

Distribution

- Native to Tropical America
- Currently known on all the main Hawaiian islands, except Kahoʻolawe

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

STRAWBERRY GUAVA (*Psidium cattleianum*)

Hawai'i Pacific Weed Risk Assessment: 18
Regulatory Status: none
Prevention and Control Category: none

Description

- A tree up to 20 feet tall with smooth reddish bark
- Shiny leathery leaves (4 inches long by 2.5 inches wide) that grow opposite
- White flowers (less than 1 inch); numerous round red or yellow fruit (1 inch long)
- Seeds spread by birds and pigs

Impacts

- Forms monotypic stands and outcompetes native plant species
- Foliage contains allelopathic properties that prevent anything from growing in the understory

- Reduces water availability - there is a 27-50% reduction of water from soils, streams, and groundwater systems
- Threatens local agriculture by building a large reservoir for damaging fruit flies

Distribution

- Native to Brazil
- Currently known on all the main Hawaiian islands, except Kahoʻolawe

COMMON GUAVA (*Psidium guajava*)

Hawai'i Pacific Weed Risk Assessment: none
Regulatory Status: none
Prevention and Control Category: none

Description

- A tree up to 30 feet tall with smooth, thin, brown bark that peels off in thin sheets
- Young stems slightly winged
- Leaves opposite, 2-4 inches long and 1-2 inches wide
- Flowers white, mostly single but sometimes 2-4 inches a cluster, 1.5 inches wide
- Fruits mostly single, yellow, and pear-shaped, up to 3 inches long. Pulp pinkish or yellow.

Impacts

- Can form dense thickets that outcompete native species
- Seeds dispersed by feral pigs, cattle, and birds

Distribution

- Native to the Caribbean, Central and South America
- Currently known on all the main Hawaiian islands, except Kahoʻolawe

FLORIDA BLACKBERRY (*Rubus argutus*)

Hawai'i Pacific Weed Risk Assessment: 21.5 (High risk)
Regulatory Status: none
Prevention and Control Category: none

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

Description

- Erect or arching thorny shrub. Stiff stems usually stand upright in open areas. Hooked or straight prickles up to 6mm in length.
- Leaves are compound and have three or five leaflets
- Flowers are white in color with five petals
- Fruit is black when ripe

Impacts

- Forms dense, impenetrable thickets that exclude other native plant species
- Seeds are spread by fruit-eating birds and mammals, also spreads vegetatively
- Thickets also make access difficult for hunters, hikers and other visitors to forest
- Can infest a variety of sites including grasslands, forest edges, stream banks, and boggy areas

Distribution

- Native to eastern and southcentral United States
- Currently known on Maui, Oʻahu, Kauaʻi, and Hawaiʻi island
    - Presence/absence unknown on Lānaʻi

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

CHRISTMAS BERRY (*Schinus terebinthifolius*)

Hawai'i Pacific Weed Risk Assessment: 19 (High risk)
Weed Fire Risk Score: 0.45 (This species is likely a high fire risk in Hawai'i)
Regulatory Status: none
Prevention and Control Category: none

Description

- Short stout trunk with numerous horizontal branches.
- Compound leaves are alternatively arranged, sometimes red, and have finely toothed leaflets.
- White flowers grow in clusters.
- Clusters of shiny fruits are green, turning red as they ripen.

Impacts

- Outcompete native plants for resources.
- Choke out pastureland and spread quickly with high germination rates.
- Suppress the growth of native species by producing allelopathic compounds, phytochemicals released in the soil that suppress nearby plant growth.
- Cause narcotic and toxic effects in grazing animals and birds that ingest the plant.
- Cost federal, state, and local land managers millions annually in control efforts.

Distribution

- Native to Brazil, Paraguay, and Argentina
- Currently known on all the main Hawaiian islands, except Kahoʻolawe

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

FIREWEED (*Senecio madagascariensis*)

Hawai'i Pacific Weed Risk Assessment: 23 (High risk)
Weed Fire Risk Score: 0.31 (This species is likely a low fire risk in Hawaiʻi)
Regulatory Status: Hawaiʻi Noxious Weed List (HAR 68)
Prevention and Control Category: KISC Target Species, OISC Target Species, MoMISC Target Species

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

Description

- Daisy-like herb that grows up to 2 feet tall
- Stem is upright and slender with bright green leaves
- Leaves are smooth, very narrow (only ¼ inch wide), have serrated edges, and approximately 5 inches long
- Small yellow flowers with 13 petals and about the size of a nickel
- Mature flowers turn into white thistle-like downy seed balls

Impacts

- Invades pastures, disturbed areas, and roadsides

- Grows in a wide range of soils in sub-humid to humid subtropical woodland
- 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

- Native to Madagascar and South Africa
- Currently known widespread on Maui, Lānaʻi, and Hawaiʻi island
- Not currently known on Kauaʻi, Oʻahu, or Molokaʻi but continually being monitored for new infestation areas

AUSTRALIAN TREE FERN (*Sphaeropteris cooperi*)

Hawai'i Pacific Weed Risk Assessment: 16 (High risk)
Regulatory Status: none
Prevention and Control Category: MoMISC Target Species

Description

- Large tree fern up to 40 feet tall with large triangular leaves (up to 20 feet long) with lacy blades
- Scaly, brown steams fall off when dead, leaving oval scars
- White hairs on stalks (unlike native hapu‘u, which has red hairs)
- Trunk doesn’t have the thick, soft fiber wrapping like native hapu‘u

Impacts

- Spores spread via wind, traveling over 7 miles from parent plant
- Fast growing and aggressively outcompetes native species in the forest understory
- Displaces native ferns, including the slower growing native hapu‘u

Distribution

- Native to Australia

- Introduced to Hawaiʻi as an ornamental. In areas where it is found, landowners are asked to remove them and plant non-invasive alternatives instead.
- Hawaiʻi island- Spreading from landscaped areas in Volcano, Laupāhoehoe, Kona, and other areas
- Kauaʻi- spreading in native forests of Hanalei, Koloa, and Kokeʻe
- Oʻahu- Spreading in the Koʻolau and Waiʻanae mountains
- Molokaʻi- No infestations known in the wild, although planted in landscaped areas at several residences
- Lānaʻi- Presence/absence unknown
- Kahoʻolawe- none known

Cabinet-level direction on invasive species issues

Hawaii Invasive Species Council

CANE TIBOUCHINA (*Tibouchina herbacea*)

Hawai'i Pacific Weed Risk Assessment: 24 (High risk)
Weed Fire Risk Score: 0.10 (This species is likely a low fire risk in Hawai‘i)
Regulatory Status: Hawaii Noxious Weed List (HAR 68)
Prevention and Control Category: OISC Target Species

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

Description

- Semi-woody shrub that can grow up to 9 feet tall
- Young stems are angled and hairy
- Leaves opposite, 3 inches by 1.4 inches wide, hairy, and have 5-7 prominent veins
- Flowers are pink with 4 petals and bright yellow anthers
- Fruit is cup-like and extremely small
- Seeds are numerous and very small

Impacts

- A prolific seeder and spread by birds
- Forms dense stands in pastures and can invade disturbed forested areas
- Displaces native species

Distribution

- Native to Southern Brazil, Uruguay, and Paraguay
- Currently known on Maui and Hawaiʻi Island, the northern Koʻolau range on Oʻahu, Molokaʻi, and Lānaʻi
- Not known to be on Kauaʻi

GORSE (*Ulex europaeus*)

Hawai'i Pacific Weed Risk Assessment: 20 (High risk)
Weed Fire Risk Score: 0.80 (This species is likely a high fire risk in Hawaiʻi)
Regulatory Status: Hawaii Noxious Weed List (HAR 68)
Prevention and Control Category: None

Description

- Thorny shrub, up to 6 feet tall, with inch-long spines
- Bright yellow flowers that smell faintly of coconut

Impacts

- Forms dense, impenetrable thickets that allow nothing else to grow
- Seeds remain viable in the soil for more than 30 years
- Deep roots help this plant survive fires
- Fire helps seeds germinate

Distribution

- Native to Western Europe
  - Introduced as a food plant for sheep and “living fence” for livestock
- Currently known on Kauaʻi, Oʻahu, Maui, Moloka'i, and Hawaiʻi
  - Kaua'i and O'ahu- Present but not a KISC/OISC target for control

- Maui- infestations in higher elevation pastures and natural areas, including Haleakalā. Landowners are asked to control gorse wherever possible.
- Moloka'i- Small population present at Kamiloloa. MoMISC is working to eradicate from the island.
- Hawai'i island- Infestations in higher elevation pastures and natural areas, including Hakalau and Puʻu Oʻo. Not a BISC target for control, but will control in some locations. Landowners are asked to control gorse on their property wherever possible.
- Lāna'i- Presence/absence unknown

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

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Maui Nui: Vulnerability Assessment and Adaptation Options

Summary

The following chapter provides a summary of the vulnerability assessment and adaptation planning results for Maui, Lānaʻi, and Kahoʻolawe.[7] Table 8 presents the overall vulnerability and confidence scores for habitats and ecosystem services. Figure 8 presents the overall vulnerabilities of habitats and ecosystem services based on the assessment of climate and non-climate sensitivity and exposure and adaptive capacity.

