U.S. Fish & Wildlife Service

Hakalau Forest National Wildlife Refuge

Comprehensive Conservation Plan

A Vision of Conservation

Hakalau Forest National Wildlife Refuge (Ka Puʻuhonua Waonahele Aupuni ʻo Hakalau)

Aia nō i uka i ke kua koʻolau o Mauna Kea ka puʻuhonua waonahele aupuni ʻo Hakalau. He wahi kēia e hui ai kānaka e laulima ma o ke kaʻanalike aku, kaʻanalike mai i ka ʻike, ka noʻeau, a me ka mana i mea e hoʻopalekana, hoʻoikaika, a hoʻōla hou ai i ke ola maoli e noho ana ma ka waonahele. Ua kapa ʻia ka inoa ʻo Hakalau no ka nui o nā haka e noho ʻia e nā manu ʻōiwi. I kēia lā ʻo Hakalau kekahi o nā home nunui no ka hui manu Hawaiʻi ʻane make loa. Kīkaha aʻela nā manu, nā pua laha ʻole hoʻi, i ka ʻohuʻohu o Hakalau a ma lalo iki e mūkīkī i ka wai pua ʻōhiʻa. Ua nani nō ka ʻikena a ʻupu aʻela nō ke aloha no kēia ʻāina nei no nā kau a kau.

On the windward slope of majestic Mauna Kea, midway between summit and sea, lies Hakalau Forest NWR, a place where people come together to laulima, “many hands working together,” to share their knowledge, to share their skills, and to share their energy to protect, to enhance, to restore, and to respect Hawaiian wildlife. Known to Hawaiians as “place of many perches,” verdant rainforest supports the largest populations of endangered Hawaiian forest birds. Crimson, orange, yellow and green hued birds, the jewels of Hakalau, flit through the mist, pausing to sip nectar from ʻōhiʻa lehua, inspire joy and wonder for present and future generations.

Kona Forest Unit (Ka Waonahele o Kona)

Mai Mauna Kea nō a kaʻa i lalo, a hiki aku i Mauna Loa, ma laila nō ka waonahele o Kona, kahi e noho lewalewa ana nā ao ʻōpua i ka ʻuhiwai e hōʻoluʻolu ana i ka ulu lāʻau. ʻIke ʻia ka ʻio e kīkaha ana ma luna loa o ka papa kaupoku i hoʻowehiwehi ʻia me ka limu. Ma lalo o ke kaupoku koa me ʻōhiʻa, e ʻimi ana ka ʻalalā me kona hoa manu i ka huaʻai, wai pua, a me nā mea kolokolo i mea ʻai na lākou. Aia nō ma ka malumalu o nā ana kahe pele kahiko nā mea kanu kākaʻikahi o ka ʻāina, a me nā iwi o nā manu make loa ma Hawaiʻi. Kuahui maila nō nā hoa mālama ʻāina i ola hou ka nohona o nā mea ʻane make loa ma kēia ʻāina nui ākea.

On leeward Mauna Loa, where the clouds kiss the slopes with cool gray fog, lies the Kona Forest. ʻAlalā and other Hawaiian forest birds forage for fruit, nectar, and insects amongst the lichen-draped branches and canopy of the old-growth koa/ʻōhiʻa forest, while the ʻio soars overhead. In their damp darkness, ancient lava tubes and cave systems shelter rare plants, archaeological resources, and the bones of extinct birds. Conservation partners collaborate to restore habitat for the native and endangered species across the landscape.

Comprehensive Conservation Plans provide long-term guidance for management decisions and set forth goals, objectives, and strategies needed to accomplish refuge purposes and identify the Service's best estimate of future needs. These plans detail program planning levels that are sometimes substantially above current budget allocations and, as such, are primarily for Service strategic planning and program prioritization purposes. The plans do not constitute a commitment for staffing increases, operational and maintenance increases, or funding for future land acquisition.

ʻŌhiʻa tree

Hakalau Forest National Wildlife Refuge
Comprehensive Conservation Plan

Prepared by:

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U.S. Fish and Wildlife Service
Pacific Islands Planning Team
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September 2010

Approved: Richard Hannan 9/30/10
Acting Regional Director, Pacific Region RICHARD R. HANNAN — Date
Portland, Oregon

U.S. Fish and Wildlife Service
Hakalau Forest National Wildlife Refuge
Comprehensive Conservation Plan
Approval Submission

In accordance with the National Wildlife Refuge System Administration Act of 1966, as amended, a Comprehensive Conservation Plan (CCP) has been prepared for Hakalau Forest National Wildlife Refuge. The purpose of the CCP is to specify a management direction for the Refuge for the next 15 years. The CCP charts a vision of the Refuge's future desired conditions, the types of habitat that will be provided, land protection, public use, partnership opportunities, and the management actions needed to achieve that vision. The effects of the CCP on the human environment were described in the Draft CCP and Environmental Assessment.

This CCP is submitted for approval by the Regional Director.

Submitted by:

Jim Kraus — 9/24/10
Date
Jim Kraus
Refuge Manager, Hakalau Forest National Wildlife Refuge

Concur:

Barry W. Stieglitz — 9/24/10
Date
Barry Stieglitz
Project Leader, Hawaiian and Pacific Islands National Wildlife Refuge Complex

Carolyn A. Bohan — 9/28/10
Date
Carolyn A. Bohan
Regional Chief, National Wildlife Refuge System

FINDING OF NO SIGNIFICANT IMPACT
for the
Hakalau Forest National Wildlife Refuge Comprehensive Conservation Plan
Hawai'i County, Hawai'i

The U.S. Fish and Wildlife Service (Service) has completed the Comprehensive Conservation Plan (CCP) and Environmental Assessment (EA) for Hakalau Forest National Wildlife Refuge (Refuge). The CCP will guide management of the Refuge for the next 15 years. The CCP and EA described the Service's proposals for managing the Refuge and their effects on the human environment under three alternatives, including the no action alternative.

Decision

Following comprehensive review and analysis of the three alternatives, the Service selected Alternative B for implementation because it is the alternative that best meets the following criteria:

- Achieves the mission of the National Wildlife Refuge System;
- Achieves the purposes of the Refuge;
- Will be able to achieve the vision and goals for the Refuge;
- Maintains and restores the ecological integrity of the habitats and populations on the Refuge;
- Addresses the important issues identified during the scoping process;
- Addresses the legal mandates of the Service and the Refuge;
- Is consistent with the scientific principles of sound wildlife management and endangered species recovery; and
- Facilitates priority public uses compatible with the Refuge's purposes and the Refuge System mission.

Summary of the Actions to be Implemented

Implementing the selected alternative will have no significant impacts on any of the environmental resources identified in the CCP/EA. Refuge management under the selected alternative will protect, maintain, and enhance habitat for priority species and resources of concern. The availability and quality of wildlife-dependent recreation on the Refuge will improve under the selected alternative. A detailed summary of the CCP actions we will implement can be found in Chapter 2, Table 2-1. Major management actions include:

- Protecting, restoring, and maintaining habitats including montane wet 'ōhi'a forest, montane mesic koa/'ōhi'a forest, dry koa/'ōhi'a/māmane forest, montane wet koa/'ōhi'a forest, montane mesic koa forest, lava tube and skylights, aquatic habitats, and grasslands. This will include additional fencing for new areas, increased control for threats such as ungulates, mammalian predators, invasive weeds, and pests and diseases, and expanded nursery capacity for restoration;
- Protecting, restoring, and maintaining the species that rely on the habitats above, with particular emphasis on listed species such as the Hawai'i 'ākepa, Hawai'i creeper, 'akiapōlā'au, 'alalā, 'ō'ū, 'io, 'alae ke'oke'o, nēnē, koloa maoli, 'ōpe'ape'a, Drosophila heteroneura, Asplenium peruvianum var. insulare, Clermontia lindseyana, Clermontia peleana, Clermontia pyrularia, Cyanea hamatiflora, Cyanea platyphylla, Cyanea shipmannii, Cyanea stictophylla, Cyrtandra tintinabula, Nothocestrum breviflorum, Phyllostegia

floribunda, Phyllostegia racemosa, Phyllostegia velutina, Portulaca sclerocarpa, Sicyos macrophyllus, and Silene hawaiiensis;

- Expanding public use opportunities by providing for a new interpretive trail and parking area, increasing volunteer opportunities and partnering, and enhancing cultural resources and historic site information and management;
- Closing public pig hunting on the Refuge; and
- Focusing scientific information and research needs to better support adaptive management on the Refuge.

Public Involvement and Changes to the Selected Alternative Based on Comments

Starting in 2008, the planning process incorporated public involvement in developing and reviewing the CCP. This included three public open houses, three planning updates, one interagency scoping meeting, one endangered forest bird workshop, updates provided through meetings with partners and elected officials, notices in the Federal Register, website postings, mail and email list circulations (including national organizations), news releases, and public review and comment on the draft CCP/EA during the public comment period of August 16-September 15, 2010. Public involvement details, our response to comments, and changes made to the CCP are outlined in detail in Appendix K. Based on the public comments we received no changes were made to the selected alternative.

Conclusions

Based on review and evaluation of the information contained in the supporting references, I have determined that implementing Alternative B as the CCP for management of Hakalau Forest National Wildlife Refuge is not a major Federal action that would significantly affect the quality of the human environment within the meaning of section 102(2) (c) of the National Environmental Policy Act of 1969. Accordingly, the Service is not required to prepare an environmental impact statement.

Richard Hannan

Acting Regional Director, Pacific Region RICHARD R. HANNAN
Portland, Oregon

9/30/10
Date

Supporting References

U.S. Fish and Wildlife Service. August 2010. Hakalau Forest National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Assessment.

U.S. Fish and Wildlife Service. September 2010. Hakalau Forest National Wildlife Refuge Comprehensive Conservation Plan.

Note: This Finding of No Significant Impact and supporting references are on file at the Hakalau Forest National Wildlife Refuge, 60 Nowelo Street, Suite 100, Hilo, Hawai‘i, 96720 and U.S. Fish and Wildlife Service, Division of Planning and Visitor Services, 911 NE 11th Avenue, Portland, Oregon, 97232. The CCP is also on our Web site: pacific.fws.gov/hakalauforest/planning.html. These documents are available for public inspection, and interested and affected parties are being notified of our decision.

Executive Summary

Hakalau Forest NWR Background:

Hakalau Forest National Wildlife Refuge (NWR) consists of the Hakalau Forest Unit and the Kona Forest Unit, collectively managed as the Big Island National Wildlife Refuge Complex. The Hakalau Forest Unit was established in 1985 to protect and manage endangered forest birds and their rainforest habitat. Located on the windward slope of Mauna Kea, Island of Hawaiʻi, this 32,733-acre unit supports a diversity of native birds and plants (27 of which are listed under the Endangered Species Act). The Kona Forest Unit was set aside in 1997 to protect native forest birds, the endangered ʻalalā (*Corvus hawaiiensis*, Hawaiian crow), and several listed plants. Located on the leeward slope of Mauna Loa, this 5,300-acre unit supports diverse native bird and plant species, as well as rare lava tube and lava tube skylight habitats.

Comprehensive Conservation Planning Process Summary:

Initial preplanning activities began in 2007. This period included team development and identification of management issues, vision, goals, and objectives. Public involvement began in 2009 with the scoping process and publication of our notice of intent to prepare a CCP. This period involved mailings of the planning update, a news release and website posting, two public open houses, an interagency scoping meeting, and briefings of public officials. In 2010, the draft CCP/EA was developed and circulated for public comment. Notification of this document as well as solicitation of public comment during the 30 day comment period was accomplished through a planning update, a notice of availability in the Federal Register, a news release and website posting, holding of a public open house meeting, and circulating announcements via email and list serves. Refuge responses to public comments received were incorporated as part of Appendix K.

Alternative Selected (Summary of Management):

Three alternatives were analyzed during the CCP process and public comment review period. Alternative B (the Refuge's preferred alternative) was chosen for implementation. This alternative focuses on protecting additional habitat; increasing management activities related to restoration and reforestation as well as controlling threats such as feral ungulates, invasive weed species, predator mammals, and other pests; better focusing and prioritizing of data collection and research for adaptive management; and expanding public use activities and collaborative partnering.

The vision (with Hawaiian translation) for Hakalau Forest NWR:

<u>Hakalau Forest National Wildlife Refuge (*Ka Puʻuhonua Waonahele Aupuni ʻo Hakalau*)</u>

Aia nō i uka i ke kua koʻolau o Mauna Kea ka puʻuhonua waonahele aupuni ʻo Hakalau. He wahi kēia e hui ai kānaka e laulima ma o ke kaʻanalike aku, kaʻanalike mai i ka ʻike, ka noʻeau, a me ka mana i mea e hoʻopalekana, hoʻoikaika, a hoʻōla hou ai i ke ola maoli e noho ana ma ka waonahele. Ua kapa ʻia ka inoa ʻo Hakalau no ka nui o nā haka e noho ʻia e nā manu ʻōiwi. I kēia lā ʻo Hakalau kekahi o nā home nunui no ka hui manu Hawaiʻi ʻane make loa. Kīkaha aʻela nā manu, nā pua laha ʻole hoʻi, i ka ʻohuʻohu o Hakalau a ma lalo iki e mūkīkī i ka wai pua ʻōhiʻa. Ua nani nō ka ʻikena a ʻupu aʻela nō ke aloha no kēia ʻāina nei no nā kau a kau.

On the windward slope of majestic Mauna Kea, midway between summit and sea, lies Hakalau Forest NWR, a place where people come together to laulima, "many hands working together," to share their knowledge, to share their skills, and to share their energy to protect, to enhance, to restore, and to respect Hawaiian wildlife. Known to Hawaiians as "place of many perches," verdant rainforest supports the largest populations of endangered Hawaiian forest birds. Crimson, orange, yellow, and green hued birds, the jewels of Hakalau, flit through the mist, pausing to sip nectar from ʻōhiʻa lehua, inspire joy and wonder for present and future generations.

Kona Forest Unit (*Ka Waonahele o Kona*)

Mai Mauna Kea nō a kaʻa i lalo, a hiki aku i Mauna Loa, ma laila nō ka waonahele o Kona, kahi e noho lewalewa ana nā ao ʻōpua i ka ʻuhiwai e hōʻoluʻolu ana i ka ulu lāʻau. ʻIke ʻia ka ʻio e kīkaha ana ma luna loa o ka papa kaupoku i hoʻowehiwehi ʻia me ka limu. Ma lalo o ke kaupoku koa me ʻōhiʻa, e ʻimi ana ka ʻalalā me kona hoa manu i ka huaʻai, wai pua, a me nā mea kolokolo i mea ʻai na lākou. Aia nō ma ka malumalu o nā ana kahe pele kahiko nā mea kanu kākaʻikahi o ka ʻāina, a me nā iwi o nā manu make loa ma Hawaiʻi. Kuahui maila nō nā hoa mālama ʻāina i ola hou ka nohona o nā mea ʻane make loa ma kēia ʻāina nui ākea.

On leeward Mauna Loa, where the clouds kiss the slopes with cool gray fog, lies the Kona Forest. ʻAlalā and other Hawaiian forest birds forage for fruit, nectar, and insects amongst the lichen-draped branches and canopy of the old-growth koa/ʻōhiʻa forest while the ʻio soars overhead. In their damp darkness, ancient lava tubes and cave systems shelter rare plants, archaeological resources, and the bones of extinct birds. Conservation partners collaborate to restore habitat for the native and endangered species across the landscape.

The six goals (with Hawaiian translation) for Hakalau Forest NWR:

Pahuhopu 1: E hoʻopalekana, mālama, a hoʻōla hou i ka waonahele ma Mauna Loa ma ke ʻano he wahi noho no nā mea a pau i mea e kūʻonoʻono hou ai ka nohona o nā mea ʻane make loa ʻo ia nō ʻo ʻoe ʻo nā manu, nā ʻōpeʻapeʻa, nā mea kanu, a me nā mea kolokolo ʻāina.

Goal 1: Protect, maintain, and restore subtropical rainforest community on the leeward slope of Mauna Loa as habitat for all life-history needs to promote the recovery of endangered species (e.g., forest birds, ʻōpeʻapeʻa, plants, and invertebrates).

Pahuhopu 2: E hoʻopalekana a mālama i nā ana kahe pele a me ke ola i ka puka mālamalama o nā ana kahe pele ma ka waonahele o Kona, e kālele ana hoʻi i ke ola o nā lāʻau ʻōiwi.

Goal 2: Protect and maintain lava tube and lava tube skylight habitat throughout the Kona Forest Unit, with special emphasis on their unique and endemic flora and fauna.

Pahuhopu 3: E hoʻopalekana, mālama, a hōʻola hou i ka waonahele ma ka ʻaoʻao koʻolau o Mauna Kea ma ke ʻano he wahi noho no nā mea a pau a me ko lākou pono ʻoia nō ʻoe ʻo nā manu, nā ʻōpeʻapeʻa, nā mea kanu, a me nā mea kolokolo ʻāina.

Goal 3: Protect, maintain, and restore subtropical rainforest community, on the windward slope of Mauna Kea as habitat for all life-history needs of endangered species (e.g., forest birds, ʻōpeʻapeʻa, plants, and invertebrates).

Pahuhopu 4: E hoʻopalekana a mālama i ka ʻāina nenelu ma Hakalau.

Goal 4: Protect and maintain wetland and aquatic habitats (e.g., streams and their associated riparian corridors, ponds, and bogs) on the Hakalau Forest Unit.

Pahuhopu 5: E hoʻopalekana a mālama i ka ʻāina mauʻu i mea e kākoʻo ai i ka hoʻōla hou ʻana i ka hui manu nēnē.

Goal 5: Protect and maintain grassland habitat to support nēnē population recovery.

Pahuhopu 6: E ʻohiʻohi i ka ʻikepili ʻepekema (waihona ʻike, nānā pono, ʻimi noiʻi, ana ʻike) e pono ai ka hoʻoholo ʻana i ke ʻano o ka hoʻokele ʻana iā Hakalau ma Mauna Kea a me Mauna Loa.

Goal 6: Collect scientific information (inventories, monitoring, research, assessments) necessary to support adaptive management decisions on both units of the Hakalau Forest NWR.

Pahuhopu 7: E kipa mai ka poʻe malihini a me ka poʻe makaʻāinana no ka hana manawaleʻa ʻana i mea e kamaʻāina ai lākou i ka nohona o ka waonahele a me ka ʻoihana mālama ma Hakalau.