Table 8. Overall vulnerability and confidence scores for Maui Nui habitats and ecosystem services.

Focal Resource	Vulnerability Score	Confidence Score
Habitats		
Coastal: Beaches and Shorelines	**Moderate-High**	**Moderate**
Coastal: Estuaries, Tidal Wetlands, and Coastal Freshwater Wetlands	**Moderate**	**Moderate**
Coastal: Anchialine Pools	**Moderate-High**	**High**
Aquatic: Streams	**Moderate**	**Moderate**
Aquatic: Groundwater, Seeps, and Springs	**Moderate**	**High**
Dry Forest	**Moderate-High**	**High**
Mesic and Wet Forest	**Moderate**	**High**
Alpine/Subalpine	**Moderate**	**High**
Ecosystem Services		
Cultural Knowledge and Heritage Values	**High**	**High**
Flood and Erosion Control	**High**	**Moderate**
Fresh Water	**High**	**High**
Food and Fiber	**Moderate-High**	**High**
Aesthetic Values	**Moderate**	**High**
Recreation and Tourism	**Moderate-High**	**Moderate**

[7] The vulnerability assessment workshop approach was not applied to Molokaʻi.

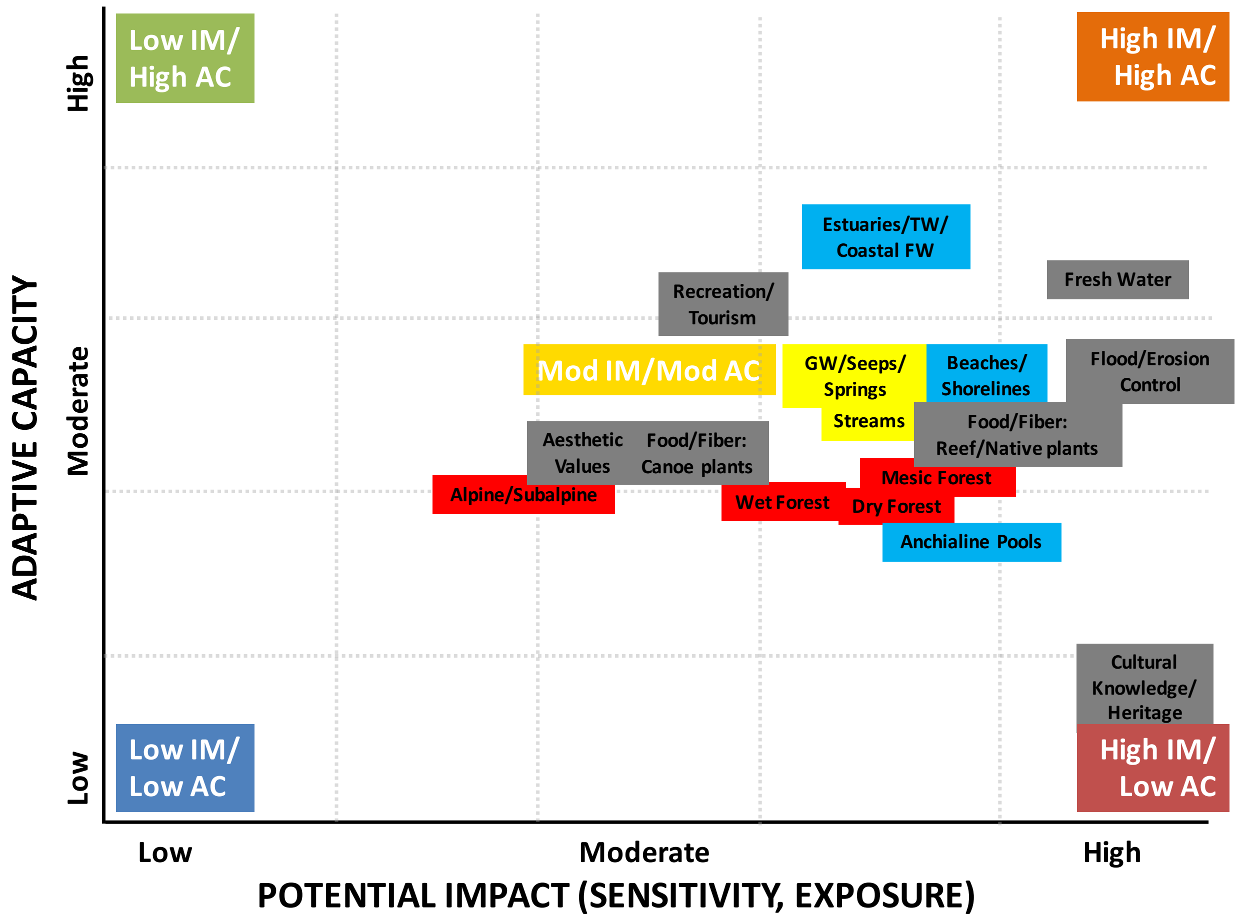

Figure 8. Overall vulnerabilities of Maui Nui habitats and ecosystem services based on the climate and non-climate sensitivity and exposure, and adaptive capacity assessment. Overall vulnerability increases with increasing sensitivity and exposure (i.e. potential impact) and decreasing adaptive capacity. Habitats listed near the upper left region were assessed as less vulnerable than those listed in the lower right region. TW: Tidal wetlands, FW: Freshwater, GW: Groundwater Color code: Terrestrial habitats (red), Coastal habitats (blue), Aquatic habitats (yellow), Ecosystem services (grey)

Coastal Habitats

Workshop participants classified coastal habitats on Maui, Lānaʻi, and Kahoʻolawe as beaches and shorelines; estuaries, tidal wetlands, and coastal freshwater wetlands; and anchialine pools. **Beach and shoreline habitats** occur in low-lying coastal areas on Maui Nui and include sandy beaches, boulder/cobblestone/rocky beaches, rocky cliffs and coastal shelves (limestone or lava), dunes, coastal shrubs and strands, and man-made coastal structures. **Estuarine and tidal wetland habitats** are characterized by brackish water conditions resulting from both freshwater and tidal influence. A range of sub-habitats fall into the estuary and tidal wetland classification, including embayments, stream mouths, salt marshes, tidal flats, brackish coastal plain wetlands, and fishponds. **Coastal freshwater wetlands** consist of ponded fresh water derived from precipitation, river and stream runoff, and groundwater inflow. **Anchialine pools** are landlocked pools found on limestone or lava flows, characterized by subsurface hydrological connectivity, but lacking surface connection to the ocean. Maui has many anchialine pools, while Kahoʻolawe has one pool with very high salinity.

Vulnerability Assessment Results

Beaches and Shorelines

Beach and shoreline habitats on Maui Nui were evaluated to have *moderate-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. Sea level rise, tropical storms, and extreme precipitation events accelerate coastal erosion and increase susceptibility to inundation. Along with drought, wildfire, and flooding, these factors influence vegetative composition, with potential implications for the persistence of native species. Non-climate stressors (e.g., development, agricultural conversion, roads, recreation, invasive ungulates, and invasive vegetation) compound climate-driven habitat reductions and vegetative shifts, and also degrade remnant habitat quality by promoting runoff and erosion and facilitating invasive vegetation establishment. The adaptive capacity of beach and shoreline habitats is bolstered by the fact that they are highly valued, highly managed, and in some areas, have protected status. However, the majority of beach and shoreline habitats have been degraded and fragmented by human activity. Development and other human land uses also prevent landward habitat migration of these habitats in response to sea level rise, and impair the natural resistance and recovery of coastal habitats experiencing disturbance.

Estuaries, Tidal Wetlands, and Coastal Freshwater Wetlands

Estuaries, tidal wetlands, and coastal freshwater wetlands were evaluated to have *moderate* vulnerability to climate change due to *moderate-high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *moderate-high* adaptive capacity. Sea level rise, saltwater intrusion, extreme precipitation events, tropical storms, drought, and coastal and riverine flooding are likely to influence the abundance, distribution, hydrology, salinity, and sediment dynamics of tidal wetlands, estuaries, and freshwater coastal wetlands. These changes, along with shifts in water temperature, pH, wildfire, and disease incidence, will drive shifts in vegetative composition, affecting habitat suitability for a variety of wildlife species. Non-climate stressors (e.g., development, agricultural conversion, roads, recreation, water diversions, invasive ungulates, and invasive vegetation) compound climate-driven habitat reductions and vegetative shifts, and also degrade remnant habitat quality by increasing runoff, erosion, and contaminant delivery. The adaptive capacity of these habitats is bolstered by the fact that they are highly valued, highly managed, and in some areas, have protected status. However, significant estuarine and coastal wetland areas on Maui have been degraded and fragmented by human activity. Development and other human land uses also prevent landward habitat migration in response to sea level rise and impair the natural resistance and recovery of coastal habitats experiencing disturbance. Additionally, societal support for managing and conserving coastal habitats is low, and some current management actions (e.g., water supplementation) may not be possible in a drier climate.