Goal 7: Visitors, with a special emphasis on experience gained through volunteer work groups and local residents, understand and/or value the native forest environment and management practices at Hakalau Forest NWR.

Pahuhopu 8: E hoʻopalekana a mālama i nā kumu waiwai a me nā wahi pana Hawaiʻi no ka hoʻonaʻauao ʻana i nā hanauna o kēia wā a me ka wā e hiki mai ana.

Goal 8: Protect and manage cultural resources and historic sites for their educational and cultural values for the benefit of present and future generations of Refuge users and communities.

The objectives and major management strategies:

Objectives	CCP Action
1.1: Restore and Protect Native Montane Wet ʻŌhiʻa Forest (2,000-4,500 ft elevation) at KFU	3,000 acres. Remove ranch debris. Build and maintain 17 mile ungulate-proof fence. Remove pest animals. Eradicate/control invasive plants. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant threatened and endangered (T&E) plants in units 2 and 3 and build site specific fencing for these plants.
1.2: Restore, Protect, and Maintain Native Montane Mesic Koa/ʻŌhiʻa Forest (4,500-5,800 ft elevation) at KFU	1,800 acres. Remove ranch debris. Build and maintain fence, eradicate/control invasive plants, and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant native plants. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
1.3: Protect, Maintain, and Restore Native Dry Koa/ʻŌhiʻa/Māmane Forest (5,800-6,100 ft elevation) at KFU	500 acres. Remove ranch debris. Build and maintain fence, eradicate/control invasive plants, and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant T&E plants and build site specific fencing for these plants.
1.4: Develop and Implement Propagation and Outplanting Program at KFU	500 T&E plants and 2,000 native plants provided annually for restoration. Develop native plant nursery at Mauna Loa field camp site, collect seeds and cuttings, develop (in 7 years) staff, volunteer, and partnering programs.
1.5, 5.3: Investigate and Initiate Landscape-level Habitat Conservation Measures	LPP completed within one year. Identify habitats to support focal species; develop protection strategies; work proactively with partners, neighbors, and private landowners where appropriate to meet conservation goals and develop specific project proposals for land acquisition, cooperative agreements, and/or conservation easements as key conservation opportunities arise and willing parties are identified.
2.1: Protect & Maintain Lava Tube and Skylight Communities at KFU	Remove ranch debris. Build and maintain fence and develop site specific access protocols to limit human disturbance to habitat. Eradicate/control invasive plants, and remove pest animals. Conduct survey for pest animals (based on surveys control threats). Inventory and map communities and support additional investigations and research.
3.1: Protect and Maintain Native Montane Wet ʻŌhiʻa/Uluhe (*Dicranopteris* sp.) Forest (2,500-4,000 ft elevation) at HFU	7,000 acres. Remove pest animals, eradicate/control invasive plants, build site-specific fencing to protect T&E plant populations and *Carex* sp. bogs. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Inventory vegetation, complete Wilderness Study.

Objectives	CCP Action
3.2: Protect and Maintain Native Montane Wet ‘Ōhi‘a Forest (4,000-5,000 ft elevation) at HFU	8,200 acres. Maintain existing fence (units 1-8), build and maintain fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant native overstory koa and ‘ōhi‘a, T&E plants, and common understory plants. Build site specific fencing for T&E plants. Complete Wilderness Study.
3.3: Restore, Protect, and Maintain Native Montane Wet Koa/‘Ōhi‘a Forest (5,000-6,000 ft elevation) at HFU	5,000 acres. Maintain existing fence, build and maintain fence along Middle Maulua tract boundary (unit 9). Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats, particularly *Vespula* sp.). Outplant T&E plants and build site-specific fencing to protect T&E plant populations.
3.4: Protect and Maintain Native Montane Mesic Koa Forest (6,000-6,600 ft elevation) at HFU	3,500 acres. Maintain existing fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats, particularly *Vespula* sp.). Outplant T&E plants and build site-specific fencing to protect T&E plant populations. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
3.5: Restore/Reforest Native Montane Mesic Koa Forest (6,000-6,600 ft elevation) at HFU	2,500 acres. Maintain fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant 300 koa per acre, use excluder devices to deter turkeys on koa seedlings, outplant native understory species and ‘ōhi‘a at 150 per acres, outplant 100-300 T&E plants and build site-specific fencing to protect these plants. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
3.6: Maintain and Enhance Propagation and Outplanting Program at HFU	Plant 10,000 koa per year for 5 years: 5,000 per year for the next 10 years, 8-10,000 natives and 300-1,200 T&E plantings per year. Expand native plant nursery at Mauna Kea administration site, collect seeds and cuttings, outplant, and develop partnerships to assist with propagation program.
4.1: Protect and Maintain Streams and Stream Corridors at HFU	Maintain fencing. Eradicate/control invasive plants. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Inventory streams and stream corridors.
4.2: Protect and Maintain Semipermanent Natural Ponds at HFU	Maintain fencing, conduct survey for pest animals (based on surveys control threats).
4.3: Protect and Maintain *Carex* Bogs within the Montane Wet ‘Ōhi‘a/Uluhe Forest at HFU	Install fencing to protect bogs, conduct survey for pest animals (based on surveys control threats), survey extent and number of bogs.

Objectives	CCP Action
5.1: Maintain Managed Grassland for Foraging Nēnē at HFU	65 acres. Maintain fuel breaks and fence corridors, build and maintain fence. Eradicate/control invasive plants. Conduct survey for pest animals (based on surveys control threats).
5.2: Maintain Grassland Habitats for Nēnē Nesting at HFU	15 acres. Maintain fence and build predator proof fence on 15-acre grassland breeding site away from administrative site at Pua ʻĀkala tract. Eradicate/control invasive plants and remove pest animals. Conduct survey for pest animals (based on surveys control threats).
6.1: Conduct High-Priority Inventory and Monitoring (Survey) Activities that Evaluate Resource Management and Public-Use Activities to Facilitate Adaptive Management	An initial list of survey and monitoring activities have been identified and include examples such as monitoring nesting density and success of nēnē, inventorying all endemic species, instituting early detection and rapid response monitoring for threat management, monitoring plant and animal diseases, and others.
6.2: Conduct High-Priority Research Projects that Provide the Best Science for Habitat and Wildlife Management On and Off the Refuge	An initial list of research projects have been identified and include examples such as investigating and monitoring endangered plant propagation and outplanting, research on arthropod abundance, researching demography, life-history, carrying capacity, and competition for native forest birds, and others.
6.3: Conduct Scientific Assessments to Provide Baseline Information to Expand Knowledge Regarding the Status of Refuge Resources to Better Inform Resource Management Decisions	An initial list of scientific assessments have been identified and include examples such as determining ecological parameters for ʻōpeʻapeʻa, determining the role of predators in native flora and fauna abundance, assessing global climate change impacts on the Refuge, and others.
7.1: Establish Compatible Wildlife Observation and Photography Opportunities	Develop Upper Maulua Tract interpretive trail (0.3-0.5 mile) and parking area. Work with Friends of Hakalau Forest to develop brochure.
7.2: Promote and Enhance Volunteer Program	Maintain volunteer program and current 35-40 service weekends at HFU, develop seasonal volunteer program to supplement staffing and weekend programs, develop KFU volunteer program similar to HFU.
7.3: Support Existing Outside Programs for On and Off Site Environmental Education and Develop Interpretive Opportunities	Increase environmental education and interpretive programs (via coordinating more with County, State, and non-governmental organizations and expanding interpretive programs relative to cultural resources/historic sites) to include 168 participants annually. Continue interpretive walks offered during annual Refuge open house.
7.4: Enhance Outreach Targeting Local Communities to Promote Appreciation of and Generate Support for the KFU	Work with existing partners to promote awareness and appreciation. Develop and cultivate new partners and outreach efforts.

Objectives	CCP Action
8.1: Increase Identification, Monitoring, Protection, and Restoration of all Cultural Resources and Historic Sites, while Increasing Staff and Public Support and Appreciation	Evaluate known/potential Refuge cultural resources and historic sites, develop guidelines for cultural activities, identify cultural practitioners to develop understanding of cultural/historic sites at the Refuge, develop interpretive programming and products relative to cultural and historic sites in partnership with Native Hawaiian groups; conduct comprehensive cultural resources investigation of both units.

Implementation of the Plan:

Over the next 15 years, Refuge staff will be implementing these various strategies as funding and staffing allow. We look forward to continue working with our partners and the public as we strive to attain our goals and vision for these unique Hawaiian rainforests and the numerous native plants and animals that depend upon them for their survival.

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Tables

Figures

Appendices

Note to Reviewers: Throughout the CCP document, all attempts have been made to use appropriate diacriticals related to the Native Hawaiian language (i.e., ‘okina and kahakō). However, places where diacriticals may not appear are in the maps, appendices, and references. Due to limitations of the Geospatial Information System (GIS) software used for the maps developed in the plan, diacriticals were unable to be used where place names or legend text appear. For items in the appendices, if documents were minutes or summaries of meetings or documents not created for the CCP that did not use diacriticals originally, the document was left as is. For references identified, if the title of the publication or original citation does not use diacriticals, references were left as is.

Chapter 1. Introduction and Background

Above: ‘Io/Robert Shallenberger
Right: ‘Amakihi/Jack Jeffrey Photography

Hakalau Forest Unit rainforest/Dick Wass

Chapter 1. Introduction and Background

1.1 Introduction

Hakalau Forest National Wildlife Refuge consists of the Hakalau Forest Unit and the Kona Forest Unit (Figure 1-1) collectively managed as the Big Island National Wildlife Refuge Complex (Complex). The Hakalau Forest Unit (HFU) (Figure 1-2) was established in 1985 to protect and manage endangered forest birds and their rainforest habitat. Located on the windward slope of Mauna Kea, Island of Hawaiʻi, the 32,733 acre unit supports a diversity of native birds and plants. The Kona Forest Unit (KFU) (Figure 1-3) was set aside in 1997 to protect native forest birds and the ʻalalā (*Corvus hawaiiensis*, Hawaiian crow). Located on the leeward slope of Mauna Loa, the 5,300 acre KFU supports diverse native bird and plant species as well as the rare lava tube and lava tube skylight habitats.

1.2 Purpose and Need for the CCP

The purpose of the CCP is to provide the Complex, the National Wildlife Refuge System, the Service, partners, and citizens with a management plan for improving fish and wildlife habitat conditions and infrastructure for wildlife, staff, and public use on the Refuge over the next 15 years. An approved CCP will ensure that the Complex staff manages Hakalau Forest NWR to achieve Refuge purposes, vision, goals, and objectives to help fulfill the Refuge System mission.

The CCP will provide reasonable, scientifically grounded guidance for managing and improving the Refuge's forest, subterranean, riparian, aquatic, and grassland habitats for the long-term conservation of native plants and animals. Appropriate actions for protecting and sustaining the biological and cultural features of forest communities; endangered species populations and habitats; and threatened or rare species have been identified. The CCP also promotes priority public use activities on the Refuge including wildlife observation, photography, environmental education, and interpretation.

The CCP is needed for a variety of reasons. Primary among these is the need to conserve the Refuge's forest, subterranean, riparian, aquatic, and grassland habitats that are in various stages of (1) degradation by pest plants and animals (most notably ungulates and invasive plants), (2) recovery from cattle grazing activities by past owners, and (3) restoration by Refuge staff. The CCP is needed to address the Refuge's contributions to aid in the recovery of listed species, and assess and possibly mitigate potential impacts of global climate change. The staff also needs to effectively work with current partners such as the Hawaiʻi Division of Forestry and Wildlife (DOFAW), the U.S. Geological Survey-Biological Resources Discipline (USGS-BRD), the U.S. Forest Service (USFS), the Department of Hawaiian Home Lands (DHHL), and the National Park Service (NPS). The Refuge also needs to seek new partnerships to restore habitats, improve the volunteer program, and identify to what extent improvements or alterations should be made to existing visitor programs. In addition, the Refuge will continue to work with the Friends of Hakalau Forest on various Refuge programs, community outreach, and Refuge management needs. These activities will allow the Refuge staff to ensure the biological integrity, diversity, and environmental health of the units are restored or maintained.

1.3 Content and Scope of the CCP

This CCP provides guidance for management of Refuge habitats and wildlife and administration of public uses on Refuge lands. The Hakalau Forest NWR CCP is also intended to comply with the requirements set forth in the National Wildlife Refuge System Administration Act of 1966 (Administration Act), as amended by the National Wildlife Refuge Improvement Act of 1997 (16 U.S.C. 668dd-668ee) and the National Environmental Policy Act (NEPA), as amended (42 U.S.C. 4321-4347). Information in the CCP includes:

- An overall vision for the Refuge, each unit's establishment history and purposes, and their role in the local ecosystem (Chapter 1);
- Goals and objectives for specific conservation targets and public use programs, as well as strategies for achieving the objectives (Chapter 2);
- A description of the physical environment of the Refuge (Chapter 3);
- A description of the conservation targets, their condition and trends on the Refuge and within the local ecosystem, a presentation of the key desired ecological conditions for sustaining the targets, and a short analysis of the threats to each conservation target (Chapter 4);
- An overview of the Refuge's public use programs and facilities, a list of desired future conditions for each program, and other management considerations (Chapter 5);
- A list of resident species (both native and nonnative) known from the Refuge (Appendix A);
- Evaluations of existing and proposed appropriate public and economic uses for compatibility with the Refuge's purposes (Appendix B);
- An outline of the projects, staff, and facilities needed to support the CCP (Appendix C);
- A review for wilderness designation (Appendix D);
- Summary of a workshop held for implementing recovery for endangered forest birds (Appendix E);
- A Biological Integrity, Diversity, and Environmental Health Table (Appendix F);
- Integrated Pest Management Program (Appendix G);
- Statement of Compliance for CCP (Appendix H);
- List of acronyms (Appendix I);
- A list of CCP Team Members (Appendix J);
- A summary of public involvement (Appendix K); and
- A summary of past and current management (Appendix L).

1.4 Planning and Management Guidance

1.4.1 U. S. Fish and Wildlife Service Mission

The mission of the Service is "working with others, to conserve, protect and enhance fish and wildlife and their habitats for the continuing benefit of the American people." National natural resources entrusted to the Service for conservation and protection include migratory birds, endangered and threatened species, interjurisdictional fish, wetlands, and certain marine mammals.

Figure 1-1. Refuge vicinity.