Anchialine Pools

Anchialine pool habitats were evaluated to have *moderate-high* vulnerability to climate change due to *high* sensitivity to climate and non-climate stressors, *high* exposure to projected future climate changes, and *low-moderate* adaptive capacity. Anchialine pools are sensitive to climate-driven changes in pool salinity or water depth caused by precipitation changes, storm surge, or saltwater intrusion; salinity and depth changes can be exacerbated by development and water diversions that alter groundwater recharge and withdrawal. Additionally, anchialine pools are sensitive to sea level rise, which may increase pool vulnerability to invasive species, as well as pool distribution, particularly if development blocks landward migration. Anchialine pool shrimp are also sensitive to pollutants and water temperature. The adaptive capacity of anchialine pools may be bolstered by subsurface connectivity, protection through natural area reserves, and knowledge gained through successful restoration efforts on other islands. However, anchialine pools are less valued by the public than other aquatic systems, and face competing interests with development and upstream water uses. Additionally, a lack of knowledge about individual pool aquatic assemblages and hydrodynamics make it difficult to know how each pool will respond to or recover from changes.

Adaptation Planning Results

Table 9 presents a summary of possible adaptation strategies and actions for Maui Nui coastal 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 9 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 9. Summary of possible adaptation strategies and actions for Maui Nui coastal habitats.

Adaptation Category	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Restore coastal habitats	• Utilize exclusion fencing and restoration in upland areas to enhance erosion control • Remove and control invasive and alien species in wetlands
	Restore and conserve native shoreline habitat	• Nourish beaches in areas where habitat retreat is not an option
	Maintain/improve water quality and quantity	• Investigate and reduce non-point source pollution • Promote and enforce use of best management practices (BMPs) to improve water quality • Manage runoff (stormwater, wastewater, nutrients) in areas affected by human activity
Resilience *Near- to mid-term approach*	Restore coastal habitats	• Restore dune and coastal strand habitats • Outplant native species in current and potential future coastal wetland habitats
	Preserve water supplies by increasing water use efficiency	• Improve rainfall capture to decrease groundwater withdrawals
	Implement climate-informed coastal zoning protections	• Modify the formula for erosion control to incorporate data on climate change • Revise setback requirements to account for projected sea level rise • Incorporate climate change into Special Management Area siting and permitting • Use gap analysis planning to identify areas that need protection based on specific climate-informed criteria
	Enhance habitat and species resilience	• Develop genetic "banks" (e.g., seed banks, captive breeding programs)
Response	Implement climate-informed	• Limit development in most vulnerable sites

Adaptation Category	Adaptation Strategy	Specific Adaptation Actions
Long-term approach	coastal zoning protections	
	Protect current and future habitat	• Establish shoreline setbacks • Identify and protect low-lying areas where wetlands and anchialine pools can migrate
	Anticipate and facilitate habitat migration	• Limit development in inland/upland areas where coastal habitats may migrate • Identify and protect currently vulnerable areas and areas of possible habitat migration based on available data, including existing infrastructure lifetime
Knowledge *Near- to long-term approach*	Anticipate and facilitate habitat migration	• Conduct a cost-benefit analysis for a range of alternatives based on climate change vulnerability assessments and prioritization processes
	Protect current and future habitat	• Use gap analysis planning to identify areas that need protection based on specific climate-informed criteria
	Monitor pollutants to protect water quality	• Monitor point- and non-point source pollutants associated with agriculture and development (e.g., fertilizers, insecticides, agricultural byproducts)
Collaboration *Near- to long-term approach*	Build support for coastal habitat protection with climate-informed public education and advocacy	• Engage community groups, develop constituencies, align interest groups, and mobilize people to demand conservation action • Conduct climate-informed public education and outreach about protected areas and habitats at risk

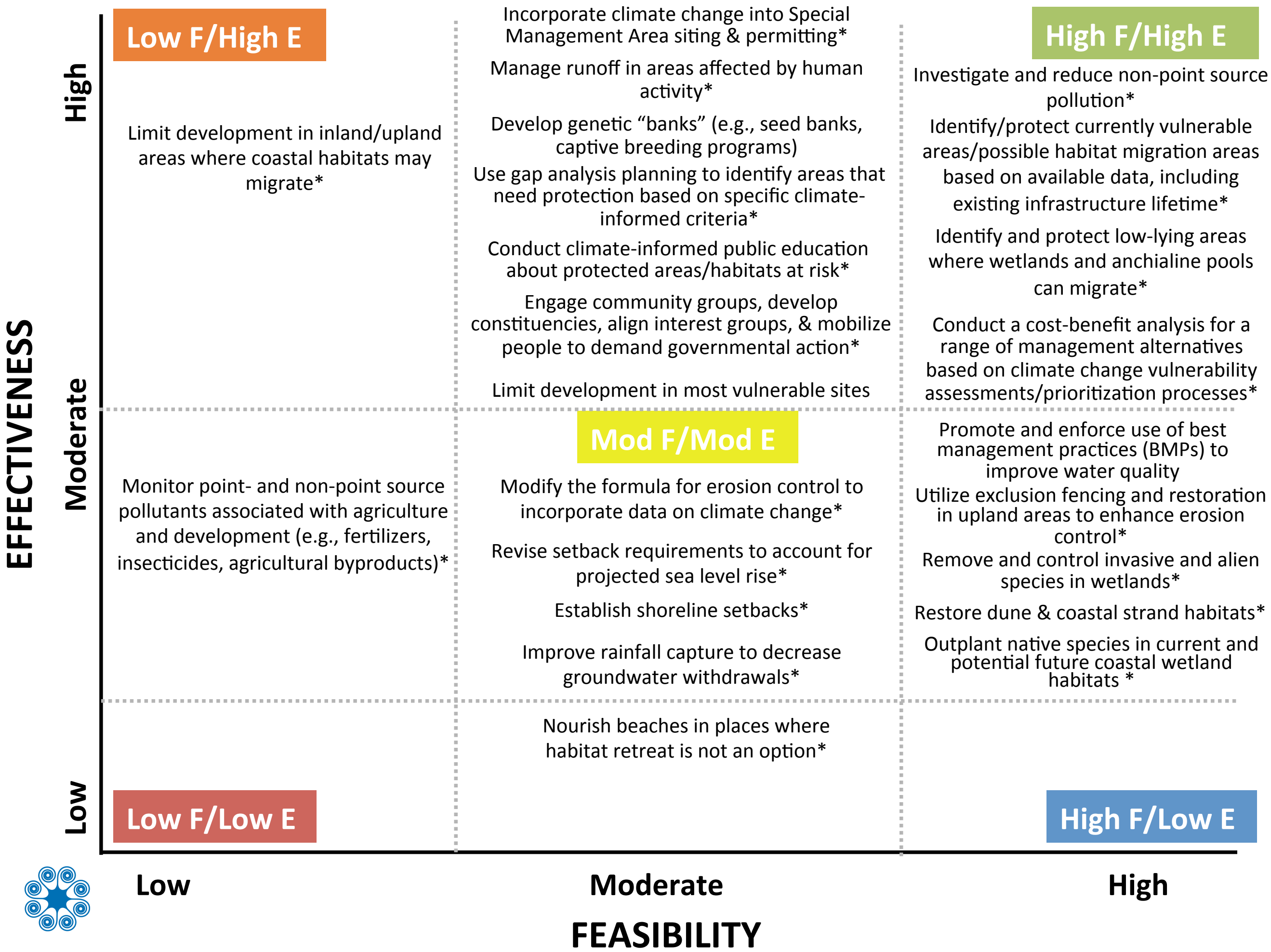

Figure 9. Maui Nui coastal habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having 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.

Aquatic Habitats

Workshop participants classified aquatic habitats on Maui, Lānaʻi, and Kahoʻolawe as streams, groundwater, seeps, and springs. Perennial and intermittent **streams** typically have high flow variability due to small catchment basins, steep slopes, and limited channel storage. **Groundwater systems** include freshwater lenses floating over saltwater on flank lavas and high-level or perched water impounded by low-permeability features such as volcanic dikes. Terrestrial perennial **seeps and springs** can be found along banks of severely incised streams and coastal rock faces. On Maui, springs also emerge from perched aquifers on Keʻanae Point.

Vulnerability Assessment Results

Streams

Stream 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. Streams are sensitive to climate changes that reduce water availability or alter streamflow volume, including precipitation amount and timing, drought, tropical storms, flooding, and air temperature. Stream fauna are also sensitive to climatic factors and disturbance regimes that impair water quality, including increased stream temperature and wildfire. Non-climate stressors such as agriculture, pollution and poisons, and development further reduce water quality by introducing contaminants and increasing sediment loads and/or stream temperatures. Additionally, water diversions magnify climate-driven reductions in streamflow, reducing aquatic habitat availability, connectivity, and quality. Despite significant modification, a majority of Maui's perennial streams remain connected to the ocean. Restoration efforts indicate that streams are able to recover from human impacts if streamflow is restored, although highly endemic biota and low biodiversity (relative to mainland systems) make stream fauna vulnerable to climatic or other change. Although streams are valued for a variety of purposes (e.g., public trust uses, recreation opportunities, agricultural and urban uses), offstream uses compete for water needed to support a functioning stream ecosystem, and these conflicts will likely increase in a drier climate.