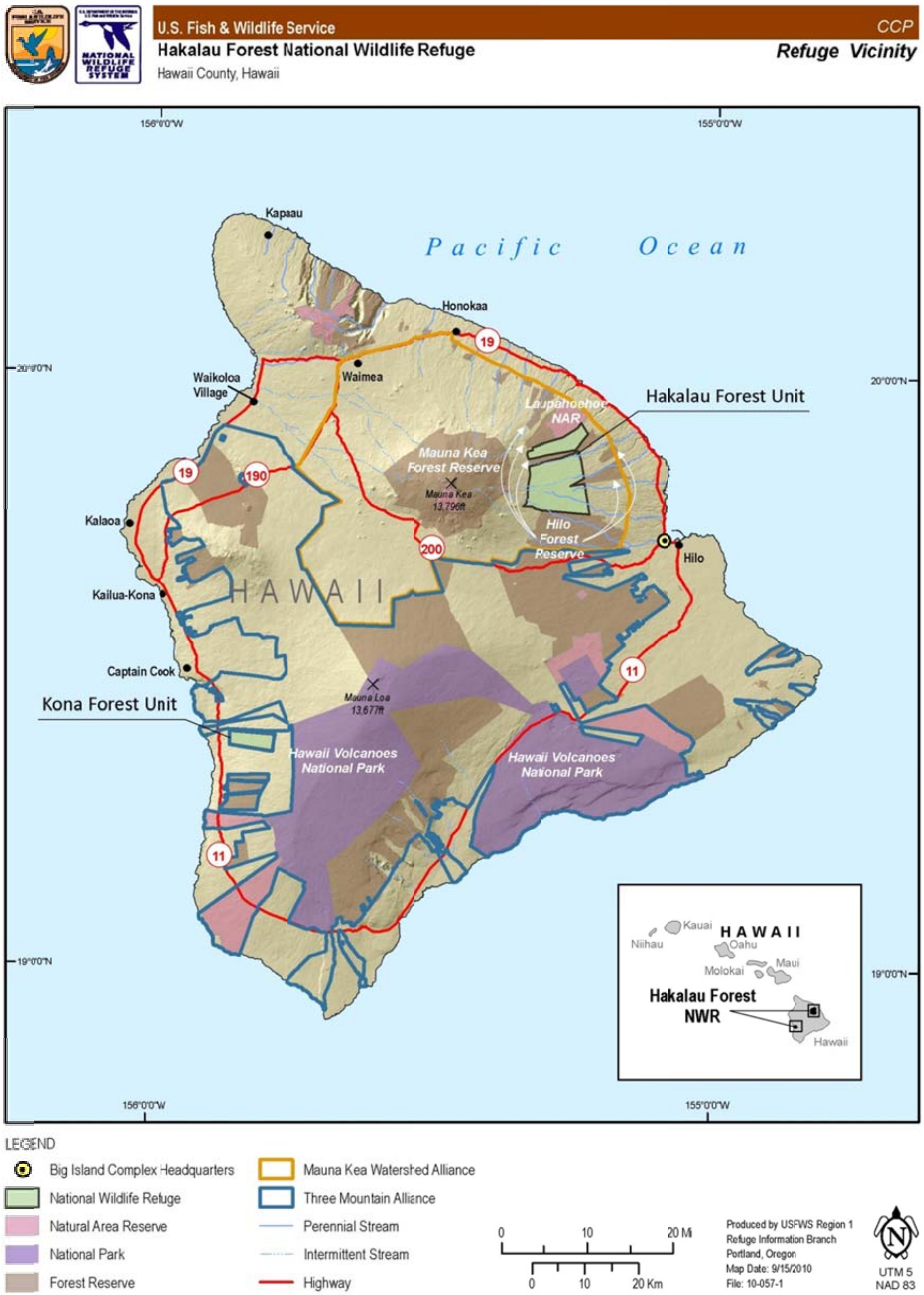

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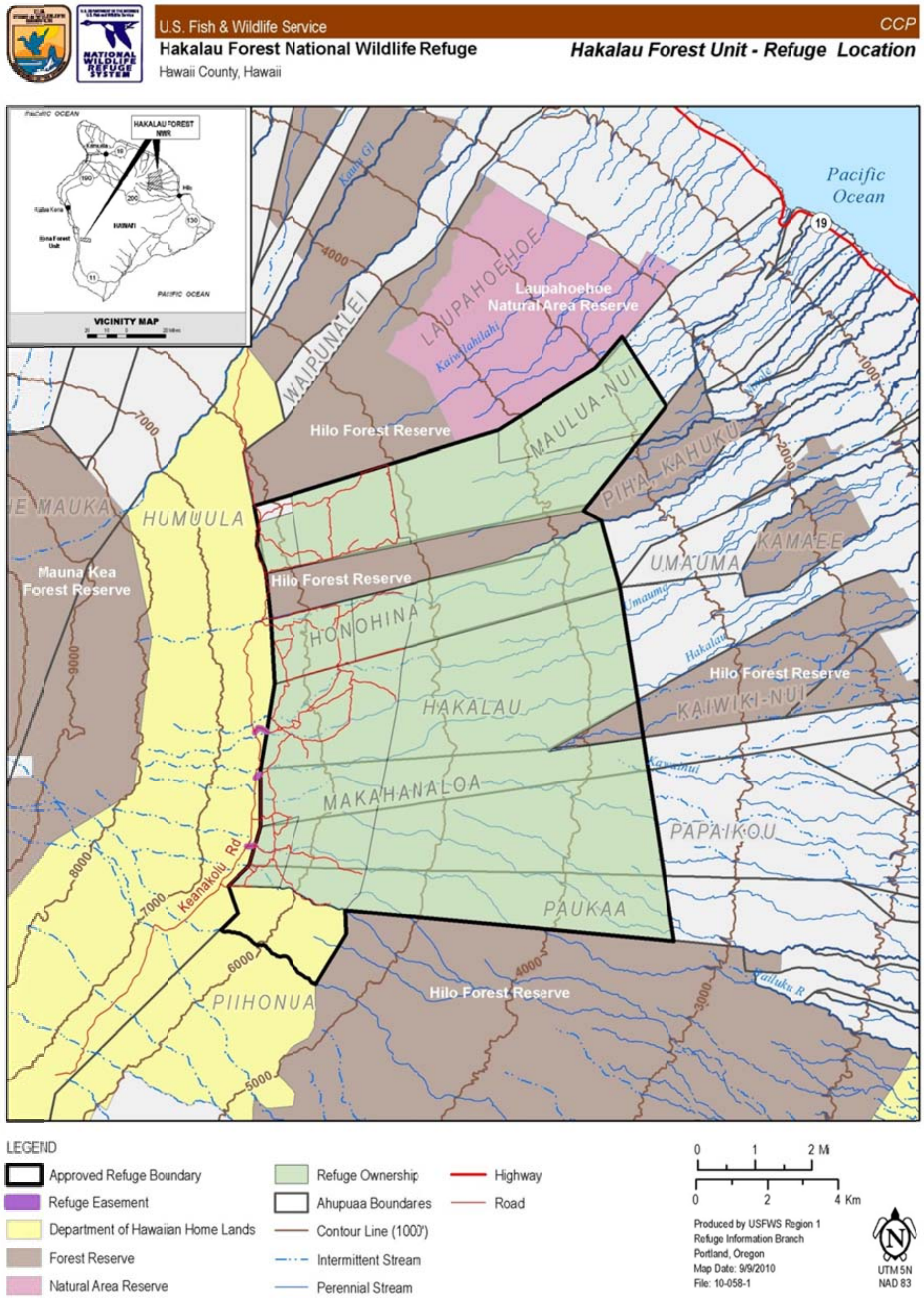
Figure 1-2. HFU location.



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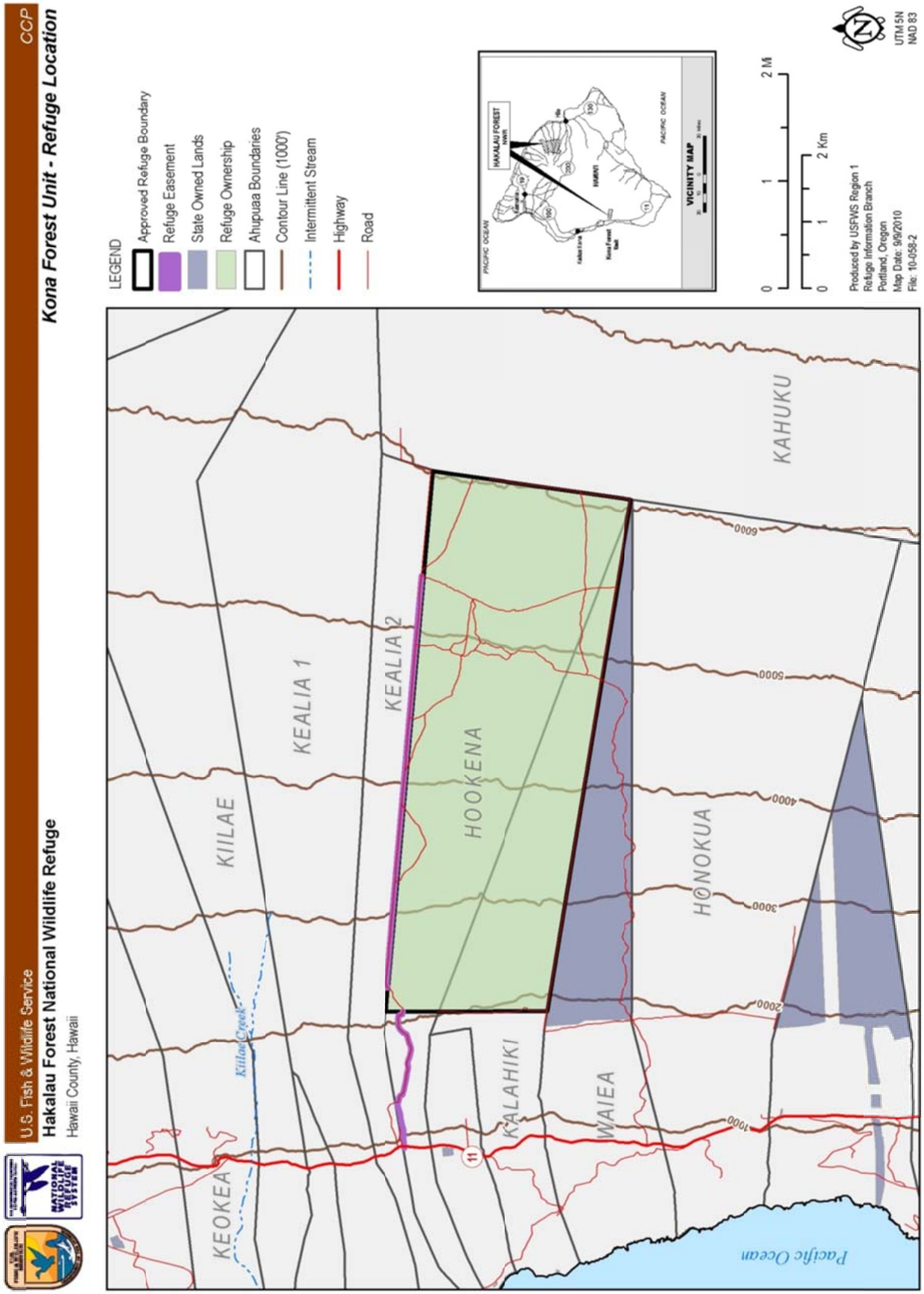

Figure 1-3. KFU location.

To preserve the quality of this figure, this side was left blank intentionally.

The Service also manages national fish hatcheries, enforces Federal wildlife laws and international treaties on importing and exporting wildlife, assists with State/Territorial fish and wildlife programs, and helps other countries develop wildlife conservation programs. The Service is an agency within the Department of the Interior (DOI), and is the principal Federal agency responsible for conserving, protecting, and enhancing fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

1.4.2 National Wildlife Refuge System

The Refuge System is the world's largest network of public lands and waters set aside specifically for conserving wildlife and protecting ecosystems. From its inception in 1903, the Refuge System has grown to encompass 553 national wildlife refuges in all 50 States, 4 U.S. territories, and a number of unincorporated U.S. possessions, and waterfowl production areas in 10 States, covering more than 150 million acres of public lands. It also manages four marine national monuments in the Pacific in coordination with the National Oceanic and Atmospheric Administration (NOAA) and affected States/Territories. More than 40 million visitors annually fish, hunt, observe and photograph wildlife, or participate in environmental education and interpretive activities on these refuges.

Refuges are guided by various Federal laws and Executive orders, Service policies, and international treaties. Fundamental are the mission and goals of the Refuge System and the designated purposes of the Refuge unit as described in establishing legislation, Executive orders, or other documents establishing, authorizing, or expanding a refuge.

Key concepts and guidance for the Refuge System derive from the Administration Act, the Refuge Recreation Act of 1962 (16 U.S.C. 460k-460k-4), as amended, Title 50 of the Code of Federal Regulations, and the Fish and Wildlife Service Manual. The Administration Act is implemented through regulations covering the Refuge System, published in Title 50, subchapter C of the Code of Federal Regulations. These regulations govern general administration of units of the Refuge System. This CCP complies with the Refuge Administration Act.

1.4.2.1 National Wildlife Refuge System Mission and Goals

The mission of the Refuge System is:

> "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans" (National Wildlife Refuge System Administration Act of 1966, as amended)(16 U.S.C. 668dd).

Wildlife conservation is the fundamental mission of the Refuge System. The goals of the Refuge System, as articulated in the Mission, Goals, and Refuge Purposes Policy (601 FW1) are:

- Conserve a diversity of fish, wildlife, and plants and their habitats, including species that are endangered or threatened with becoming endangered;

- Develop and maintain a network of habitats for migratory birds, anadromous and interjurisdictional fish, and marine mammal populations that is strategically distributed and carefully managed to meet important life-history needs of these species across their ranges;

- Conserve those ecosystems, plant communities, wetlands of national or international significance and landscapes and seascapes that are unique, rare, declining, or underrepresented in existing protection efforts;

- Provide and enhance opportunities to participate in compatible wildlife-dependent recreation (hunting, fishing, wildlife observation and photography, and environmental education and interpretation); and

- Foster understanding and instill appreciation of the diversity and interconnectedness of fish, wildlife, and plants and their habitats.

1.4.3 National Wildlife Refuge System Administration Act

Of all the laws governing activities on refuges, the Administration Act exerts the greatest influence. The National Wildlife Refuge System Improvement Act of 1997 (Improvement Act) amended the Administration Act by including a unifying mission for all refuges as a system, a new process for determining compatible uses on refuges, and a requirement that each refuge will be managed under a CCP developed in an open public process.

The Administration Act states the Secretary of the Interior shall provide for the conservation of fish, wildlife, and plants, and their habitats within the Refuge System as well as ensure that the biological integrity, diversity, and environmental health of the Refuge System are maintained. House Report 105–106 accompanying the Improvement Act states ‘‘… the fundamental mission of our System is wildlife conservation: wildlife and wildlife conservation must come first.’’ Biological integrity, diversity, and environmental health (BIDEH) are critical components of wildlife conservation. As later made clear in the BIDEH Policy, “the highest measure of biological integrity, diversity, and environmental health is viewed as those intact and self-sustaining habitats and wildlife populations that existed during historic conditions.”

Under the Administration Act, each refuge must be managed to fulfill the Refuge System mission as well as the specific purposes for which it was established. The Administration Act requires the Service to monitor the status and trends of fish, wildlife, and plants in each refuge.

Additionally, the Administration Act identifies six wildlife-dependent recreational uses for priority consideration. These uses are hunting, fishing, wildlife observation and photography, and environmental education and interpretation. Under the Administration Act, the Refuge is to grant these six wildlife-dependent public uses special consideration in the planning for, management of, and establishment and expansion of units of the Refuge System. The overarching goal is to enhance wildlife-dependent recreation opportunities and access to quality visitor experiences on refuges while managing refuges to conserve fish, wildlife, plants, and their habitats. New and ongoing recreational uses should help visitors focus on wildlife and other natural resources. These uses should provide an opportunity to make visitors aware of resource issues, management plans, and how the refuge contributes to the Refuge System and the Service mission. When determined compatible on a refuge-specific basis, these six uses assume priority status among all uses of the refuge in question. The refuge is then directed to make extra effort to facilitate priority wildlife-dependent public use opportunities.

When preparing a CCP, refuge managers must reevaluate all general public, recreational, and economic uses (even those occurring to further refuge habitat management goals) proposed or occurring on a refuge for appropriateness and compatibility. No refuge use may be allowed or continued unless it is determined to be appropriate and compatible. Generally, an appropriate use is one that contributes to fulfilling the refuge purpose(s), the Refuge System mission, or goals or objectives described in a refuge management plan, such as this CCP. A compatible use is a use that, in the sound professional judgment of the refuge manager, will not materially interfere with or detract from the fulfillment of the mission of the Refuge System or the purposes of the refuge. Updated Appropriateness Findings and Compatibility Determinations for existing and proposed uses for Hakalau Forest NWR are in Appendix B.

The Administration Act also requires that, in addition to formally established guidance, the CCP must be developed with the participation of the public. Issues and concerns articulated by the public played a role in guiding the development of the CCP, and together with the formal guidance, played a role in development of the final CCP. It is the Service's policy to invite public participation in CCP development, to carry out an open public CCP process, and secure public input throughout the process.

1.5 Relationship to Previous and Future Refuge Plans

Planning has been a part of refuge operations since establishing refuges began. However, not all plans were completed in a comprehensive fashion, or with public participation considered adequate today. For Hakalau Forest NWR, a considerable number of plans were completed over the years to guide managers.

1.5.1 Previous Plans

Plans and/or management agreements (plans addressing one program or resource) have been developed for Hakalau Forest NWR (Hakalau Forest Unit and Kona Forest Unit). Existing plans include:

- Refuge Management Plan (1989);
- Feral Ungulate Management Plan (1996);
- Draft Reforestation Management Plan (May 1996);
- Wildland Fire Management Plan-Hakalau (2002);
- Wildland Fire Management Plan-Kona (2002);
- Occupant Emergency Plan (2003);
- Annual Habitat Work Plan (2004);
- Visitor Services Evaluation Report (2004);
- Safety Plan, Hakalau Forest Unit (April 2004);
- Aviation Mishap Response Plan (2005);
- Continuity of Operations Plan (2009);
- Fleet Management Plan (2009);
- USFWS Pandemic Influenza Plan (2009); and
- Medical Emergency Dispatch Plan (2009).

1.5.2 Future Planning

The CCP will be revised every 15 years or sooner if monitoring and evaluation determine that changes are needed to achieve the Refuge's purposes, vision, goals, or objectives. The CCP provides guidance in the form of goals, objectives, and strategies for Refuge program areas but may lack some of the specifics needed for implementation. Stepdown management plans may be developed for individual program areas, as needed, following completion and approval of the CCP. Stepdown plans may require additional NEPA and other compliance. Several stepdown plans (e.g., Habitat Management Plan, Inventory and Monitoring Plan, and Integrated Pest Management Plan) are appropriate to develop and/or update following the CCP completion; all of these will be founded on the management goals, objectives, and strategies outlined in the CCP. The Integrated Pest Management Plan (IPM) should address coordination with all other Federal, State, and regional agencies as well as neighboring private landowners in order to effectively combat the spread of invasive species.

In addition, national wildlife refuges may serve as important strategic anchor points for area conservation efforts. With the completion of the CCP, the Refuge staff has initiated and will complete a Land Protection Planning effort in cooperation with other agencies and interested parties to assess and identify land conservation priorities and opportunities in the vicinity of Refuge units. The Refuge staff will expand coordination efforts with existing partners on both the windward Mauna Kea (Hakalau Forest Unit) and the South Kona (Kona Forest Unit) sides of Hawaiʻi Island to seek input on potential Refuge involvement in area conservation efforts and needs beyond our current boundaries in order to determine a desired goal and appropriate role for the Refuge. Potential additions or expansion of Hakalau Forest NWR and examination of various land protection tools will be explored. Land protection as part of the Refuge System may include fee title acquisition, conservation easements, and/or cooperative agreements.

Currently, the Refuge identifies parcels on a case-by-case basis for protection as they become available from willing sellers. A landscape approach on the slopes of Mauna Kea and Mauna Loa will allow staff to focus efforts and work with partners to ensure that habitat needs are met over a larger area. In addition, corridors between patches of protected habitat are critical for species migration in response to climate change. Species distribution and abundance is likely to change based upon precipitation patterns, temperature variations, and shifts in mosquito zones. The Refuge will take a landscape level view of opportunities to augment the habitat protection currently provided by the existing Refuge lands.

1.6 Refuge Establishment and Purposes

The Administration Act directs the Service to manage each refuge to fulfill the mission of the Refuge System, as well as the specific purposes for which that refuge was established. Refuge purposes are the driving force in developing refuge vision statements, goals, objectives, and strategies in the CCP. Refuge purposes are also critical to determining the appropriateness and compatibility of all existing and proposed refuge uses.

Lands within the Refuge System are acquired and managed under a variety of legislative acts, administrative orders, and legal authorities. The official purpose or purposes for a refuge are specified in or derived from the law, proclamation, Executive order, agreement, public land order, donation document, or administrative memorandum establishing, authorizing, or expanding a refuge, refuge unit, or refuge subunit. The Service defines the purpose of a refuge when it is established or when new land is added to an existing refuge. When an addition to a refuge is acquired under an authority different from the authority used to establish the original refuge, the addition takes on the purposes of the original refuge, but the original refuge does not take on the purposes of the addition. Refuge managers must consider all of these purposes. Additionally, refuge boundaries may encompass lands that the refuge itself does not own. Therefore, note in Figures 1-2 and 1-3 the distinction between Refuge ownership and authorized boundaries.

1.6.1 Hakalau Forest Unit Purposes

Established on October 29, 1985, the purposes of Hakalau Forest Unit are:

- "… to conserve (A) fish or wildlife which are listed as endangered species or threatened species. . . or (B) plants . . . (C) the ecosystems upon which endangered species and threatened species depend . . ." (Endangered Species Act of 1973, as amended, 16 U.S.C. 1534);

- "To assure the perpetuation of native forest habitats of the Upper Hakalau Forest for the protection of a number of endangered animals and plants endemic to the area. . . ." (FONSI for the Environmental Assessment: Proposal to Establish an Upper Hakalau National Wildlife Refuge, Hawaiʻi County, Hawaiʻi, May 1985).