Groundwater, Seeps, and Springs

Groundwater and seep and spring 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. Groundwater, seeps, and springs are sensitive to climate-driven changes and non-climate stressors that affect groundwater recharge, storage, and water quality. Tropical storms promote recharge while shifts in precipitation amount and timing and drought potentially reduce recharge, increasing vulnerability to saltwater intrusion. Groundwater recharge and storage are also negatively impacted by urban water withdrawals and water diversions. Comparatively, agricultural irrigation promotes groundwater recharge, but irrigation contributions have been declining over the past several decades, and the future of large-scale agriculture is uncertain with the recent cessation of sugarcane production. The extent and integrity of groundwater, seep, and spring habitats is threatened by increasing withdrawal rates; the location of a given system, along with current and past management, will affect its ability to resist and recover from impacts. Workshop participants indicated that Maui's groundwater, seeps, and springs are moderately valued by the public. However, these habitats compete for water with a variety of off-stream water uses, and these conflicts may increase in a drier climate.

Adaptation Planning Results

Table 10 presents a summary of possible adaptation strategies and actions for Maui Nui aquatic 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 10 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 10. Summary of possible adaptation strategies and actions for Maui Nui aquatic habitats.

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)

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
	Maintain and enhance groundwater quality and quantity	• Adopt well source protection ordinances
	Improve water conservation efforts	• Develop a water budget to account for all water sources, connectivity, uses/withdrawals, and disposal/discharges
Resilience *Near- to mid-term approach*	Increase streamflow to protect habitat and water supply	• Establish and enforce mandated instream flow standards • Encourage non-extractive water uses (e.g., taro farming)
	Protect forests to increase recharge and water retention	• Support healthy native forests through land acquisition and plant restoration
	Restore streamflows to restore connectivity, stream quality, and native species movement and re-establishment	• Modify culverts to accommodate extreme flooding • Modify stream crossings to enhance fish passage and habitat connectivity
	Mandate acquisition of new technologies to maintain and enhance water quality	• Install diversion gates • Extract sodium to increase fresh water supplies
Response *Long-term approach*	Use assisted colonization to restore rare species	• Identify and prioritize suitable habitat based on factors that suggest long-term ecological sustainability
	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)
Knowledge *Near- to long-term approach*	Collect data on stream habitats	• Add additional gauges to monitor streamflow, water temperature, and salinity • Create a flexible monitoring system to track water extraction, including who is withdrawing water and for what purpose • Install automatic sensors that monitor streams 24/7
	Monitor pollutants to protect water quality	• Monitor point- and non-point source pollutants associated with agriculture and development (e.g., fertilizers, insecticides, agricultural byproducts) • Monitor and regulate salinity and other indicators of water quality in wells and groundwater
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 • Conduct place-based education to encourage watershed conservation

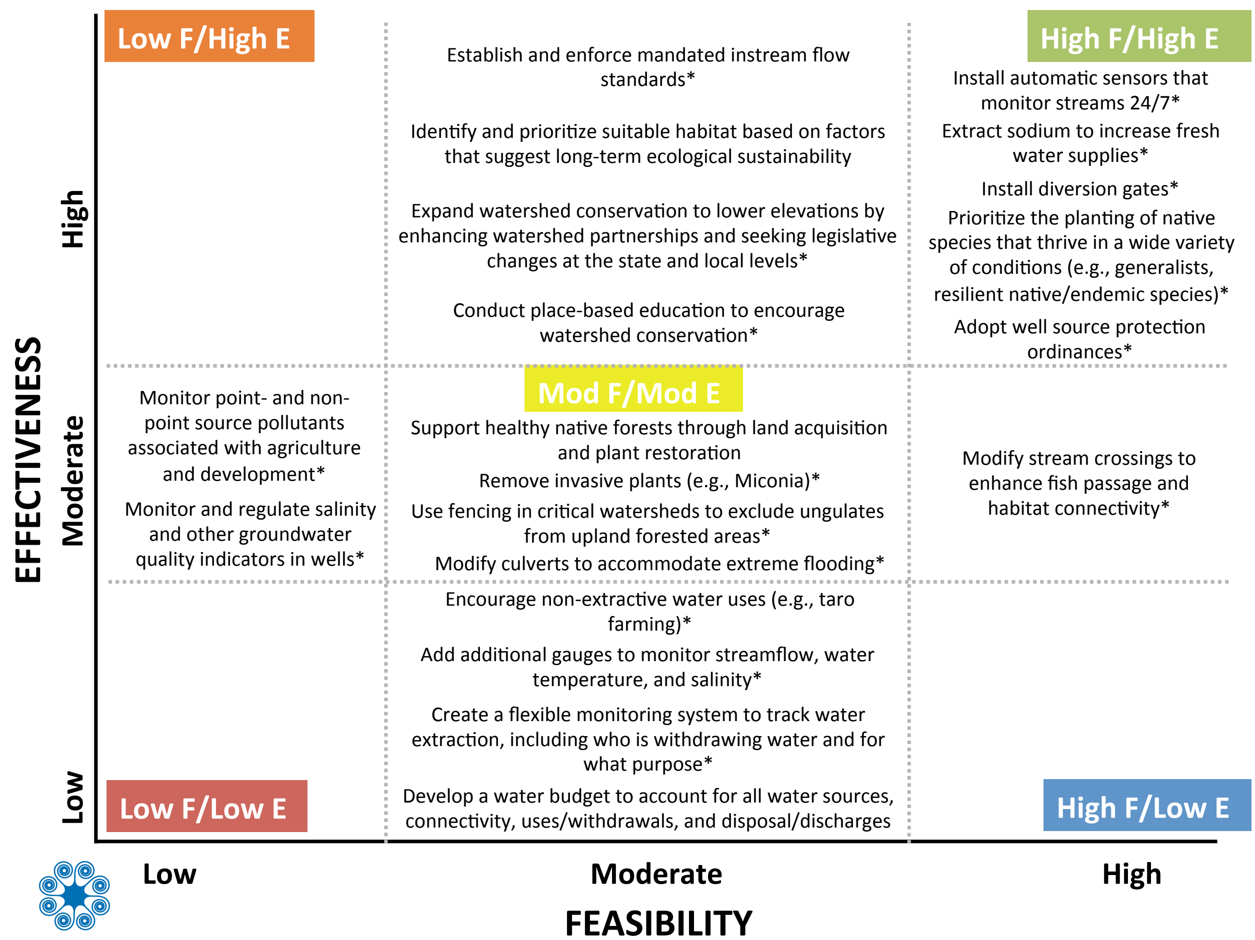

Figure 10. Maui Nui aquatic habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having 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 Hawaiʻi 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