1.6.2 Kona Forest Unit Purposes

The Kona Forest Unit, acquired on December 12, 1997, has the following purposes:

- The purposes listed for the Hakalau Forest Unit also apply to the Kona Forest Unit;
- In addition, ". . .to protect, conserve, and manage a portion of the native forest in south Kona, primarily for the benefit of the ʻalalā and other endangered and threatened species" (1997 Final Environmental Assessment for the Proposed Kona Forest Unit of the Hakalau Forest NWR).

1.7 Relationship to Ecosystem Management Goals or Plans

1.7.1 Landscape Level Initiatives

Strategic Habitat Conservation (SHC): Through a cooperative effort culminating in the 2006 National Ecological Assessment Team Report, the Service and USGS outlined a unifying adaptive resource management approach for conservation at "landscape" scales, the entire range of a priority species or suite of species. Known as "strategic habitat conservation" or SHC, it is a way of thinking and of doing business that requires us to set biological goals for priority species populations, allows us to make strategic decisions about our work, and encourages us to constantly reassess and improve our actions – all critical steps in dealing with large-scale conservation challenges and the uncertainty of accelerated climate change.

In April 2009, Service leadership set up a national geographic framework for implementing landscape conservation. This framework has led to the creation of Landscape Conservation

Cooperatives (LCCs). The LCCs are conservation-science partnerships between the Service, Federal agencies, States, Territories, tribes, NGOs, universities, and other entities. They are fundamental units of planning and science capacity to help us carry out the functional elements of SHC, biological planning, conservation design, conservation delivery, monitoring, and research, and inform our strategic response to accelerated climate change.

The Pacific Islands Climate Change Cooperative (PICCC) is the LCC focused on Hawaiʻi, the Mariana Islands, and American Samoa. Established in late 2009, it will create the technical capacity, decision support tools, and organizational structure to address landscape-scale conservation issues using SHC. These tools will help managers reach explicit conservation objectives for native species and habitats in the face of climate change and ongoing threats such as fire, land conversion, and invasive species. Under the direction of a steering committee that includes Service representatives, the PICCC will develop models that predict how natural resources and processes may respond to climate change, assess management options using models and historical data, and collectively determine priority conservation strategies. To make the link between modeling and management, the PICCC will assess the vulnerability of targeted species and ecosystems, and assist partners in choosing among potential management strategies based on their likelihood for success. Monitoring of response variables and ecosystem change will be coordinated across agencies and jurisdictions, and will include the structures provided by the Refuge System's Inventory and Monitoring program.

The Hawaiian and Pacific Islands NWRs anticipate using climate change information provided by the PICCC as foundational products from which to do more detailed site-specific and species-specific analyses critical to the preparation of planning documents and to prioritize on-the-ground conservation actions. Although the information developed by PICCC will be focused on priority species and habitats determined by the partnership and may not be specifically targeting all of the Service climate science needs, it is hoped that it will provide much of the basic scientific information needed to design and deliver climate-informed conservation actions.

Watershed Partnerships: The Hawaiʻi Association of Watershed Partnerships (HAWP) was established in 2003. HAWP includes 9 island-based Watershed Partnerships, including more than 60 public and private partners on 6 islands. Over 1.2 million acres of forest lands are covered by existing plans. The Watershed Partnerships consist of public and private landowners and other partners working in voluntary collaboration to protect forested watersheds and preserve ecosystem services.

The HAWP works to facilitate sharing of watershed management knowledge, build public support and awareness of watershed values, and develop sustainable funding sources for the Watershed Partnerships.

Forested watersheds are vital recharge regions for Hawaiʻi's underground aquifers and a dependable source of clean water for its streams and people. They are also home to the last remaining native ecosystems in Hawaiʻi and house thousands of native species of animals and plants found nowhere else on Earth. Most management actions are habitat based and revolve around combating the main threats of ungulates (hoofed animals such as goats, deer, sheep, pigs, etc.) and invasive species. Partnership activities include fencing and ungulate removal, invasive species control, rare plant outplanting and native habitat restoration, and outreach and education. These management actions make a critical difference by benefitting native forests, watersheds, coastal, and coral reef areas by reducing erosion and sedimentation runoff into streams.

On the Island of Hawaiʻi, there are presently two Watershed Partnerships in the vicinity of the Refuge: Three Mountain Alliance and the Mauna Kea Watershed Alliance. The Big Island National Wildlife Refuge Complex participates in both of these groups.

The largest Watershed Partnership in the islands, the Three Mountain Alliance (originally known as the ʻŌlaʻa-Kīlauea Partnership), was formed in 2007 and covers 1,116,300 ac. With nine partners, the overall goal of the Three Mountain Alliance (TMA) is to sustain the multiple ecosystem benefits of the three mountains of Kīlauea, Mauna Loa, and Hualālai by responsibly managing its watershed areas, native habitats and species, and historic, cultural, and socioeconomic resources for all who benefit from the continued health of these three mountains.

The TMA was formed when members of the ʻŌlaʻa-Kīlauea Partnership (OKP), based on their 10-year success of partnering, decided to enlarge watershed protection and management to more than 1 million acres across Mauna Loa, Kīlauea, and Hualālai as part of an expanded Partnership. Members have agreed there is a compelling need to collaborate on a wide variety of land management issues in forested watersheds across this TMA landscape. Coordinated management across this landscape is critical to sustain adequate quality and quantity of water and to provide important habitat for a wide diversity of native plants and animals, including endangered species. In addition, the health of these lands is strongly connected with the quality of life for people and local communities. Even in the absence of a formal partnership, private and public landowners in this region have recognized the value of collaboration to address shared management challenges such as invasive weeds, fire, and feral cattle.

The OKP has been highly successful in addressing conservation challenges within a 30,000 ac area, centered on the ʻŌlaʻa Tract of Hawaiʻi Volcanoes National Park (HAVO). The OKP includes the State (DLNR, Department of Public Safety), National Park Service, Fish and Wildlife Service, U.S. Geological Survey Pacific Island Ecosystems Research Center, Kamehameha Schools, U.S. Department of Agriculture's Forest Service, and The Nature Conservancy.

Cooperating in the areas of staff expertise and funding to conserve native ecosystems for over a decade has significantly reduced the threats of invasive ungulates and weeds on Federal, State, and private lands.

The TMA includes the original Federal, State, and private partners of the OKP, as well as the U.S. Department of Agriculture's Natural Resources Conservation Service. Other agencies and key private landowners with a management interest in the landscape issues will be invited to join the TMA to participate in collaborative efforts addressing specific management challenges.

A Memorandum of Understanding (MOU) outlines the following overall principles that serve as the foundation of the TMA:

- The three mountains of Kīlauea, Mauna Loa, and Hualālai are ancient, sacred to Hawaiians, and critically important to the life, health, and well being of the native ecosystems and human communities that inhabit them;
- TMA members have a responsibility (kuleana) to care for these mountains, including native ecosystems and human communities that share this landscape;
- Management is needed to maintain healthy forested watersheds on the slopes of Kīlauea, Mauna Loa, and Hualālai to sustain the future quality and quantity of fresh water;

- Other lands (e.g., younger lava flows, grasslands, crop land and coastal lands) within the TMA area also contribute to water quality and quantity;
- The health of the nearshore ocean resources are intimately connected to the health of the uplands in the traditional ahupuaʻa;
- Management of these lands would benefit Hawaiʻi's native flora and fauna;
- Many of the threats to the watershed, such as ungulates, fire, insects, diseases, and invasive nonnative plants, occur across common land ownership boundaries; and
- Effective management is best achieved through the coordinated actions of all major landowners in the TMA area irrespective of property lines.

Approximately 85 percent of the total TMA land area is comprised of native ecosystems. The TMA contains some of the largest expanses of intact native forest remaining in the Hawaiian Islands (approximately 50 percent of the State's remaining native habitat). Due to the variations in elevation, climate, and vegetation, the TMA is home to thousands of native species, as well as rare and threatened or endangered species (many of which are endemic to the island).

Management programs address habitat protection and restoration, watershed protection, compatible economic use, compatible recreation and ecotourism, education, awareness and public outreach, cultural resource protection and research, and monitoring and management program indicators.

The Mauna Kea Watershed Alliance (MKWA) encompasses over 525,000 ac or over 820 mi^2 above the 2,000 ft elevation on the windward slopes of Mauna Kea, Hawaiʻi Island's tallest mountain. Members of this newly formed collaboration include the Hawaiʻi DLNR, by and through its Division of Forestry and Wildlife and its Land Management Division, Kamehameha Schools, Parker Ranch, U.S. Army (Pōhakuloa Training Area), the Service, DHHL, University of Hawaiʻi (Office of Mauna Kea Management), and Kūkaʻiau Ranch. A draft management plan for the watershed was completed in 2010.

The vision of the MKWA is to protect and enhance watershed ecosystems, biodiversity, and resources through responsible management, while promoting economic sustainability and providing recreational, subsistence, educational, and research opportunities. The MKWA will identify Watershed Areas of importance on Mauna Kea that include lands owned or controlled by one or more of the members for which coordinated care and management would be suitable; and where appropriate, with the consent of the members owning or controlling lands within the Watershed Area, cooperate in the development and implementation of watershed management plans that will document resource values and identify priority watershed management objectives and strategies.

Department of Hawaiian Home Lands ʻĀina Mauna Legacy Program: Land use is subject to the Hawaiian Homes Commission. The DHHL owns and manages the Humuʻula/Piʻihonua area adjacent to the HFU. This area, at 56,000 acres, represents 48 percent of the entire land acreage owned by DHHL on Hawaiʻi Island. Two plans guide the management of these lands, the Hawaiʻi Island Plan and the ʻĀina Mauna Legacy Plan (2009). The mission of the ʻĀina Mauna Legacy Program (the Legacy Program) and its implementation is to protect approximately 56,000 ac of native Hawaiian forest that is ecologically, culturally, and economically self-sustaining for the Hawaiian Home Lands Trust, its beneficiaries and the community. Initial goals for the ʻĀina Mauna Legacy Program include:

Goal 1: Develop an economically self-sustaining improvement and preservation program for the natural and cultural resources (invasive species eradication and native ecosystem restoration) and implementation strategy.

The focus of the ‘Āina Mauna Legacy Program shall be on:
- Restoration and enhancement of DHHL trust resources;
- Identification of immediate and future opportunities for DHHL beneficiaries;
- Removal of invasive species – gorse, etc.;
- Conserve natural and cultural resources and endangered species;
- Address reforestation and restoration of the ecosystem;
- Develop revenue generation, reinvestment in land to sustain activities;
- Provide educational and cultural opportunities;
- Identify and secure partners to sustain activities;
- Identify opportunities for alternative/renewable energy projects; and
- Be a lead and/or model for others to engage in ecosystem restoration in a culturally sensitive manner based on partnerships to develop a self-sustaining model.

Goal 2: Develop an outreach program to gain interest, participation, and support from the Hawaiian Homes Commission, DHHL staff, beneficiaries groups, cultural practitioners, natural resource scientists, and the broader community for the Legacy Program and its implementation.

The goals and actions of the Legacy Program mesh very well with the vision, goals, and objectives of the Hakalau Forest NWR CCP. Specifically, the removal of invasive species, conservation of natural and cultural resources and endangered species, habitat restoration, reforestation, fencing, and climate change, along with partnership opportunities, are all key components where we can work together. We look forward to the exchange of ideas, resources, and technical assistance that coordination with this important adjacent landowner can provide.

Hawai‘i Experimental Tropical Forest: Established in 2007, the mission of the Hawai‘i Experimental Tropical Forest (HETF) is to provide landscapes, facilities, and data/information for those wishing to conduct research and education activities contributing to a better understanding of the biological diversity and functioning of tropical forest and stream ecosystems and their management. The HETF represents a significant contribution in the global effort that is necessary to understand and protect some of the most threatened and endangered ecosystems in the world. This can best be accomplished by facilitating tropical natural areas/species research, fostering an environment for interaction and exchange of information among scientists and to those outside the scientific community, and providing education and demonstration opportunities for those interested in tropical forest studies and management. Major research topics of the HETF are:

1. **Structure and function of tropical wet forest and dry forest watersheds and their component parts.**
   This emphasis area will focus on how tropical forest ecosystems work. Research will strive to gain a better understanding of the physical, chemical, and biological processes at all relevant geographic and time scales.
2. **Structure and function of freshwater and nearshore marine ecosystems in tropical landscapes.**

3. **Invasive Alien Species.**
   One of the greatest threats Hawaiian forests currently face are invasive alien species. It is impossible to determine what new challenges resource managers will be faced with in the future. But this underscores the need for long-term databases in Hawaiʻi.
4. **Methods/tools for restoration of tropical forest ecosystems.**
   Hawaiian forests have been subject to a number of natural and human-induced perturbations over the last 250 years. A key information need for land managers involves learning the most effective and cost-efficient methods for restoring disturbed habitats and landscapes. There are ample opportunities for investigating different restoration methods in different kinds of plant communities that are found on the HETF.
5. **Impact of global climate change on tropical ecosystems.**
6. **Native Hawaiian/traditional resource management techniques.**
   There is a need to provide opportunities for investigation of traditional land management practices originally used by Native Hawaiians (Polynesians). The HETF has the capacity to accommodate some experimentation of customary traditional uses and learn how the forest ecosystem responds to these methods of management.
7. **Specialty wildland management topics.**
   Some special or unique land and resource management activities require additional research or demonstration to hone management techniques and inform future decisionmaking. Some examples that could be accommodated in the HETF include:
   - Impacts of fire/fire ecology;
   - Reintroduction of threatened and endangered species; and
   - Introduction of biocontrol agents for invasive species.

The geographic study areas of the HETF are located adjacent to the Refuge. The HETF investigators and their associates have study plots on the Refuge for a number of collaborative research efforts. It is anticipated that many of the research findings from this initiative will assist the Refuge with management of similar habitats and species, especially given the long relationship that the Refuge has had with the USFS in testing applied research to improve management at the Refuge.

1.7.2 Statewide Plans (including Threatened and Endangered Species Recovery Plans)

Hawaiʻi's Comprehensive Wildlife Conservation Strategy (Mitchell, C. et al., 2005): Hawaiʻi's Comprehensive Wildlife Conservation Strategy (CWCS) (now known as Hawaiʻi's Wildlife Action Plan) presents strategies for long-term conservation of the full range of the State's native terrestrial and aquatic species, over 10,000 of which are found nowhere else on earth, and their habitats. The reason for developing a CWCS is to continue participation in the State Wildlife Grant (SWG) program administered by the Service. The Hawaiʻi Department of Land and Natural Resources took the lead in preparing the CWCS and went beyond simply meeting mandated requirements by making the CWCS a useful document to guide conservation efforts across the State. The CWCS builds on and synthesizes information gathered from existing conservation partnerships and cooperative efforts, such that the development of this Strategy is based on collaboration with other local, State, and Federal agencies, nongovernmental organizations, private landowners, and interested citizens.

Recognizing the effectiveness of taking conservation actions at a habitat level in addition to a species-specific level, the CWCS emphasizes threats to species and their habitats and conservation needs at three levels: Statewide, islandwide, and taxa-specific. The CWCS presents an overview of Hawaiʻi's unique species and their habitats, identifies the major threats to the long-term conservation of these species and habitats, and presents seven conservation objectives to address these threats. Under each objective, strategies of highest priority are labeled; however, because conservation needs in Hawaiʻi far exceed the resources available, implementation of any of the identified strategies will benefit native wildlife and habitats.

Hawaiʻi's Species of Greatest Conservation Need (SGCN) include the ʻōpeʻapeʻa, the only native terrestrial mammal in the State, all endemic aquatic animals, additional indigenous aquatic animals identified as in need of conservation attention, a range of native plants identified as in need of conservation attention, and all identified endemic algae. The SGCN includes: terrestrial mammal (1), birds (77), terrestrial invertebrates (approximately 5,000), freshwater fishes (5), freshwater invertebrates (12), anchialine pond-associated fauna (20), marine mammals (26), marine reptiles (6), marine fishes (154), marine invertebrates (197), and flora (over 600).

The major threats facing Hawaiʻi's native wildlife are common to most species groups and habitats and include:

- Loss and degradation of habitat resulting from human development, alteration of hydrology, wildfire, invasive species, recreational overuse, natural disaster, and climate change;
- Introduced invasive species (e.g., habitat modifiers, including weeds, ungulates, algae and corals, predators, competitors, disease carriers, and disease);
- Limited information and insufficient information management;
- Uneven compliance with existing conservation laws, rules, and regulations;
- Overharvesting and excessive extractive use;
- Management constraints; and
- Inadequate funding to implement needed conservation actions.

To address these threats, the CWCS identifies multiple strategies to implement the following seven priority conservation objectives for the State:

1. Maintain, protect, manage, and restore native species and habitats in sufficient quantity and quality to allow native species to thrive;
2. Combat invasive species through a three-tiered approach combining prevention and interdiction, early detection and rapid response, and ongoing control or eradication;
3. Develop and implement programs to obtain, manage, and disseminate information needed to guide conservation management and recovery programs;
4. Strengthen existing and create new partnerships and cooperative efforts;
5. Expand and strengthen outreach and education to improve understanding of our native wildlife resources among the people of Hawaiʻi;
6. Support policy changes aimed at improving and protecting native species and habitats; and
7. Enhance funding opportunities to implement needed conservation actions.

The Hakalau Forest NWR CCP includes strategies that address these priority conservation objectives. In particular, objectives 1, 2, 4, and 5 are key components of Refuge management programs.

Revised Recovery Plan for Hawaiian Forest Birds (USFWS 2006)**:** The Recovery Plan for Hawaiian Forest Birds applies to 21 species. It identifies four species that are found on Hakalau Forest NWR (Hakalau Forest and Kona Forest Units). The overall recovery plan efforts are outlined here followed by specific recommendations for the individual species. The individual species sections focus only on Recovery Strategies, as life-history and habitat requirements are covered in Chapter 4.

Threats: The primary threats to Hawaiian forest birds are habitat loss and degradation due to agriculture, urbanization, cattle grazing, browsing by ungulate species, timber harvesting, and invasion of nonnative plant species into native-dominated plant communities; predation by alien mammals; and diseases carried by alien mosquitoes. The periodic dieback of native plant species due to natural or alien-species-induced processes is a threat in some areas. The majority of recovery actions therefore address threats to habitat, disease, and predation. The direct overutilization of Hawaiian forest birds for commercial, recreational, scientific, or educational purposes; and the inadequacies of existing regulatory mechanisms are not considered significant current threats. Several Hawaiian forest birds now occur in such low numbers and in such restricted ranges that they are threatened by natural processes, such as inbreeding depression and demographic stochasticity, and by natural and manmade factors such as hurricanes, wildfires, and periodic vegetation dieback. Impacts of alien birds are not well understood, but include aggressive behavior toward native bird species; possible competition for food, nest sites, and roosting sites; and possibly supporting elevated predator population levels.

Recovery Objectives: The primary recovery objectives for each species (taxon) are to:
1. Restore populations to levels that allow the taxon to persist despite demographic and environmental stochasticity and that are large enough to allow natural demographic and evolutionary processes to occur;
2. Protect enough habitat to support these population levels; and
3. Identify and remove the threats responsible for its decline.

Recovery Criteria: Recovery criteria were developed for each taxon to guide recovery efforts and ensure that all their recovery needs are addressed. The criteria are similar for all species because they face similar threats and many of them occur in the same geographic areas, but the first criterion in particular was adapted for each species and reflects the unique characteristics of the ecology, conservation needs, and current and historical distribution of each species.

A taxon may be downlisted from endangered to threatened when all four of the following criteria have been met, as well as any species-specific criteria listed in Table 6 (Section III, Recovery Criteria):
(1) The species occurs in two or more viable populations or a viable metapopulation that represent the ecological, morphological, behavioral, and genetic diversity of the species;
(2) Viability of the populations is demonstrated through either (a) quantitative surveys show that the number of individuals in each isolated population or in the metapopulation has been stable or increasing for 15 consecutive years, or (b) demographic monitoring shows that each population or the metapopulation exhibits an average growth rate (lambda, λ) not less than 1.0 over a period of at least 15 consecutive years; and total population size is not expected to decline by more than 20 percent within the next 15 consecutive years for any reason;
(3) Sufficient habitat in recovery areas is protected and managed to achieve criteria 1 and 2 above; and
(4) The threats that were responsible for the decline of the species have been identified and controlled.

A taxon may be delisted when all four of the criteria above have been met for a 30-year period.

ʻŌʻū (*Psittirostra psittacea*): The ʻōʻū is currently one of the rarest birds in Hawaʻi, and may possibly be extinct, although past survey efforts have been insufficient to determine its status (Reynolds and Snetsinger 2001). The most recent observations indicate any remaining populations are extremely localized in occurrence and are restricted to only a fraction of their former range in the midelevation ʻōhiʻa forest on the islands of Kauaʻi and Hawaiʻi only.

No conservation efforts have been initiated specifically targeting ʻōʻū, but several research projects and Federal and State land management programs aimed at removing limiting factors for endangered birds and plants have been undertaken since 1985, and these provide some benefits to ʻōʻū. On Hawaiʻi Island, large tracts of State and federally owned land are being intensively managed for habitat restoration. Hawaiʻi Volcanoes National Park, Hakalau Forest NWR, Puʻu Makaʻala Natural Area Reserve, and the ʻŌlaʻa-Kīlauea Partnership (now TMA) area have been known to harbor ʻōʻū in the past 25 years, and each area currently has management programs aimed at removing ungulates to restore native forest habitat and ongoing research into eliminating other threats.

ʻAkiapōlāʻau (*Hemignathus munroi*): Four categories of recovery strategies have been identified; research, recovery areas, predator control, and captive propagation/reintroduction. For research, studies are identified as necessary in four main areas: (1) testing of survey methodology, followed by surveying and mapping of all populations and long-term monitoring; (2) demographic studies to measure life-history parameters such as population structure, dispersion, dispersal, adult survivorship, clutch size, nesting success, social system, and phenology of nesting and molting; (3) habitat selection and foraging ecology, including diet and food availability, particularly in regenerating forest, as well as the role that koa silviculture practices play in the creation of suitable habitat; and (4) response of ʻakiapōlāʻau populations to control of mammalian predators, particularly in low-stature dry forests where the species has difficulty maintaining itself.

For recovery areas, the most important component of the recovery strategy for the ʻakiapōlāʻau is protection, management, and restoration of koa/ʻōhiʻa forests above 4,400 ft elevation. Fencing and/or removal of ungulates from the remaining high elevation forests will protect these areas and allow natural regeneration. Predator control is identified as an effective method of increasing reproduction and survival in other Hawaiian forest birds (VanderWerf and Smith 2002). However, the degree of threat from alien rodents may vary among species and locations, and rodent control programs initially should be conducted in an experimental way to document their effect on ʻakiapōlāʻau populations.

Finally, captive propagation and reintroduction can augment natural recovery of ʻakiapōlāʻau and reestablishment of wild populations in portions of the former range. Captive propagation techniques such as collection of eggs from the wild, artificial incubation and hand rearing, captive breeding, and reintroduction may be required to speed recovery. Feasibility should be determined for reintroducing ʻakiapōlāʻau into now protected areas of its former range, particularly at the Puʻu Waʻawaʻa Forest Bird Sanctuary, the KFU of the Hakalau Forest NWR, Mauna Loa Strip of Hawaiʻi Volcanoes National Park, and, if it is managed as planned, the upper forests of Kīpāhoehoe Natural Area Reserve.

Hawaiʻi creeper (*Oreomystis mana*): The primary strategy for the recovery of the Hawaiʻi creeper is the protection and management of remaining koa/ʻōhiʻa forests above 4,900 ft elevation, and the restoration of degraded forests. Because the population is relatively large and the threat of extinction is not imminent, recovery may be achieved more cost effectively through habitat management, therefore captive propagation currently is of lower priority for this species.

Hawai‘i ‘ākepa (*Loxops coccineus coccineus*): The following four strategies have been identified for Hawai‘i ‘ākepa; (1) habitat protection and nest site management, (2) disease resistance, (3) predator control, and (4) captive propagation. The recovery plan identifies the most important component of the recovery strategy for the Hawai‘i ‘ākepa as habitat protection and nest site management. This includes protection of old-growth forest ecosystems, the use of artificial cavities to enable existing populations to hold their own despite loss of nest-site trees, and research to address factors that affect the growth form of regenerating ‘ōhi‘a.

Next, management of disease is identified as a major recovery strategy. Since eradication of mosquitoes is not practical with methods currently available, the birds themselves may be the best way of addressing the threat from disease. If individuals are discovered that tolerate disease, then genetic techniques can determine if those genotypes are present outside the range of disease. If those genotypes are not present outside the range, then an appropriate management strategy would be to move birds with pertinent genotypes into populations of birds that are not tolerant.

Third, predator control, especially rats, has been shown to be an effective method of increasing reproduction and survival in other Hawaiian forest birds (VanderWerf and Smith 2002). However, the degree of threat from alien rodents may vary among species and locations, and rodent control programs initially should be conducted in an experimental way to document their effect on ‘ākepa populations.

Finally captive propagation is not considered essential for recovery at this time. However, it is anticipated that the Hawai‘i ‘ākepa will breed in captivity when they reach reproductive age. Progeny from such captive propagation efforts would provide birds for reintroduction in order to establish and enhance wild populations.

Since native forest birds are a Refuge purpose species, many of the CCP goals, objectives, and strategies tie directly to forest bird recovery. Native forest restoration, including plant and animal species that are components of the forest, is the key component of this CCP and future management at Hakalau Forest NWR.

Recovery Plan for the ‘Ōpe‘ape‘a (*Lasiurus cinereus semotus*, Hawaiian Hoary Bat) (USFWS 1998)**:** The ‘ōpe‘ape‘a is the only native land mammal in the Hawaiian Islands. Research is the key to reaching the ultimate goal of delisting the ‘ōpe‘ape‘a, because currently available information is so limited that even the most basic management actions cannot be undertaken with the certainty that such actions will benefit the subspecies. The initial focus for developing standardized survey and monitoring techniques and collecting basic life-history information will be on ‘ōpe‘ape‘a populations on the Island of Hawai‘i, which apparently has the largest population of ‘ōpe‘ape‘a. Completion of research tasks will not only establish the distribution and abundance of ‘ōpe‘ape‘a, but will also provide information on specific roosting habitat associations and food habits.

With basic information on the location of ‘ōpe‘ape‘a and their resource needs, threats can then be identified and managed. Management actions that may be needed to address threats include protection of key roosting and foraging areas, particularly if ‘ōpe‘ape‘a or their food resources depend on native vegetation. Predation, the potential impacts of pesticides to bats or their food resources, and other threats may also need to be addressed.

Refuge staff are interested in helping to learn more about the ʻōpeʻapeʻa to assist in developing conservation strategies that could be incorporated into management actions at Hakalau Forest NWR.

Recovery Plan for the Big Island Plant Cluster (I & II) (USFWS 1996, 1998): The recovery plan and addendum for plants that are found on Hawaiʻi Island include 13 species that are or have been found on one or both of the units of Hakalau Forest NWR. For the purposes of this review, we have grouped the endangered plants according to recovery actions. This allows Refuge staff to review recovery actions to determine the greatest conservation benefit that Refuge habitat management actions can have on various species.

Species*: Clermontia lindseyana, Cyanea hamatiflora ssp. carlsonii, Portulaca sclerocarpa*
Recovery Action: Current populations of these species should be protected from ungulates wherever possible, and their habitat managed for deterrence of nonnative plant invasions. Propagation and outplanting efforts should be encouraged and continued.

Species*: Clermontia peleana, Clermontia pyrularia, Cyanea shipmanii*
Recovery Action: In order to prevent possible extinction of these taxa, maintenance of *ex situ* genetic stock is necessary. The known plants should be protected from ungulates, particularly pigs, via fencing or other means. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of plants for recovery within each location and an additional location will need to be established.

Species*: Cyanea stictophylla*
Recovery Action: In order to prevent possible extinction of this taxon, maintenance of *ex situ* genetic stock is necessary. The known plants should be protected from ungulates, particularly pigs, via fencing or other means. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of plants for recovery within each location and an additional two locations will need to be established.

Species*: Cyrtandra tintinnabula*
Recovery Action: In order to prevent possible extinction of this taxon, maintenance of *ex situ* genetic stock is necessary. The known plants should be protected from ungulates, particularly pigs, via fencing or other means. Propagation and outplanting of *ex situ* stock will likely be needed in order to establish a sufficient number of plants for recovery within each location and an additional location will need to be established. Research into pollination vectors is needed.

Species*: Nothocestrum breviflorum*
Recovery Action: Propagation and maintenance of *ex situ* genetic stock is necessary. Populations should be protected from cattle via fencing or other means, and competing alien plant taxa, specifically *Schinus terebinthifolius*, lantana, and fountain grass, should be controlled. Habitat of this species should be protected from residential and recreational development in sufficient area to allow for full recovery of the species.

Species*: Silene hawaiiensis*
Recovery Action: Recent discoveries of several large populations indicate that this plant is not as rare as once thought. Populations should be monitored to ensure that numbers are being maintained. After habitat on which at least five of the larger populations occur is managed to control threats from feral animals, alien taxa, and military training, delisting of this species can be considered.

Species*: Phyllostegia racemosa, Phyllostegia velutina, Sicyos macrophyllus*
Recovery Actions: Construct fenced exclosures around the known populations, and initiate removal of ungulates and alien plant taxa. Once they are fenced, ungulates and alien plants should be removed. Outplant new populations in areas of reduced threat. Prior to and following outplanting, the sites' alien plants should be removed.

Since endangered plants are a Refuge Purpose species, many of the CCP goals, objectives, and strategies tie directly to plant recovery. Native forest restoration, including plant and animal species that are components of the forest, is the key element of this CCP and future management at Hakalau Forest NWR.

Recovery Plan for Four Species of Hawaiian Ferns (USFWS 1998)**:** The most important recovery action for these taxa is to protect high elevation lava tubes, including removal of feral animals. *Asplenium fragile var. insulare* (now named *Asplenium peruvianum* var. *insulare*) has a very scattered distribution and surveys will help determine the best areas for habitat protection. Optimal survey areas can be determined by considering the age of the substrate and the vegetation type.

Protection of high elevation lava tubes is included as Goal 2. The key elements of fencing and ungulate removal will provide a direct benefit to this species.

Revised Recovery Plan for the ʻAlalā (*Corvus hawaiiensis*) (USFWS 2009): The ʻalalā is listed as endangered without critical habitat. No individuals are known to exist in the wild. As of 2010, 77 ʻalalā, representing the entire population of the species, are in captivity; including 1 bird at the San Diego Wild Animal Park and the remaining 76 at the Keauhou and Maui Bird Conservation Centers on Hawaiʻi and Maui islands, respectively.

Recovery Objective: The ʻalalā currently exists only as a small population in captivity, and so the exact needs of the recovery program cannot be specified beyond a relatively short time horizon. Recovery of this species will require both sustained, long-term conservation actions and repeated experimentation to determine the optimal means to reestablish wild populations. This recovery plan's structure reflects these needs by articulating both long-term strategies (the Strategic Plan) and short-term actions (Implementation Plans) which will be revised regularly. The elements of the recovery strategy are to (1) expand captive propagation to minimize the loss of genetic diversity, (2) identify, protect, and manage suitable habitat, and reduce threats at the selected release sites, (3) introduce birds into the wild in suitably managed habitat once the captive population is stabilized, (4) garner public support and funding, and (5) conduct research and adaptively manage the ʻalalā recovery program.

Recovery Actions:
1. Manage the population of ʻalalā by increasing the number of captive ʻalalā to at least 75 individuals to retain all possible genetic diversity and provide individuals for release into the

wild. This will require construction and appropriate staffing of the captive propagation infrastructure necessary to accommodate the increasing size of the captive population.

2. Identify suitable habitat and manage threats by selecting and managing at least one site within historical habitat so that threats, including disease and predator numbers, are minimized to the extent the site is suitable for the release of captive reared ʻalalā.

3. Establish new populations in suitable habitat by selecting and preparing captive-reared ʻalalā for release, and planning release protocols to maximize survival and obtain crucial information for improvement of subsequent releases.

4. Garner public support using professionally designed strategies to develop nongovernmental funding sources to support expanded captive propagation, habitat management and ʻalalā reintroduction. Also, achieve stakeholder support for predator and ungulate management and post-release ʻalalā monitoring.

5. Conduct research and adaptively manage the recovery program by establishing a recovery implementation working group involving key stakeholders and by assigning overall recovery coordination to a single individual with performance milestones to be reviewed annually by the recovery team.

The KFU was originally acquired and set aside specifically for protection of the ʻalalā. Native forest restoration at KFU is a key component of recovery actions 2 and 3.

The Hawaiian Hawk Recovery Plan (USFWS 1984): The ʻio (*Buteo solitarius*, Hawaiian hawk) was listed as endangered on March 11, 1967, based on its restricted range (found only on the Island of Hawaiʻi), its small population size, and the loss of native forest habitat from agriculture, logging, and commercial development.

However, at the time of listing there had been no systematic surveys or ecological studies of the species, and the only information available was from anecdotal accounts that gave differing reports on its abundance and population trend in various parts of the island.

Due to implementation of recovery actions and other conservation efforts, the species is now found throughout the Island of Hawaiʻi and has had a stable population for at least 20 years. It is nesting and foraging successfully in both native and altered habitats and has large areas of protected habitat. The ʻio is not currently believed to be threatened by overutilization, disease, predation, contaminants, lack of adequate regulatory mechanisms, or other factors.

On August 6, 2008, the Service proposed to remove the ʻio from its current listing as endangered under the Endangered Species Act. On February 11, 2009, the Service formally announced the availability of the draft Post-Delisting Monitoring Plan for the ʻio and reopened a 60-day public comment period that closed on April 13, 2009 (74 FR 6853). The Service is considering public comments received during the public review periods and has not yet published a final rule.

The recovery plan for ʻio has not been updated since 1984. The recovery objectives listed here are relevant; however, review and update will help to obtain current data and refine or adjust recovery objectives and/or actions.

Recovery Criteria: The prime objective is to ensure a self-sustaining ‘io population in the range of 1,500-2,500 adult birds in the wild, as distributed in 1983, and maintained in stable, secure habitat. For purposes of tracking the progress, 2,000 will be used as a target to reclassify to threatened status.

Both units of Hakalau Forest NWR provide habitat for the ‘io. Management strategies that improve native habitat conditions will benefit ‘io populations.

Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose (*Branta sandvicensis*) (USFWS 2004): Of the five or so endemic goose species described from the Hawaiian Islands, only the nēnē has survived to the present day (Olson and James 1984; Olson and James 1991). Fossil remains of nēnē have been discovered on most of the main Hawaiian Islands, including Hawai‘i, Maui, Kaho‘olawe, Lāna‘i, Moloka‘i, and Kaua‘i (Olson and James 1991). Historically (after 1778), nēnē are known with certainty only from the Island of Hawai‘i. The nēnē was declared a federally endangered species in 1967. It is considered one of the most endangered geese in the world and is the second most endangered waterfowl in the United States.

Recovery Criteria: Restore and maintain multiple self-sustaining nēnē populations on Hawai‘i, Maui Nui (Maui, Moloka‘i, Lāna‘i, Kaho‘olawe), and Kaua‘i. Additionally, the threats to the species must be reduced to allow for the long-term viability of these populations, and sufficient suitable habitat must be identified, protected, and managed in perpetuity on each of these islands such that the species no longer meets the definition of endangered or threatened under the Endangered Species Act.

Recovery Actions:
1. Identify and protect nēnē habitat, focusing on the identification and protection of sufficient habitat to sustain target population levels;

2. Manage habitat and existing populations for sustainable productivity and survival complemented by monitoring changes in distribution and abundance;

3. Control alien predators, which addresses control of introduced mammals to enhance nēnē populations;

4. Continue captive propagation program, which describes techniques and priorities for the captive propagation and release of nēnē into the wild;

5. Establish additional nēnē populations, which focuses on partnerships with private landowners;

6. Address conflicts between nēnē and human activities, which includes potential management and relocation of nēnē in unsuitable areas;

7. Identify new research needs and continue research, which describes general categories of research needed to better evaluate threats to nēnē and develop and evaluate management strategies to address these threats;

8. Provide a public education and information program, which describes important outreach and education activities; and

9. Validate recovery actions, which calls for formalizing the Nēnē Recovery Action Group and evaluating management and research projects to determine if recovery objectives have been met.

The CCP identifies specific management actions that will benefit the nēnē population on the Hakalau Forest Unit. Strategies include nonnative predator control and maintenance of firebreaks and access roads for nēnē foraging.