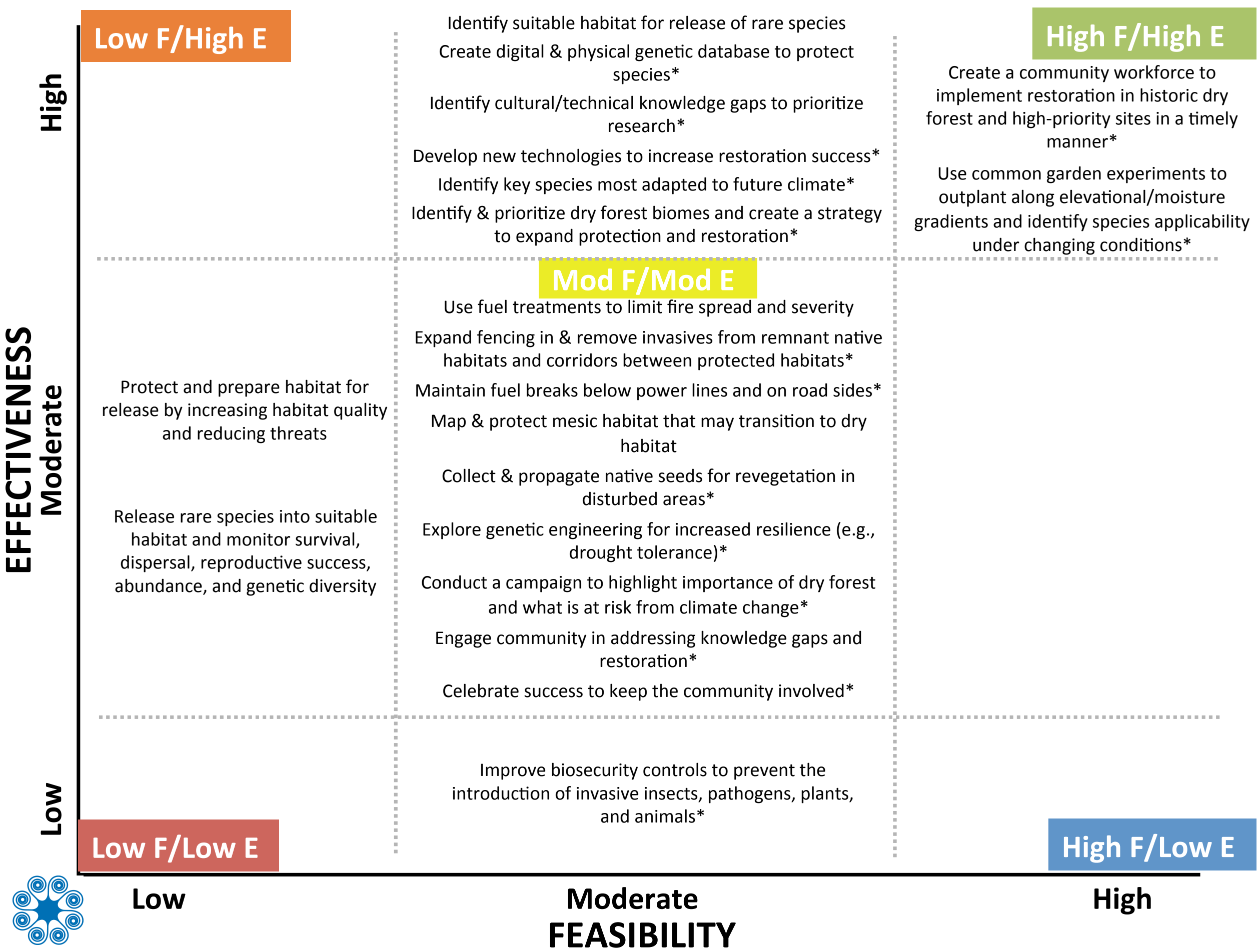

Figure 11. Maui Nui dry forest habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions 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

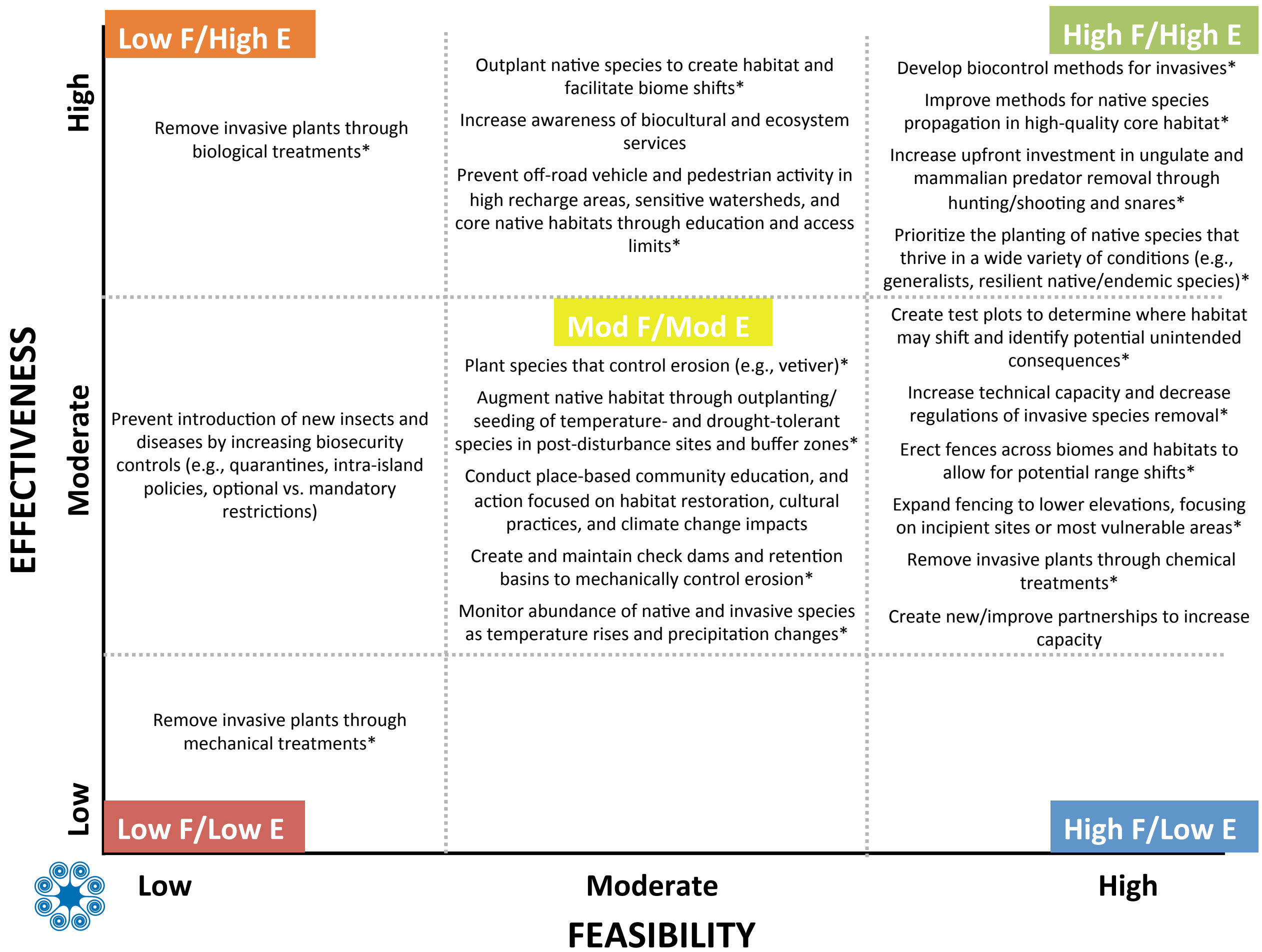

Figure 12. Maui Nui mesic and wet forest habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those 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

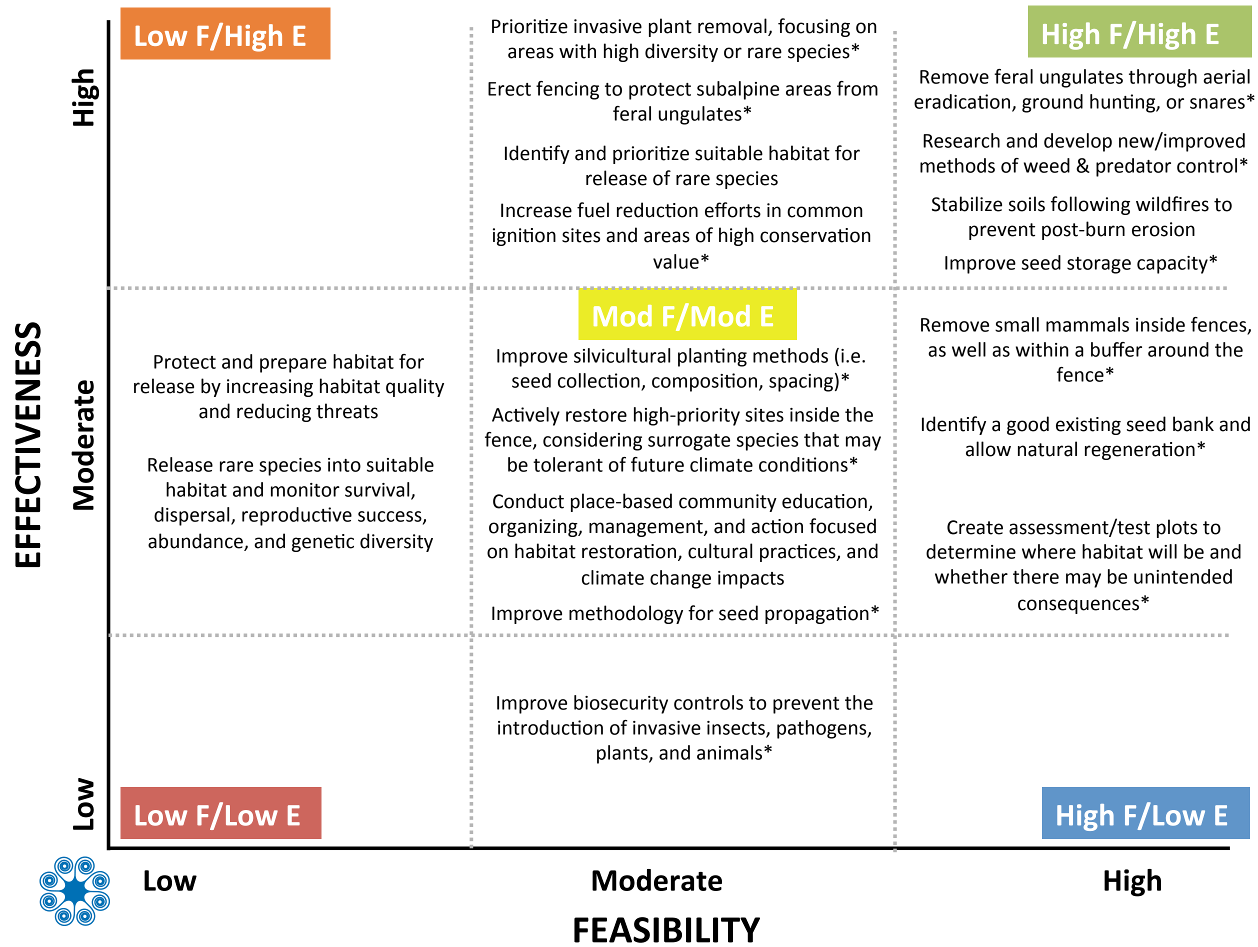

Figure 13. Maui Nui alpine and subalpine habitat adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those 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