1.8 Planning and Issue Identification

In February 2009, we mailed approximately 150 copies of Planning Update 1 to interested individuals, local conservation and interest groups, research organizations, Native Hawaiian organizations, and local, State, and Federal government agencies.. Planning Update 1 was available at two public open house meetings we held in Hilo and Captain Cook, Hawai‘i, in March 2009. It was also posted on the Refuge's website (*http://www.fws.gov/hakalauforest/planning.html*) and the Service's Pacific Region refuge planning website (*http://www.fws.gov/pacific/planning/main/docs/HI-PI/docshakalau.htm*).

In Planning Update 1, we described the CCP planning process; Refuge purposes; draft wildlife, habitat, and public use goals; and preliminary issues to be considered in the CCP. In Planning Update 2 (made available in October 2009 and similarly circulated as the first update), we summarized the comments we received and listed primary management issues we used to draft alternatives and refine draft goals and objectives. We also included draft vision statements for both units. A full summary of public involvement is in Appendix K.

1.8.1 Public Scoping Sessions

The public scoping period for this CCP opened February 25, 2009, and ended March 27, 2009. Two public meetings were held, in Hilo and Captain Cook, Hawai‘i, on March 3, 2009, and March 4, 2009, respectively. At the meetings, Refuge staff explained the CCP planning process; the Refuge purposes, vision, and management; and preliminary management issues, concerns, and opportunities. Refuge staff also answered questions from attendees and received written comments. Twelve private citizens and representatives from various organizations attended the meetings and commented on the issues and opportunities we presented. Six written responses were received from individuals or organizations during scoping. The comments we received addressed broad or long-range issues and very specific or detailed strategies that could be used to achieve biological or public use objectives. Summaries of the issues identified and Service responses are provided follow.

How can we best protect endangered forest birds and the nēnē?

The primary purpose of the Refuge is protection of endangered species. We manage Refuge resources to ensure high-quality habitat is available for endangered species, especially forest birds. Drawing on 20 years of Refuge management experience at the HFU, we have included objectives and strategies in this Draft CCP/EA for maintaining and enhancing native habitat communities to provide the life-history needs of Hakalau Forest NWR's endangered species.

How can we best protect montane wet koa/‘ōhi‘a forest, montane dry koa/‘ōhi‘a/māmane forest, lava tubes, and lavatube skylights?

These habitat types are key to the survival of endangered species. Refuge management objectives and strategies will be designed to protect these habitat types, and where appropriate, restore areas to high-quality habitat. We describe alternatives for managing these important resources in Chapter 2.

What opportunities exist for expanding environmental education through outreach and onsite programs?

Refuge staff have worked with ‘Imi Pono no ka ‘Āina on environmental education opportunities onsite and offsite in local schools. Through the CCP planning process, we have identified additional partnerships or opportunities to expand upon the work that is already in place (e.g., through the Friends of Hakalau Forest Refuge).

How can we best prepare for, manage, and prevent the spread of wildfires?

There is concern, especially from adjacent landowners, that a wildfire could be ignited on the Refuge then spread onto private land. The Refuge currently coordinates with the County of Hawai‘i to provide wildland fire fighting capabilities. We are also concerned about the potential for wildfire as habitat restoration efforts are implemented. Within the past year, a fire adjacent to the HFU came close to spreading onto Refuge lands. Close coordination with the County, other agencies, and adjacent landowners is essential to ensure an efficient response to fire threats. As part of the Draft CCP/EA, Refuge staff will review options for creating firebreaks and obtaining the equipment and personnel required to meet firefighting needs at both units.

How can we keep refuge visitors and others (e.g., contractors, Service staff) from trespassing on adjacent lands?

The KFU is currently closed to the public. At both units, a number of contractors and Refuge staff use the easements for accessing the Refuge. We continue to impress upon all individuals who access the areas the importance of using only the authorized and in some cases court-ordered easements. Where appropriate, trespass incidents will be referred to Service law enforcement.

Is acquiring additional easements for accessing the Kona Forest Unit feasible?

The existing easement includes difficult access from the Mamalahoa Highway, steep slopes, and multiple gates. At this point, no additional access or easement opportunities have been identified. We will continue to explore options if they arise.

What Native Hawaiian gathering activities occur on the Refuge?

To date, there have been very few access requests for gathering activities. As part of the CCP, Refuge staff plan to review the process for granting Special Use Permits for gathering activities.

Can we maintain public access to the historic Kaunene Trail?

We have reviewed options for access to the trail. At this time access, safety, and resource management needs preclude maintenance and public access to the trail. Over time, we could revisit opportunities to reopen the Kaunene Trail.

Do the Refuge units meet the minimum requirements for a wilderness designation nomination?

A wilderness review, as required by Service policy, has been conducted as part of the CCP planning process and is included as Appendix D.

Is there the potential to protect habitat for endangered forest birds through additional land acquisition or conservation easements?

At each unit we will consider opportunities for Refuge boundary expansion on a case-by-case basis, and in accordance with Service policy. The Refuge is working with nongovernment conservation organizations (NGOs) that are familiar with private lands in the vicinity of existing Refuge units in evaluating any feasible acquisition opportunities that may arise. Currently, two tracts of land with high-quality habitat within the HFU's approved acquisition boundary have not been acquired and are being managed by an agency partner. All of the land within the acquisition boundary for the KFU has been acquired. We encourage landowners with high-quality habitat for forest birds to manage their lands for conservation. In addition, Refuge staff will work with Regional staff to develop a land conservation plan as outlined in objectives 1e and 3e in Chapter 2.

How can we better manage the Kona Forest Unit's ungulate populations?

Refuge staff are in the process of administering a contract to build a perimeter fence around the unit and two interior fences that would create three management areas within the unit. Options and opportunities for ungulate management, including removal, are included as part of the management of the KFU in the preferred alternative.

How will climate change impact the Refuge?

The Refuge's two units are unique in the Hawaiian Islands because of the range of elevations that occur on Refuge lands. Through the CCP planning process we will evaluate the effectiveness, impacts, and benefits of providing wildlife habitats at a variety of elevations, temperatures, and rainfall regimes, so that wildlife can move between as conditions are altered through climate change processes.

1.8.2 Interagency Scoping

On July 1, 2009, Refuge and Hawaiian and Pacific Islands staff members met with some of our agency partners to discuss planning for Hakalau Forest NWR. Individuals from the DLNR, DHHL, USGS-BRD, and USFS attended the meeting. Refuge staff provided an overview of the planning process and current management of the Refuge. The following list of issues was developed based upon feedback received from these individuals.

- Desire by partners to see staff and a satellite office in the vicinity of the KFU;
- Potential for some joint planning with NPS at Kahuku;
- Interest in developing some sort of "Partnership Boundary" that could include Three Mountain Alliance, Mauna Kea Watershed Alliance, Wai'ea;
- Need for strong management partnerships at KFU;
- Climate Change
  - Issues that will likely become larger in the context of climate change include avian malaria, the need for corridors to connect habitat fragments;
  - Quote - "This is one of Hawai'i's great opportunities to deal with climate change";
  - The Plan should look for opportunities to connect the subalpine habitat with wet-lower elevation habitats;
- On adjacent lands, DHHL is considering māmane restoration, bird corridors, koa restoration, and gorse control. [Since this meeting DHHL's 'Āina Mauna Legacy Program more completely outlines specific plans for adjacent areas.];
- Endangered plants are an important piece of the habitats that are being restored. We should specify actions and species;
- There should be more exploration into carbon sequestration. Previous efforts did not get off the ground, but there is an emerging market for "boutique" carbon that could serve Hakalau well;
- Research
  - There is a need for research into habitat and species responses to adaptive management to help make adjustments over time;
  - There is a greater need for monitoring than for pure research;
  - Consider developing a Research Management Plan with a formal subcommittee;
  - Need a way to filter research requests;
- Additional enforcement should be present at both units;
- Education/Outreach
  - Consider expanding the open house to twice per year;
  - Develop an airport kiosk;
  - Host an annual "low-budget" research symposium: potential ideas include poster sessions, keynote speakers, in conjunction with other events that may be occurring on island.
- Hakalau nēnē appear to be a migratory subpopulation that could provide an additional avenue for education about management at Hakalau;
- Develop a bibliography of Hakalau research; and
- Review and use the Hawai'i Volcanoes National Park ungulate control Environmental Impact Statement (EIS).

1.8.3 Forest Bird Workshop

The Service held a workshop with partner agencies, renowned forest bird researchers, and statisticians in Hilo October 8-10, 2008, to expand a review of the current status of the Hawai'i 'ākepa and other endangered Hawaiian forest birds at the Refuge for development of options for management alternatives for the CCP.

The Service has received contradictory information over the population status of the endangered Hawai'i 'ākepa in a portion of the Refuge, a major stronghold of the species, over the last several years. The Regional Director obtained the assistance of the USGS' Dr. J. Michael Scott in conducting a review of available information on the Hawaiʻi ʻākepa, and this workshop was an extension of the review.

The agenda was focused on the endangered Hawaiian forest birds found at the Refuge. It was anticipated that although the workshop focused specifically on the Refuge, much of the information shared would be applicable to these species throughout their ranges and to the broader Mauna Kea and Hawaiʻi Island ecosystems or forest bird survey methodology in general.

The workshop purposes and objectives were:

1. Identify and prioritize management needs and activities, including research, at Hakalau Forest NWR to recover endangered Hawaiian forest birds;
2. Incorporate identified needs and activities in the Hakalau Forest 15-year CCP; and
3. Extrapolate Hakalau-specific information to the broader Mauna Kea area and other geographic areas and bird species and suites of birds as appropriate.

A number of suggestions came out of the workshop, as listed below. The rankings for each of the lists are based upon voting by workshop participants. The complete forest bird workshop summary is included as Appendix E.

Immediate Threats to Hawaiian Forest Birds at Hakalau Forest NWR

1. Ungulates;
2. Lack of Habitat;
3. Invasive Plants;
4. Predation;
5. Data Insufficient to Meet Management Needs;
6. Parasites; and
7. Interspecific Competition.

Management Actions (Priority Ranking by Workshop Participants)

1. *Grazers/browsers (Habitat destruction/relative to mosquito production) (High)
   - Fence construction, maintenance, and removal of animals;
   - See Research Priorities;
2. Habitat Restoration (High)
   - Revegetation of pasture land;
   - Improve ʻōhiʻa densities;
3. Invasive plants (High)
   - Continue invasive species control (e.g., blackberry, banana poka, gorse);
   - Prevent and eliminate incipient weeds;
   - See Research Priorities;
4. Monitoring and Data Needs (High)
   - See Research priorities;
   - Delivery of technical information;
5. Predation (Medium)
   - See Research priorities;
6. Parasites (Low)

- Incipient invasive parasites, true population counts, delouse birds;

7. Interspecific competition (Low)
    - See Research priorities;
    - Identify ectoparasites/mites.

Research Priorities (Priority Ranked by Workshop Participants)

1. Monitoring and Data: Expand point counts/banding data (combined primary counter training, consider use of a B-Bird (Breeding Biology Research and Monitoring Database) system (*http://www.umt.edu/bbird/info.htm*), and threat surveillance);
2. Predation: Investigate effects of rats on forest birds; rodent population index;
3. Invasive Plants: Develop effective biocontrols;
4. *Grazers/Browsers: Predator proof fencing;
5. Invasive Plants: Develop more efficient control methods and registration of herbicides;
5. Determine the effects of global climate change at the Refuge;
6. Develop more effective cat control techniques;
6. Determine effects of ectoparasites on non-endangered bird populations; and
7. Experimental control of Japanese white-eyes.

*Caveat: Activities to construct an ungulate-proof fence and a predator-proof fence caused some confusion. Dr. Scott obtained consensus that these activities could be combined with a third separate but related activity of removing ungulates.

1.9 Refuge Vision

A CCP describes management actions that help bring a refuge closer to its vision. A vision broadly reflects the refuge purposes, the Refuge System mission and goals, other statutory requirements, and larger-scale plans as appropriate. Public use and wildlife/habitat management goals then define general targets in support of the vision, followed by objectives that direct effort into incremental and measurable steps toward achieving those goals. Finally, strategies identify specific tools and actions to accomplish objectives.

Hakalau Forest National Wildlife Refuge (*Ka Puʻuhonua Waonahele Aupuni ʻo Hakalau*)

Aia nō i uka i ke kua koʻolau o Mauna Kea ka puʻuhonua waonahele aupuni ʻo Hakalau. He wahi kēia e hui ai kānaka e laulima ma o ke kaʻanalike aku, kaʻanalike mai i ka ʻike, ka noʻeau, a me ka mana i mea e hoʻopalekana, hoʻoikaika, a hoʻōla hou ai i ke ola maoli e noho ana ma ka waonahele. Ua kapa ʻia ka inoa ʻo Hakalau no ka nui o nā haka e noho ʻia e nā manu ʻōiwi. I kēia lā ʻo Hakalau kekahi o nā home nunui no ka hui manu Hawaiʻi ʻane make loa. Kīkaha aʻela nā manu, nā pua laha ʻole hoʻi, i ka ʻohuʻohu o Hakalau a ma lalo iki e mūkīkī i ka wai pua ʻōhiʻa. Ua nani nō ka ʻikena a ʻupu aʻela nō ke aloha no kēia ʻāina nei no nā kau a kau.

On the windward slope of majestic Mauna Kea, midway between summit and sea, lies Hakalau Forest NWR, a place where people come together to laulima, “many hands working together,” to share their knowledge, to share their skills, and to share their energy to protect, to enhance, to restore, and to respect Hawaiian wildlife. Known to Hawaiians as “place of many perches,” verdant rainforest supports the largest populations of endangered Hawaiian forest birds. Crimson, orange, yellow, and green hued birds, the jewels of Hakalau, flit through the mist, pausing to sip nectar from ʻōhiʻa lehua, inspire joy and wonder for present and future generations.

Kona Forest Unit (*Ka Waonahele o Kona*)

Mai Mauna Kea nō a kaʻa i lalo, a hiki aku i Mauna Loa, ma laila nō ka waonahele o Kona, kahi e noho lewalewa ana nā ao ʻōpua i ka ʻuhiwai e hōʻoluʻolu ana i ka ulu lāʻau. ʻIke ʻia ka ʻio e kīkaha ana ma luna loa o ka papa kaupoku i hoʻowehiwehi ʻia me ka limu. Ma lalo o ke kaupoku koa me ʻōhiʻa, e ʻimi ana ka ʻalalā me kona hoa manu i ka huaʻai, wai pua, a me nā mea kolokolo i mea ʻai na lākou. Aia nō ma ka malumalu o nā ana kahe pele kahiko nā mea kanu kākaʻikahi o ka ʻāina, a me nā iwi o nā manu make loa ma Hawaiʻi. Kuahui maila nō nā hoa mālama ʻāina i ola hou ka nohona o nā mea ʻane make loa ma kēia ʻāina nui ākea.

On leeward Mauna Loa, where the clouds kiss the slopes with cool gray fog, lies the Kona Forest. ʻAlalā and other Hawaiian forest birds forage for fruit, nectar, and insects amongst the lichen-draped branches and canopy of the old-growth koa/ʻōhiʻa forest while the ʻio soars overhead. In their damp darkness, ancient lava tubes and cave systems shelter rare plants, archaeological resources, and the bones of extinct birds. Conservation partners collaborate to restore habitat for the native and endangered species across the landscape.

1.10 Refuge Goals

Goals and objectives are the unifying elements of successful refuge management. They identify and focus management priorities, resolve issues, and link to refuge purposes, Service policy, and the Refuge System mission.

The goal order does not imply any priority in this CCP.

Pahuhopu 1: E hoʻopalekana, mālama, a hoʻōla hou i ka waonahele ma Mauna Loa ma ke ʻano he wahi noho no nā mea a pau i mea e kūʻonoʻono hou ai ka nohona o nā mea ʻane make loa ʻo ia nō ʻo ʻoe ʻo nā manu, nā ʻōpeʻapeʻa, nā mea kanu, a me nā mea kolokolo ʻāina.

Goal 1: Protect, maintain, and restore subtropical rainforest community on the leeward slope of Mauna Loa as habitat for all life-history needs to promote the recovery of endangered species (e.g., forest birds, ʻōpeʻapeʻa, plants, and invertebrates).

Pahuhopu 2: E hoʻopalekana a mālama i nā ana kahe pele a me ke ola i ka puka mālamalama o nā ana kahe pele ma ka waonahele o Kona, e kālele ana hoʻi i ke ola o nā lāʻau ʻōiwi.

Goal 2: Protect and maintain lava tube and lava tube skylight habitat throughout the Kona Forest Unit, with special emphasis on their unique and endemic flora and fauna.

Pahuhopu 3: E hoʻopalekana, mālama, a hōʻola hou i ka waonahele ma ka ʻaoʻao koʻolau o Mauna Kea ma ke ʻano he wahi noho no nā mea a pau a me ko lākou pono ʻoia nō ʻoe ʻo nā manu, nā ʻōpeʻapeʻa, nā mea kanu, a me nā mea kolokolo ʻāina.

Goal 3: Protect, maintain, and restore subtropical rainforest community, on the windward slope of Mauna Kea as habitat for all life-history needs of endangered species (e.g., forest birds, ʻōpeʻapeʻa, plants, and invertebrates).

Pahuhopu 4: E hoʻopalekana a mālama i ka ʻāina nenelu ma Hakalau.

Goal 4: Protect and maintain wetland and aquatic habitats (e.g., streams and their associated riparian corridors, ponds, and bogs) on the Hakalau Forest Unit.

Pahuhopu 5: E hoʻopalekana a mālama i ka ʻāina mauʻu i mea e kākoʻo ai i ka hoʻōla hou ʻana i ka hui manu nēnē.

Goal 5: Protect and maintain grassland habitat to support nēnē population recovery.

Pahuhopu 6: E ʻohiʻohi i ka ʻikepili ʻepekema (waihona ʻike, nānā pono, ʻimi noiʻi, ana ʻike) e pono ai ka hoʻoholo ʻana i ke ʻano o ka hoʻokele ʻana iā Hakalau ma Mauna Kea a me Mauna Loa.

Goal 6: Collect scientific information (inventories, monitoring, research, assessments) necessary to support adaptive management decisions on both units of the Hakalau Forest NWR.

Pahuhopu 7: E kipa mai ka poʻe malihini a me ka poʻe makaʻāinana no ka hana manawaleʻa ʻana i mea e kamaʻāina ai lākou i ka nohona o ka waonahele a me ka ʻoihana mālama ma Hakalau.