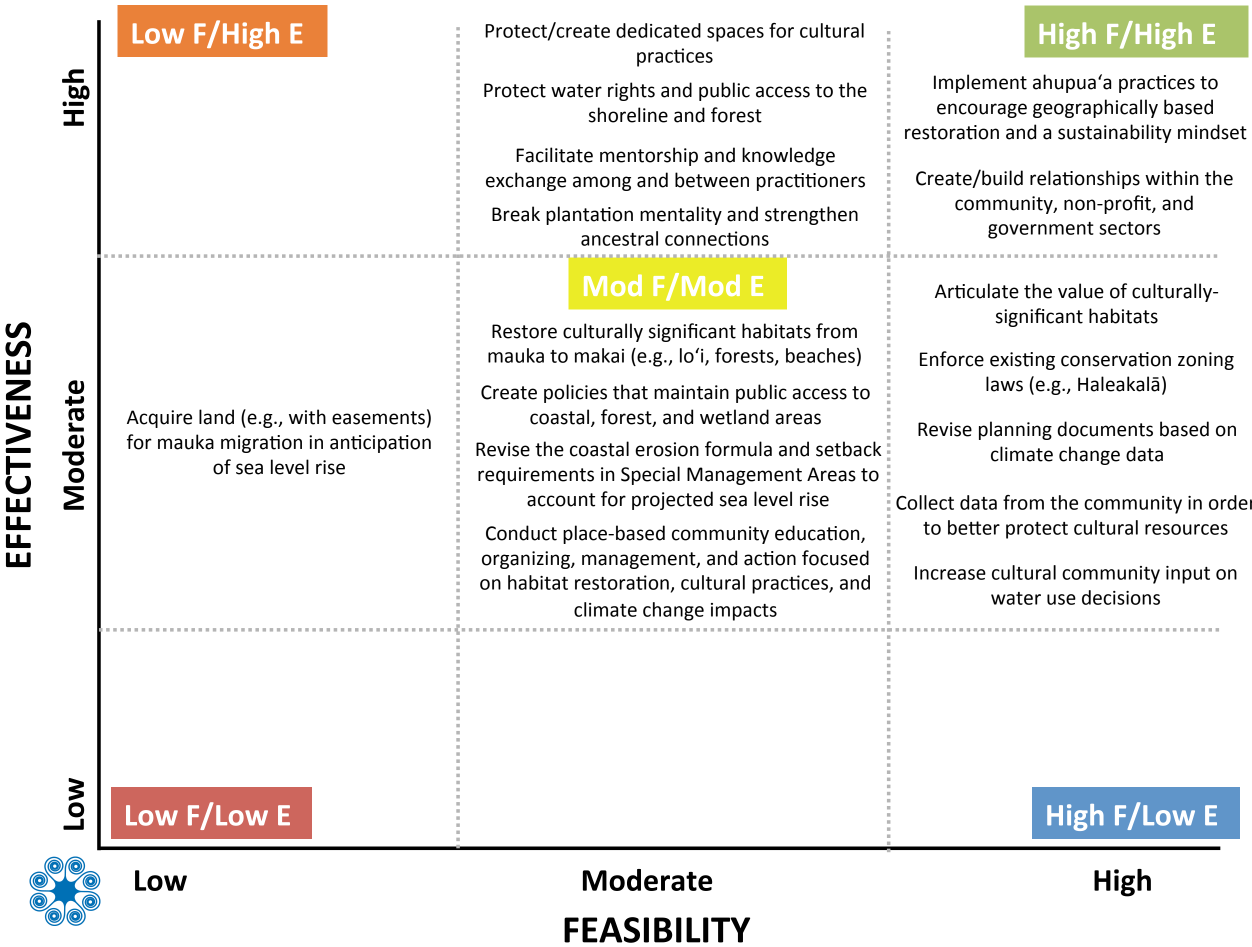

Figure 14. Maui Nui cultural knowledge and heritage values adaptation actions plotted according to implementation feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability). Those actions having high feasibility and effectiveness appear in the upper right corner 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

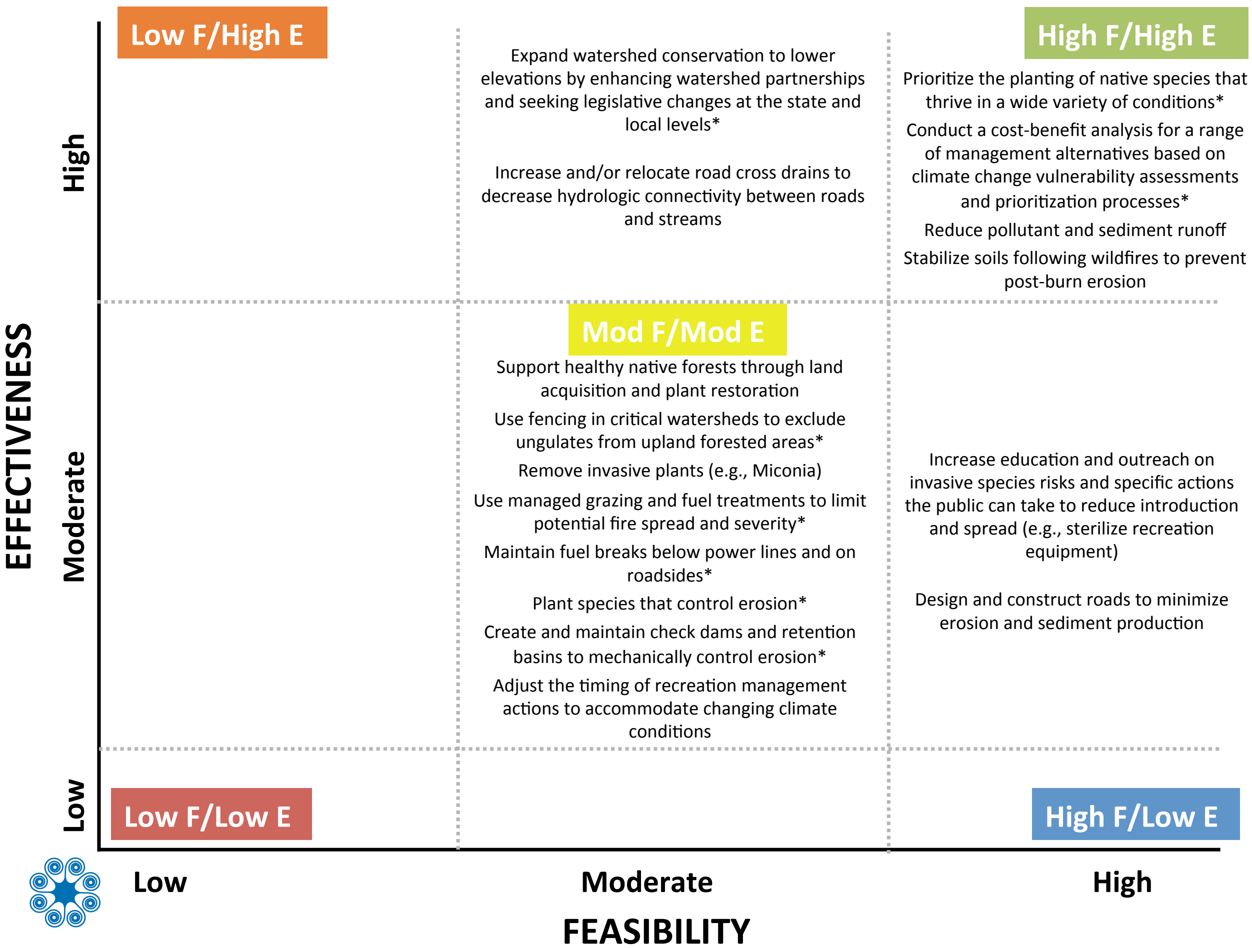

Figure 15. Maui Nui flood and erosion control adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions 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.

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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

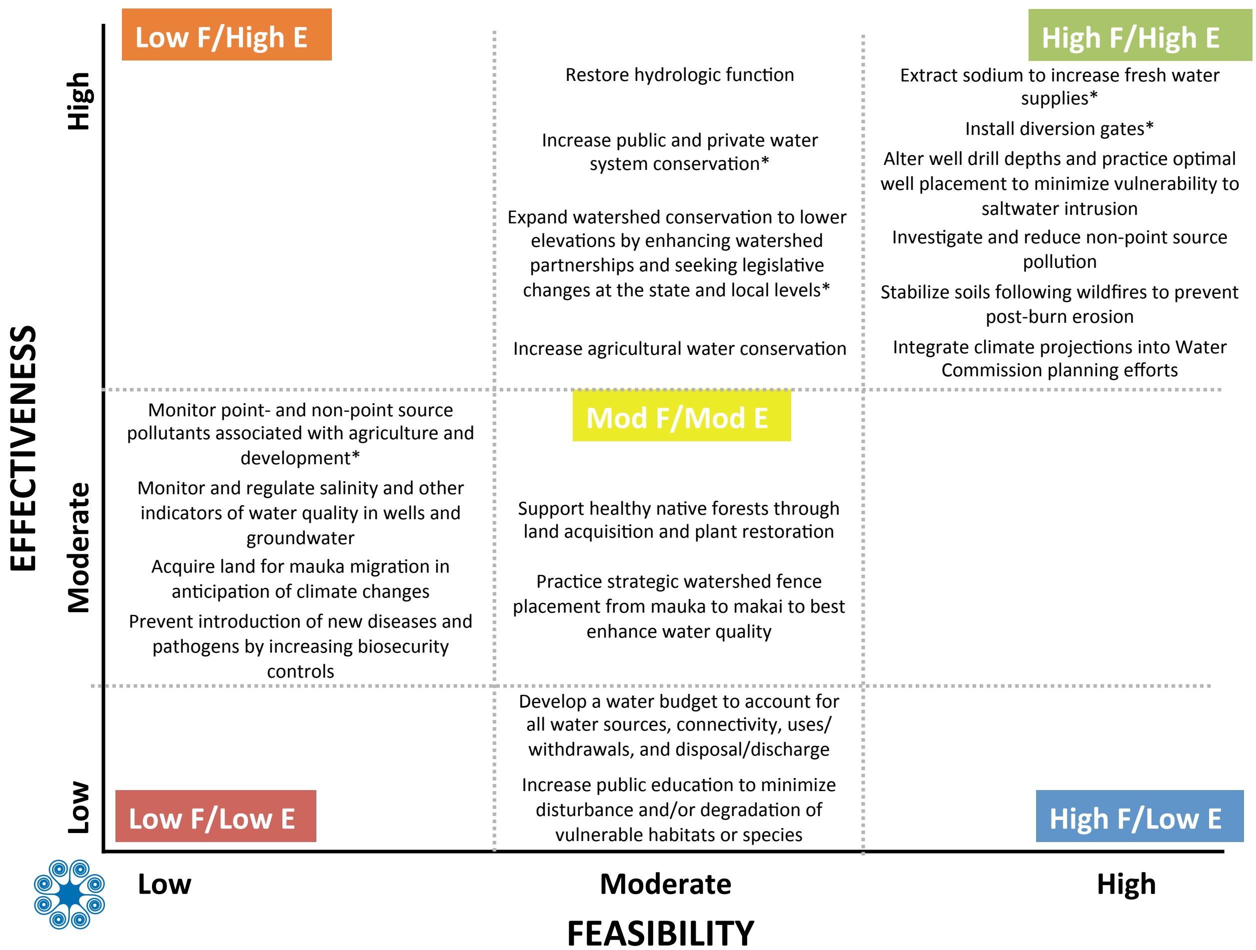

Figure 16. Maui Nui fresh water adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having 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

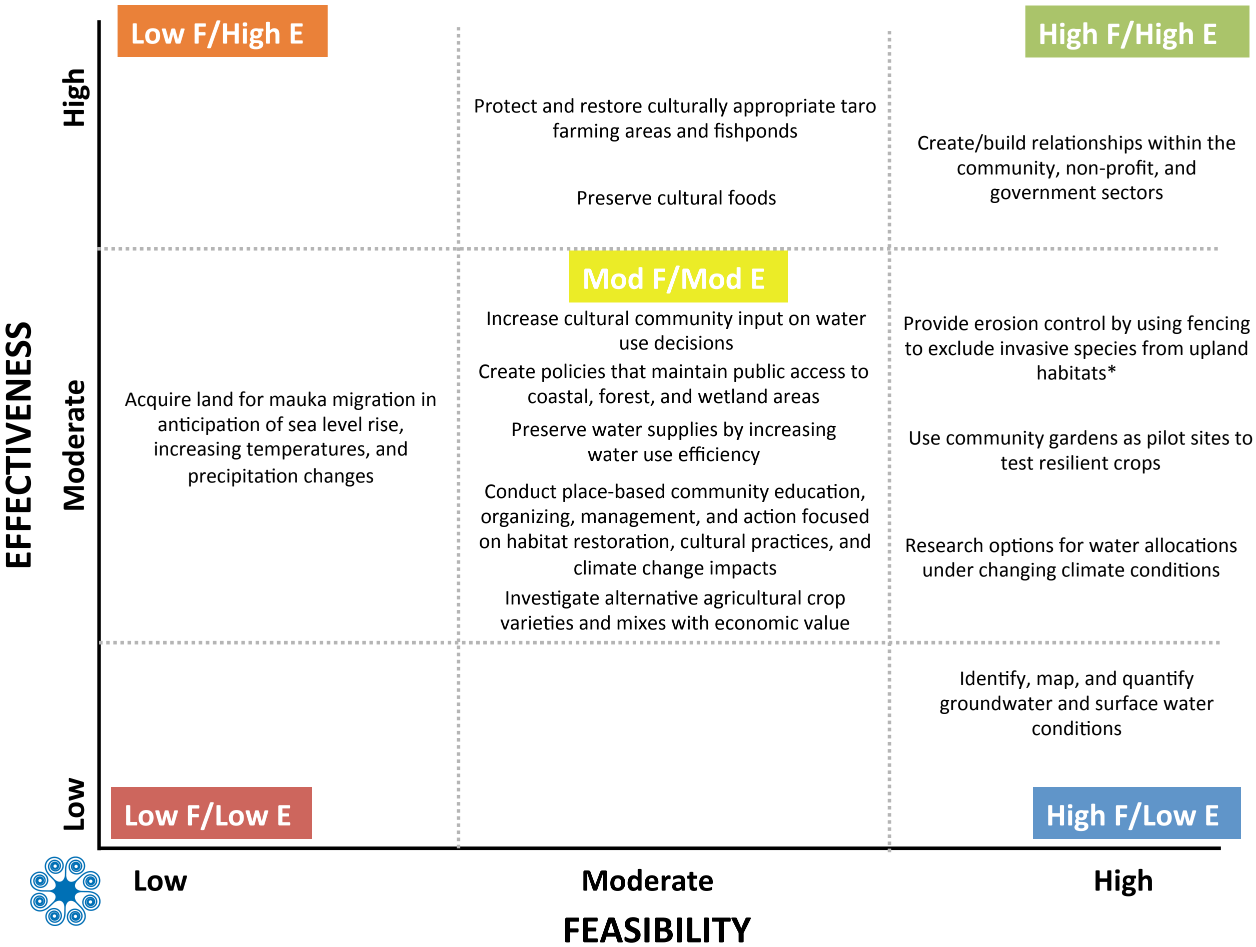

Figure 17. Maui Nui food and fiber adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having 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.

Aesthetic Values

Aesthetic ecosystem services include the value of visual scenery, emotional response, and appreciation of the natural environment experienced by humans (e.g., sand between toes, smell of a plant, joy of a sunset). The perception of visual aesthetic value increases with perceived naturalness, well-preserved man-made cultural elements, percentage of plant cover, presence of water or mountains, and landscape heterogeneity.

Vulnerability Assessment Results

Aesthetic value ecosystem services on Maui Nui 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 *moderate* adaptive capacity. This ecosystem service is sensitive to factors that impact or alter iconic or highly valued natural areas (e.g., beaches, waterfalls), including sea level rise, coastal erosion, and changes in the amount of precipitation. Disturbances, such as wildfire, tropical storms/hurricanes, and insect outbreaks, may cause noticeable damage to these natural areas, affecting people's enjoyment of natural and cultural features. Additionally, development and agriculture/aquaculture activities can also cause damage or exacerbate the impact of climate stressors. Tourism is a large contributor to the economy of Maui Nui, which is known for its beautiful landscapes, so public support for aesthetic values is relatively high. However, this service receives little support as a management priority.