Goal 7: Visitors, with a special emphasis on experience gained through volunteer work groups and local residents, understand and/or value the native forest environment and management practices at Hakalau Forest NWR.

Pahuhopu 8: E hoʻopalekana a mālama i nā kumu waiwai a me nā wahi pana Hawaiʻi no ka hoʻonaʻauao ʻana i nā hanauna o kēia wā a me ka wā e hiki mai ana.

Goal 8: Protect and manage cultural resources and historic sites for their educational and cultural values for the benefit of present and future generations of Refuge users and communities.

1.11 References

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Chapter 2. Refuge Management Direction

‘Hawai‘i ‘Elepaio/Jack Jeffrey Photography

Thousands of koa trees planted in corridors are the first step toward restoring degraded habitat/USFWS

Chapter 2. Refuge Management Direction

2.1 Considerations in the Design of the CCP

The Refuge reviewed and considered a variety of resource, social, economic, and organizational aspects important for managing the Refuge. These background conditions are described more fully in Chapters 3, 4, and 5. In addition, past and current management actions were also considered (a summary of which can be found in Appendix L). As is appropriate for a national wildlife refuge, resource considerations were fundamental in designing alternatives. House Report 105-106 accompanying the Improvement Act states "…the fundamental mission of our System is wildlife conservation: wildlife and wildlife conservation must come first." The CCP team reviewed scientific reports and studies to better understand ecosystem trends and the latest scientific recommendations for species and habitats. Refuge staff met with elected officials and staff from local, State, and Federal agencies to ascertain priorities and problems as perceived by others. Refuge staff also met with Refuge users, nonprofit or nongovernmental groups (NGOs), university/academic members, and community organizations to ensure that their comments and ideas were considered during CCP development.

Refuge staff developed tables of focal species, conservation targets, and supporting habitats for Refuge management (Appendix F) based upon the Refuge purposes for Hakalau Forest NWR, a variety of national, regional, and State plans, and discussion with Service biologists, managers, and outside researchers. These conservation targets provide the basis for our habitat management goals, objectives, and strategies.

2.2 General Guidelines

General guidelines for implementing the CCP follow, as do maps that summarize the CCP actions by the Refuge. To reduce the length and redundancy of the descriptions for each unit, common features are presented below.

Ungulate-proof Boundary Fencing and Sequence of Management Actions (HFU and KFU): The perimeter (ownership) boundary of Hakalau Forest NWR will be enclosed by fencing, with internal fencing to divide into management units following. Establishing perimeter boundary fencing is a critical first step in habitat protection and restoration to deter major threats to the ecosystem and their impacts to wildlife population and species recovery. Once fences are established, the standard management strategy sequence would be to remove ungulates, then concentrate on invasive species control (e.g., invasive plants, predators such as rats, mongooses, cats, and dogs) while simultaneously restoring habitat through native plant outplantings. Surveys and monitoring for threats (e.g., invasive weeds, ungulates, predators, etc.) would be ongoing as well as species and habitat monitoring. If threats are found, they will be eradicated or controlled. Protection of special habitats (e.g., *Carex* sp. bogs) and endangered plant outplantings would occur once habitats are stabilized and threats managed and include actions such as site-specific fencing.

Maintaining/Upgrading Existing Facilities and Fences: Periodic maintenance and upgrading of Refuge buildings, fences, and facilities will be necessary for safety and accessibility and to support management and public use needs. Periodic maintenance and upgrading of fences is necessary to exclude ungulates from management units. The use of a helicopter is required in remote areas of the Refuge to deliver management materials.

Invasive Species Control and Integrated Pest Management: In accordance with 517 DM 1 and 569 FW 1, an integrated pest management (IPM) approach would be utilized, where practicable, to eradicate, control, or contain pest and invasive species (herein collectively referred to as pests) on refuge lands. The IPM would involve using methods based upon effectiveness, cost, and minimal ecological disruption, which considers minimum potential effects to nontarget species and the refuge environment. Pesticides may be used where physical, cultural, and biological methods or combinations thereof, are impractical or incapable of providing adequate control, eradication, or containment. If a pesticide would be needed on refuge lands, the most specific (selective) chemical available for the target species would be used unless considerations of persistence or other environmental and/or biotic hazards would preclude it. In accordance with 517 DM 1, pesticide use would be further restricted because only pesticides registered with the U.S. Environmental Protection Agency (EPA) in full compliance with the Federal Insecticide, Fungicide, and Rodenticide Act and as provided in regulations, orders, or permits issued by EPA may be applied on lands and waters under refuge jurisdiction.

Environmental harm by pest species would refer to a biologically substantial decrease in environmental quality as indicated by a variety of potential factors including declines in native species populations or communities, degraded habitat quality or long-term habitat loss, and/or altered ecological processes. Environmental harm may be a result of direct effects of pests on native species including preying and feeding on them; causing or vectoring diseases; preventing them from reproducing or killing their young; outcompeting them for food, nutrients, light, nest sites or other vital resources; or hybridizing with them so frequently that within a few generations, few if any truly native individuals remain. Environmental harm also can be the result of an indirect effect of pest species. For example, decreased waterfowl use may result from invasive plant infestations reducing the availability and/or abundance of native wetland plants that provide forage during the winter.

Environmental harm may involve detrimental changes in ecological processes. Environmental harm may also cause or be associated with economic losses and damage to human, plant, and animal health. For example, invasions by fire-promoting grasses that alter entire plant and animal communities, eliminating or sharply reducing populations of many native plant and animal species, can also greatly increase firefighting costs.

The greatest threats to most habitat types on the Refuge are invasive plant and animal species. Therefore, control of invasive species that negatively impact Refuge wildlife populations or habitats will be a priority management strategy. The top priorities for invasive plant control are gorse, banana poka, and Florida blackberry. The top priorities for invasive animal control are ungulates (including pigs, sheep, cattle, donkeys, and horses) as described in the Refuge's Feral Ungulate Management Plan. Control of introduced mammalian predators include pest animals such as rats, cats and dogs, and mongooses supports recovery of federally endangered species by reducing the loss of eggs and nestlings. Vertebrate pests damaging/destroying Federal property and/or detrimental to the management program of a refuge may be controlled as described in 50 CFR 31.14 (Official Animal Control Operations). Based upon 50 CFR 28.43 (Destruction of Dogs and Cats), dogs and cats running at large on a national wildlife refuge and observed in the act of killing, injuring, harassing or molesting humans or wildlife may be disposed of in the interest of public safety and protection of the wildlife.

Invasive plants and animals will be treated with IPM techniques and tools. Refer to Appendix G for the Refuge's IPM program documentation to manage pests for this CCP. Along with a more detailed discussion of IPM techniques, this document describes the selective use of pesticides for pest management on Refuge lands, where necessary.

Quarantine Protocols: Staff currently employ strict quarantine protocols with all staff, Service authorized agents (e.g., researchers, USDA–APHIS/WS), and visitors to both units of the Refuge. These techniques, including cleaning of equipment and personal gear, will be used under all alternatives in all habitat types to prevent movement of invasive species from one area to another.

Land Protection: The Refuge has begun a Land Protection Planning process that will be completed within 1 year of CCP completion. This effort is in cooperation with other agencies and interested parties to assess and identify land conservation priorities in the vicinity of Refuge units. Potential additions or expansion of the Hakalau Forest NWR and examination of various land protection tools will be explored. Land Protection as part of the Refuge System may include fee title acquisition, conservation easements, and/or cooperative agreements.

Adaptive Management: Based upon 522 DM 1 (Adaptive Management Implementation policy), refuge staff shall utilize adaptive management for conserving, protecting, and, where appropriate, restoring lands and resources. Within 43 CFR 46.30, adaptive management is defined as a system of management practices based upon clearly identified outcomes, where monitoring evaluates whether management actions are achieving desired results (objectives). The recently published *DOI Adaptive Management Technical Guide* also defines adaptive management as a decision process that "promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood." Adaptive management accounts for the fact that complete knowledge about fish, wildlife, plants, habitats, and the ecological processes supporting them may be lacking. The role of natural variability contributing to ecological resilience also is recognized as an important principle of adaptive management. It is not a "trial and error" process, but rather emphasizes learning while doing based upon available scientific information and best professional judgment considering site-specific biotic and abiotic factors on refuge lands. This policy will be adopted by the Refuge throughout the lifespan of its CCP.

Implementation Subject to Funding Availability: Actions (strategies) will be implemented over the 15 year life span of the CCP, contingent upon available funding. It is the intent of the Refuge that annual priorities will follow the final CCP guidelines, although funding initiatives, unforeseeable management challenges, and varying budgets may impact feasibility of actions from year to year. The CCP will be reviewed every 5 years and updated as necessary throughout its life.

Permanent Full Time Staffing Additions: This CCP proposes adding 11 new permanent full time positions to the staff of the Hakalau Forest NWR (HFU and KFU) to achieve the goals and objectives outlined in the plan. All staffing additions are subject to Regional approval and allocation of additional base funding.

Participation in Planning and Review of Regional Development Activities: The Refuge will actively participate in and contribute to planning and studies for ongoing and future industrial, urban, housing and energy development, contamination, and other potential concerns that may adversely affect Refuge wildlife resources and habitats. Working with the Ecological Services program of the Service, the Refuge will cultivate working relationships with pertinent local, County, State, and Federal agencies to stay abreast of current and potential developments and will utilize outreach, education and information as needed to raise awareness of Refuge resources and dependence on the local environment.

State Coordination: The Refuge will continue to maintain regular discussions with the State of Hawaiʻi Department of Land and Natural Resources (DLNR) Division of Forestry of Wildlife (DOFAW). Key topics for discussion with DOFAW will be wildlife monitoring, forest bird monitoring and management, threatened and endangered species management, wildlife mortality and disease monitoring, predator management, and response to climate change. Public use opportunities, as well as protection of Refuge wildlife and habitat, will be the primary topics of discussion with DLNR and its other divisions.

Volunteer Opportunities and Partnerships: Volunteer opportunities and partnerships are key components of the successful management of public lands and vital to implementation of Refuge programs, plans, and projects, especially in times of declining budgets.

Requests for Public Uses on Refuge Lands: Nonwildlife-dependent recreational activities will be subject to the criteria of Appropriate Refuge Use Policy, and if found appropriate, will be analyzed through a Compatibility Determination (CD). Existing public uses (wildlife observation, wildlife photography, environmental education and interpretation, hunting, and fishing) were evaluated through CDs, as appropriate. Through the CCP development process, public hunting was determined as an incompatible use; therefore, public hunting is closed on both units. Appropriate use findings for nonwildlife-dependent public uses were made based on policy guidance in the Service's Appropriate Refuge Uses Policy; 603 FW 1, and were documented on the Service's Form 3-2319 (finding of appropriateness of a refuge use) in Appendix B. Compatibility determinations are also included in Appendix B.

Refuge Revenue Sharing Payment: Annual payments to the County of Hawaiʻi under the Refuge Revenue Sharing Program will continue according to the established formula, subject to payments authorized by Congress.

Regulatory Compliance: All activities requiring review, permits, and clearances (e.g., Section 106 of the National Historic Preservation Act, Section 7 of the Endangered Species Act) will undergo appropriate review and obtain necessary permits and/or clearances as needed.

Figure 2-1. HFU CCP management.

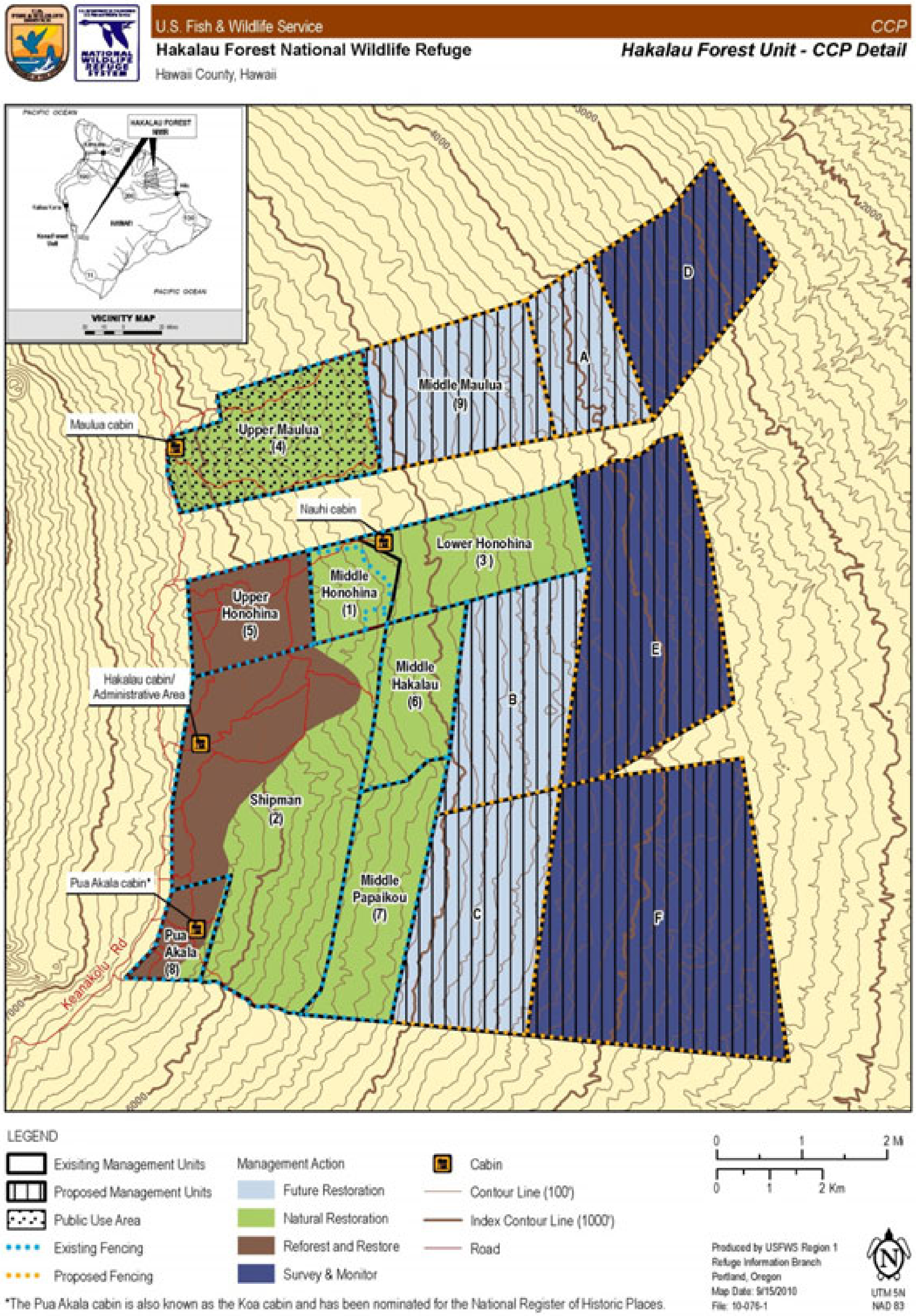

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Figure 2-2. KFU CCP management.

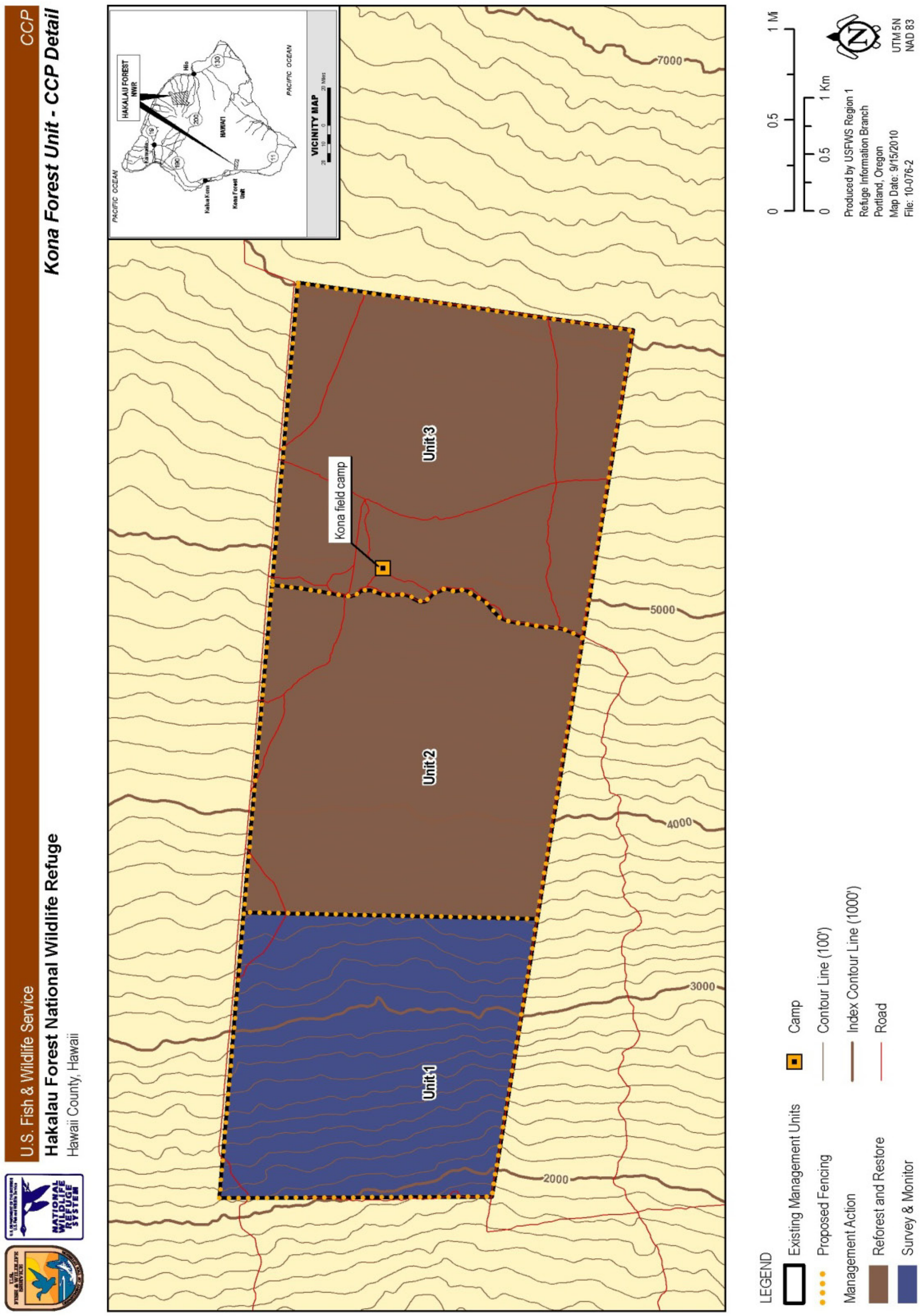

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Table 2-1. Summary of CCP Actions.