Adaptation Planning Results

Table 18 presents a summary of possible adaptation strategies and actions for Maui Nui aesthetic 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 18 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 18. Summary of possible adaptation strategies and actions for Maui Nui aesthetic values.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	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
	Manage invasive species	• Improve biosecurity controls to prevent the introduction of invasive insects, pathogens, plants, and animals
	Improve water conservation efforts	• Increase agricultural water conservation (i.e. promote soil moisture management, capture rain water)
Resilience *Near- to mid-term approach*	Maintain intact, native-dominated ecosystems	• Support healthy native forests through land acquisition and plant restoration • Consider climate projections in the timing and seasonality of planting to promote natural recruitment
Response *Long-term approach*	Implement climate-informed coastal zoning protections	• Revise setback requirements to account for projected sea level rise • Incorporate climate change into Special Management Area siting and permitting
	Anticipate and facilitate habitat migration	• Implement living shorelines and green infrastructure • Limit development in inland/upland areas where coastal habitats may migrate
Knowledge *Near- to long-term approach*	Conduct research to support adaptive policies and technology	• Identify gaps in cultural and technical knowledge to prioritize research needs • Research and develop new/improved methods of small predator and weed control
Collaboration *Near- to long-*	Build support through public education and advocacy	• Conduct climate-informed public education and outreach about protected areas and habitats at risk

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
term approach		• Conduct place-based education to encourage watershed conservation • Create remote sites and viewpoints and post public signage about the natural and cultural importance of habitats

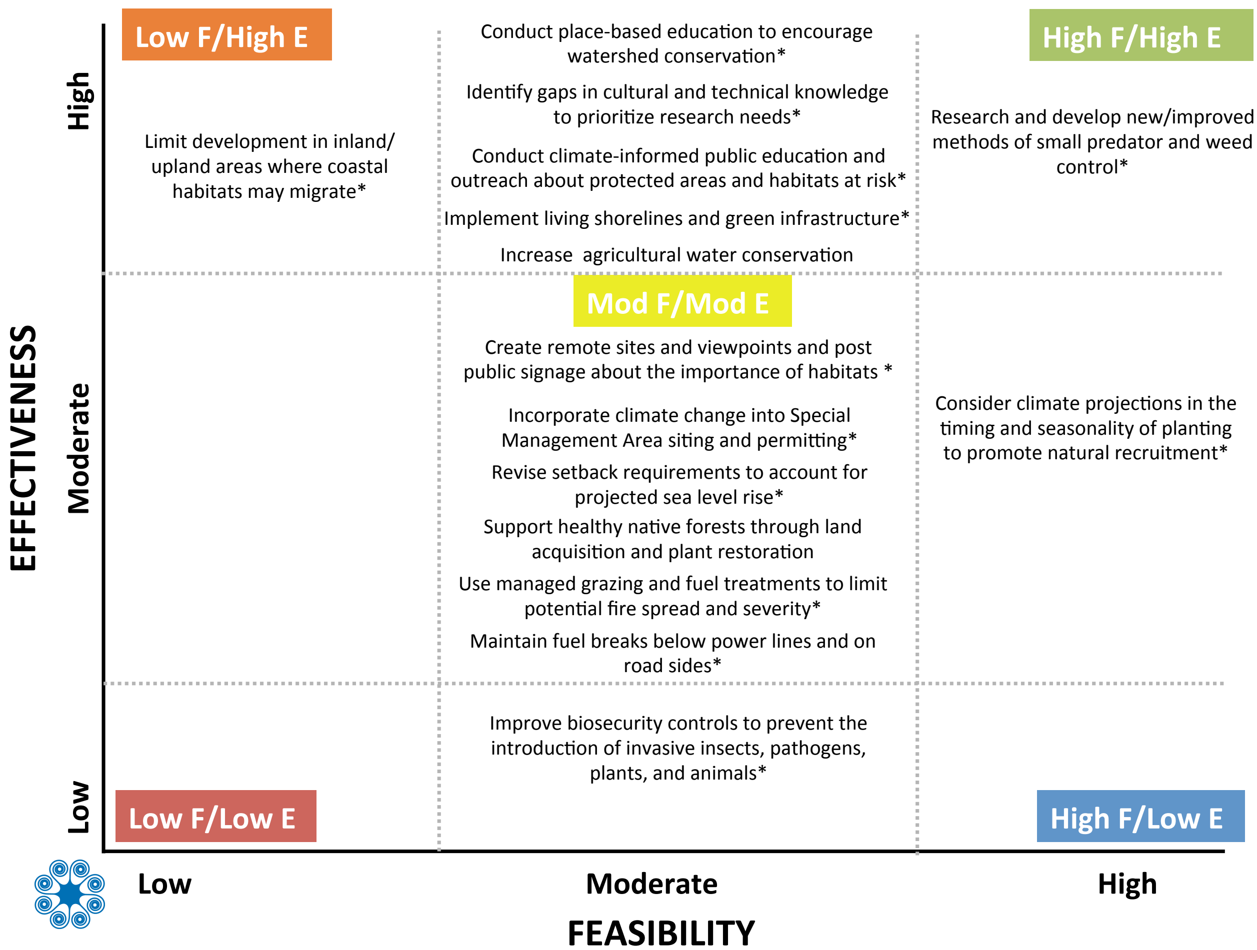

Figure 18. Maui Nui aesthetic values adaptation actions plotted according to implementation feasibility and effectiveness. Those actions having high feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability) appear in the upper right corner and those actions having 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.

Recreation and Tourism

Maui Nui's native ecosystems and cultural landscapes provide a diversity of recreation and tourism opportunities. Mauka activities include hiking, camping, bird watching, and sport hunting; makai activities include hiking, wildlife viewing, beach access, sport fishing, snorkeling and scuba diving, whale watching, and other water-based activities. Cultural tourism (e.g., visiting historic sites), ecotourism (e.g., enjoying scenic views/forested landscapes), and geotourism (e.g., visiting volcanic areas) occur across the mauka to makai continuum.

Vulnerability Assessment Results

Maui Nui recreation and tourism was 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-high* adaptive capacity. Recreation and tourism are sensitive to climatic factors that reduce the integrity or naturalness of native systems or affect the health and behavioral patterns of wildlife, including drought, low streamflow, sea surface temperature changes, and increasing air temperatures. Recreation and tourism are also sensitive to factors such as sea level rise, flooding, tropical storms, extreme precipitation events, and wildfire, which contribute to loss of recreation and tourism opportunities (e.g., physical loss of beaches, loss of access in burned or flooded areas). Insects and disease also degrade tourism and recreation experiences by negatively impacting Hawaiian landscapes and wildlife, and posing a health hazard to visitors. A variety of non-climate stressors threaten recreation and tourism by affecting natural landscape integrity and access and degrading water quality via elevated runoff. Land-use changes (e.g., urban development, agriculture, roads/highways/trails, water diversions, energy development) eliminate natural areas and alter ecosystem processes, impacting valued wildlife and native plant species characteristic of Hawaiʻi and exacerbating some impacts of climate change (e.g., flooding, erosion). Similarly, invasive species (e.g., ungulates, flammable grasses, trees, reptiles/amphibians, parasites/pathogens, social insects) displace native species and alter regional forest and watershed processes, affecting tourism and recreation access, quality, and safety.

As a main component of Maui Nui's economy, recreation and tourism are highly valued and management for these ecosystem services has moderate-high societal support. However, management can be challenging because recreation and tourism can potentially degrade other ecosystem services (e.g., fresh water, food production, aesthetic values, cultural services), though recreation and tourism can benefit some services as well (e.g., provide support for biodiversity and conservation).

Adaptation Planning Results

Table 19 presents a summary of possible adaptation strategies and actions for Maui Nui recreation and tourism, 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 19 plots adaptation actions according to implementation feasibility (action is capable of being implemented) and effectiveness (action reduces vulnerability).

Table 19. Summary of possible adaptation strategies and actions for Maui Nui recreation and tourism.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Improve fire prevention and response	• Enhance public awareness of the risks and consequences of wildfire to native plant ecosystems • Increase funding for support of fire response agencies and Community Wildland Protection Plans
	Improve water conservation efforts	• Increase public and private water system conservation (i.e. alter rate structure, use low-flow fixtures, detect and fix leaks) • Increase agricultural water conservation (i.e.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
		promote soil moisture management, capture rain water)
	Reduce non-climate stressors	• Increase public education to minimize disturbance and/or degradation of vulnerable habitats or species
	Manage invasive species	• Prevent introduction of new diseases and pathogens by increasing biosecurity controls (e.g., quarantines, interisland policies, optional vs. mandatory restrictions)
	Maintain/improve water quality and quantity	• Investigate and reduce non-point source pollution
Resilience *Near- to mid-term approach*	Ensure no new development occurs in areas that will likely be inundated in the future	• Change permitting rules to limit development along the shoreline and floodplain to higher elevations above the 100-year sea level rise projections
	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
	Enhance habitat and species resilience	• Identify and protect refugia (e.g., temperature-tolerant coral areas)
	Manage recreation sites to mitigate risks to public safety and infrastructure and to continue to provide recreation opportunities	• Modify existing infrastructure to better withstand future climate conditions • Adjust infrastructure maintenance schedule as needed to accommodate changing climate conditions • Relocate at-risk infrastructure
Response *Long-term approach*	Implement climate-informed coastal zoning protections	• Revise setback requirements to account for projected sea level rise • Modify the formula for erosion control to incorporate data on climate change • Limit development in most vulnerable sites
	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)
Knowledge *Near- to long-term approach*	Monitor pollutants to protect water quality	• Monitor point- and non-point source pollutants associated with agriculture and development (e.g., fertilizers, insecticides, agricultural byproducts)
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

DIVISION OF FORESTRY AND WILDLIFE
MANAGEMENT GUIDELINES

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

DIVISION OF FORESTRY AND WILDLIFE
MANAGEMENT GUIDELINES

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.