Objectives	CCP Action
1.1: Restore and Protect Native Montane Wet ʻŌhiʻa Forest (2,000-4,500 ft elevation) at KFU	3,000 acres. Remove ranch debris. Build and maintain 17 mile ungulate-proof fence. Remove pest animals. Eradicate/control invasive plants. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant threatened and endangered (T&E) plants in units 2 and 3 and build site specific fencing for these plants.
1.2: Restore, Protect, and Maintain Native Montane Mesic Koa/ʻŌhiʻa Forest (4,500-5,800 ft elevation) at KFU	1,800 acres. Remove ranch debris. Build and maintain fence, eradicate/control invasive plants, and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant native plants. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
1.3: Protect, Maintain, and Restore Native Dry Koa/ʻŌhiʻa/Māmane Forest (5,800-6,100 ft elevation) at KFU	500 acres. Remove ranch debris. Build and maintain fence, eradicate/control invasive plants, and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant T&E plants and build site specific fencing for these plants
1.4: Develop and Implement Propagation and Outplanting Program at KFU	500 T&E plants and 2,000 native plants provided annually for restoration. Develop native plant nursery at Mauna Loa field camp site, collect seeds and cuttings, develop (in 7 years) staff, volunteer, and partnering programs.
1.5, 5.3: Investigate and Initiate Landscape-level Habitat Conservation Measures	LPP completed within one year. Identify habitats to support focal species; develop protection strategies; work proactively with partners, neighbors, and private landowners where appropriate to meet conservation goals and develop specific project proposals for land acquisition, cooperative agreements, and/or conservation easements as key conservation opportunities arise and willing parties are identified.
2.1: Protect & Maintain Lava Tube and Skylight Communities at KFU	Remove ranch debris. Build and maintain fence and develop site specific access protocols to limit human disturbance to habitat. Eradicate/control invasive plants, and remove pest animals. Conduct survey for pest animals (based on surveys control threats). Inventory and map communities and support additional investigations and research.
3.1: Protect and Maintain Native Montane Wet ʻŌhiʻa/Uluhe (*Dicranopteris* sp.) Forest (2,500-4,000 ft elevation) at HFU	7,000 acres. Remove pest animals, eradicate/control invasive plants, build site-specific fencing to protect T&E plant populations and *Carex* sp. bogs. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Inventory vegetation, complete Wilderness Study.

Objectives	CCP Action
3.2: Protect and Maintain Native Montane Wet ʻŌhiʻa Forest (4,000-5,000 ft elevation) at HFU	8,200 acres. Maintain existing fence (units 1-8), build and maintain fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant native overstory koa and ʻōhiʻa, T&E plants, and common understory plants. Build site specific fencing for T&E plants. Complete Wilderness Study.
3.3: Restore, Protect, and Maintain Native Montane Wet Koa/ʻŌhiʻa Forest (5,000-6,000 ft elevation) at HFU	5,000 acres. Maintain existing fence, build and maintain fence along Middle Maulua tract boundary (unit 9). Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats, particularly *Vespula* sp.). Outplant T&E plants and build site-specific fencing to protect T&E plant populations.
3.4: Protect and Maintain Native Montane Mesic Koa Forest (6,000-6,600 ft elevation) at HFU	3,500 acres. Maintain existing fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats, particularly *Vespula* sp.). Outplant T&E plants and build site-specific fencing to protect T&E plant populations. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
3.5: Restore/Reforest Native Montane Mesic Koa Forest (6,000-6,600 ft elevation) at HFU	2,500 acres. Maintain fence. Eradicate/control invasive plants and remove pest animals. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Outplant 300 koa per acre, use excluder devices to deter turkeys on koa seedlings, outplant native understory species and ʻōhiʻa at 150 per acres, outplant 100-300 T&E plants and build site-specific fencing to protect these plants. Address wildfire through hazardous fuels treatment, maintaining fuelbreaks, developing fire prevention program.
3.6: Maintain and Enhance Propagation and Outplanting Program at HFU	Plant 10,000 koa per year for 5 years: 5,000 per year for the next 10 years, 8-10,000 natives and 300-1,200 T&E plantings per year. Expand native plant nursery at Mauna Kea administration site, collect seeds and cuttings, outplant, and develop partnerships to assist with propagation program.
4.1: Protect and Maintain Streams and Stream Corridors at HFU	Maintain fencing. Eradicate/control invasive plants. Conduct annual invasive plant survey; conduct survey for pest animals (based on surveys control threats). Inventory streams and stream corridors.
4.2: Protect and Maintain Semipermanent Natural Ponds at HFU	Maintain fencing, conduct survey for pest animals (based on surveys control threats).
4.3: Protect and Maintain *Carex* Bogs within the Montane Wet ʻŌhiʻa/Uluhe Forest at HFU	Install fencing to protect bogs, conduct survey for pest animals (based on surveys control threats), survey extent and number of bogs.

Objectives	CCP Action
5.1: Maintain Managed Grassland for Foraging Nēnē at HFU	65 acres. Maintain fuel breaks and fence corridors, build and maintain fence. Eradicate/control invasive plants. Conduct survey for pest animals (based on surveys control threats).
5.2: Maintain Grassland Habitats for Nēnē Nesting at HFU	15 acres. Maintain fence and build predator proof fence on 15-acre grassland breeding site away from administrative site at Pua ʻĀkala tract. Eradicate/control invasive plants and remove pest animals. Conduct survey for pest animals (based on surveys control threats).
6.1: Conduct High-Priority Inventory and Monitoring (Survey) Activities that Evaluate Resource Management and Public-Use Activities to Facilitate Adaptive Management	An initial list of survey and monitoring activities have been identified and include examples such as monitoring nesting density and success of nēnē, inventorying all endemic species, instituting early detection and rapid response monitoring for threat management, monitoring plant and animal diseases, and others.
6.2: Conduct High-Priority Research Projects that Provide the Best Science for Habitat and Wildlife Management On and Off the Refuge	An initial list of research projects have been identified and include examples such as investigating and monitoring endangered plant propagation and outplanting, research on arthropod abundance, researching demography, life-history, carrying capacity, and competition for native forest birds, and others.
6.3: Conduct Scientific Assessments to Provide Baseline Information to Expand Knowledge Regarding the Status of Refuge Resources to Better Inform Resource Management Decisions	An initial list of scientific assessments have been identified and include examples such as determining ecological parameters for ʻōpeʻapeʻa, determining the role of predators in native flora and fauna abundance, assessing global climate change impacts on the Refuge, and others.
7.1: Establish Compatible Wildlife Observation and Photography Opportunities	Develop Upper Maulua Tract interpretive trail (0.3-0.5 mile) and parking area. Work with Friends of Hakalau Forest to develop brochure.
7.2: Promote and Enhance Volunteer Program	Maintain volunteer program and current 35-40 service weekends at HFU, develop seasonal volunteer program to supplement staffing and weekend programs, develop KFU volunteer program similar to HFU.
7.3: Support Existing Outside Programs for On and Off Site Environmental Education and Develop Interpretive Opportunities	Increase environmental education and interpretive programs (via coordinating more with County, State, and non-governmental organizations and expanding interpretive programs relative to cultural resources/historic sites) to include 168 participants annually. Continue interpretive walks offered during annual Refuge open house.
7.4: Enhance Outreach Targeting Local Communities to Promote Appreciation of and Generate Support for the KFU	Work with existing partners to promote awareness and appreciation. Develop and cultivate new partners and outreach efforts.

Objectives	CCP Action
8.1: Increase Identification, Monitoring, Protection, and Restoration of all Cultural Resources and Historic Sites, while Increasing Staff and Public Support and Appreciation	Evaluate known/potential Refuge cultural resources and historic sites, develop guidelines for cultural activities, identify cultural practitioners to develop understanding of cultural/historic sites at the Refuge, develop interpretive programming and products relative to cultural and historic sites in partnership with Native Hawaiian groups; conduct comprehensive cultural resources investigation of both units.

2.3 Goals, Objectives, and Strategies

Goals and objectives are the unifying elements of successful refuge management. They identify and focus management priorities, resolve issues, and link to refuge purposes, Service policy, and the Refuge System mission.

A CCP describes management actions that help bring a refuge closer to its vision. A vision broadly reflects the refuge purposes, the Refuge System mission and goals, other statutory requirements, and larger-scale plans as appropriate. Goals then define general targets in support of the vision, followed by objectives that direct effort into incremental and measurable steps toward achieving those goals. Finally, strategies identify specific tools and actions to accomplish objectives.

The goals for the Hakalau Forest NWR over the lifetime of the CCP (15 years) are presented on the following pages. Each goal is followed by the objective(s) that pertain to that goal. The goal order does not imply any priority in this CCP. Each objective will be implemented over the life of the plan subject to funding, unless otherwise stated. Below each objective are the management strategies that could be employed in order to accomplish it. Following the goals, objectives, and strategies is a brief rationale intended to provide further background information pertaining to the importance of an objective relative to legal mandates for managing units of the Refuge System including refuge purpose, trust resource responsibilities (federally listed threatened and endangered species and migratory birds), and maintaining/restoring biological integrity, diversity, and environmental health. The rationale also describes how management strategies are used to achieve objectives.

Habitat management goals and objectives have been developed separately for the two units of Hakalau Forest NWR. Although the habitats at each Refuge unit are similar, they are in different conditions. The Kona Forest Unit (KFU) contains unique lava tube and lava tube skylight habitats; whereas the Hakalau Forest Unit (HFU) contains stream habitats that are not present at the KFU. Restoration strategies for each unit will be somewhat different based upon these contrasting features.

Description of the implementation and monitoring of the CCP can be found in Appendix C. Note that implementation timetables in this chapter as well as Appendix C are dependent upon available funding.

2.3.1 Kona Forest Unit (KFU)

2.3.1.1 Goal 1: Protect, maintain, and restore subtropical rainforest community on the leeward slope of Mauna Loa as habitat for all life-history needs to promote the recovery of endangered species (e.g., forest birds, ‘ōpe‘ape‘a, plants, and invertebrates).

Strategy definitions: ***Reforestation*** entails planting appropriate overstory species to bring habitat into a basic forested condition. ***Restoration*** is the planting of koa to restore forested condition, allowing time for development of a forest canopy, following up with later plantings of native understory shrub species.

Objective 1.1: Restore and protect native montane wet ‘ōhi‘a forest.
Restore and then protect and maintain approximately 3,000 acres of native montane wet ‘ōhi‘a forest habitat on the KFU for endangered plant and animal species, with special emphasis for the repatriation of ‘alalā, with the following attributes: • 2,000 and 4,500 ft elevation; • Tree canopy is dominated by 60-80 ft mature closed canopy ‘ōhi‘a; • Midcanopy is dominated by a mix of native flowering and fruiting tree species (e.g., ‘ōhi‘a, hame, kōlea, pilo, C*lermontia* sp., ‘ōlapa, kāwa‘u, kōlea, pūkiawe), tree ferns (up to 15 ft), ‘ie‘ie, and epiphytes); • Ground cover is dominated by a mix of native ferns, herbs, and forbs; • <25-40% cover of invasive plant species; • No ungulates (pigs, sheep, cattle, donkeys, horses); • Free of abandoned fence and ranch debris; • No new invertebrate and plant pest species; and • No dogs and cats.
Strategies to achieve objective:
Remove existing abandoned fence and other former ranch debris.
Build and maintain 17-mile ungulate-proof fence around each of Units 1-3 with a 15 ft wide fuel break corridor (Figure 2-2).
Remove all ungulates as well as dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct annual invasive plant species (e.g., *Clidemia* and Christmas berry) presence/absence surveys and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25-40% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, invertebrates, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, and shooting (ground and aerial).

Outplanting of endangered plants in units 2 & 3 (supported by propagation program identified under Objective 1.4) as well as mix of other native plants as identified in the attributes above.
Conduct site-specific fencing to protect endangered plant populations.
Rationale: Control of ungulates is needed to restore acres identified as they are a major habitat modifying threat. Pigs grub up the ground and create wallows where water can collect to become mosquito breeding habitats. Mosquitoes are vectors for deadly avian diseases harmful to native forest birds. In addition, ungulates eat and trample native plants. Therefore, reforestation (which would create more forest in an elevation where climate change could impact native forest elevational gradients) would not be possible without addressing this threat first. Aerial control has been proven to be the most effective management tool in terms of efficacy and minimizing impacts of ground-based shooting and other control efforts. Shooting options would not be considered until the fencing is completed to maximize benefits while minimizing potential effects. The primary differences between the upper and lower elevation gradients in this habitat type are the increased plant diversity in the midcanopy of the upper gradient, and the change from an herbaceous ground cover in the lower gradient to a grass-dominated ground cover in the upper gradient. A diverse native bird community first appears in the upper gradient of this habitat type, primarily above the mosquito zone and in the more diverse forest. Species of conservation and management concern covered in existing recovery plans include forest birds, ‘alalā, ‘ōpe‘ape‘a, and endangered plants. The KFU was the location of the last known wild ‘alalā in the wild and fits many of the criteria outlined in the ‘Alalā Recovery Plan as a potential repatriation site. Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Native pollinators on the Refuge include native birds and native insects. The habitat improvements outlined in each of the objectives and strategies are designed to provide suitable habitat that should help increase populations of native pollinators. Past human disturbances include traditional farming and ranching practices and fire. The effects of this past activity include increased grasslands and a loss of native plant species. This lowest elevation unit contains some intact native tree canopy but mostly highly disturbed, nonnative pest species habitat. It provides minimal life-history functions for canopy dwelling species and is the most invasive species degraded unit of the three KFU units. The amount of effort required to restore this habitat makes it best suited to serve as a buffer between lower elevation off Refuge lands and less disturbed upper elevation areas. This unit will be the lowest priority for restoration and will not likely receive active management during the life of this plan (unit1 Figure 2-2).

Objective 1.2: Restore and then protect and maintain native montane mesic koa/ʻōhiʻa forest.
Restore and then protect and maintain 1,800 acres of native montane mesic koa/ʻōhiʻa forest for all life-history needs of endangered plant and animal species, with special emphasis for Hawaiʻi ʻākepa, Hawaiʻi creeper, ʻakiapōlāʻau, and the repatriation of ʻalalā; with the following attributes: • 4,500-5,800 ft in elevation; • Koa and ʻōhiʻa dominated canopy; • Midcanopy is dominated by a mix of native flowering and fruiting trees (e.g., *Clermontia* sp., pilo, pūkiawe, ʻōhelo, kōlea, kāwaʻu), tree ferns, mixed ferns, and epiphytes; • Ground cover is dominated by a mix of native ferns, herbs and forbs; • No ungulates (e.g., pigs, sheep); • No new invertebrate and plant pest species; • <25-40% cover of invasive plant species; • Free of abandoned fence and ranch debris; • No increase in wildland fire incidents; and • No dogs and cats.
Strategies to achieve objective:
Remove existing abandoned fence and other former ranch debris.
Build and maintain ungulate-proof fence with a 15 ft wide fuel break corridor (same fence as Obj 1.1).
Remove all ungulates as well as dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct annual invasive plant species (e.g., *Clidemia* and Christmas berry) presence/absence surveys and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25-40% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, invertebrates, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, and shooting (ground and aerial).
Outplanting of native plant species.
Conduct hazardous fuels treatments (e.g., prescribed fire, mechanical removals, herbicides) to reduce the threat from wildland fires, giving special attention to invasive species that increase fire risk.
Maintain a system of fuels breaks by mowing roadways and areas around infrastructures.
Establish a fire prevention program that includes signage, education, and area fire closure criteria.

Rationale: Species of conservation and management concern covered in existing recovery plans include forest birds, ʻalalā, ʻōpeʻapeʻa, and endangered plants. The KFU is the location of the last known wild ʻalalā and fits many of the criteria outlined in the ʻAlalā Recovery Plan as a potential repatriation site. Open areas occur in this zone, left over from logging and timber activities. Outplanting native plants will occur to restore forest habitat. Closed canopy and understory will help protect ʻalalā from ʻio predation.

Objective 1.3: Protect, maintain, and restore native dry koa/ʻōhiʻa /māmane forest.
Protect, maintain, and restore approximately 500 acres of native dry koa/ʻōhiʻa /māmane forest habitat for all life-history needs of endangered plant and animal species, with special emphasis for Hawaiʻi ʻākepa, Hawaiʻi creeper, ʻakiapōlāʻau, and the repatriation of ʻalalā; with the following attributes: • 5,800-6,100 ft elevation; • Koa, ʻōhiʻa, and māmane codominate the canopy; • Midcanopy is dominated by a mix of flowering and fruiting trees (e.g., ʻiliahi (sandalwood), pilo, naio, pūkiawe, ʻaʻaliʻi), and shrubs (e.g., ʻōhelo); • Ground cover is composed of lichens, bryophytes, native grasses, herbs, and mixed ferns; • No ungulates; • No new invertebrate and plant pest species; • <25-40% cover of invasive plant species; • Free of abandoned fence and ranch debris; and • No dogs and cats.
Strategies to achieve objective:
Remove existing abandoned fence and other former ranch debris.
Build and maintain ungulate-proof fence with 15 ft wide fuel break/fence (same fence as Obj 1.1).
Remove all ungulates as well as dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct annual invasive plant species (e.g., *Clidemia* and Christmas berry) presence/absence and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25-40% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, invertebrates, cats, and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, and shooting (ground and aerial).

Outplanting of T&E plant species as well as mix of other native plants as identified in the attributes above.
Conduct site-specific fencing to protect endangered plant populations.
Rationale: Species of conservation and management concern covered in existing recovery plans include forest birds, ‘alalā, ‘ōpe‘ape‘a, and endangered plants. The KFU is the location of the last known wild ‘alalā and fits many of the criteria outlined in the ‘Alalā Recovery Plan as a potential repatriation site. Native pollinators on the Refuge include native birds and native insects. The habitat improvements outlined in each of the objectives and strategies are designed to provide suitable habitat that should help increase populations of native pollinators.

Objective 1.4: Develop and implement propagation and outplanting program.
Within 7 years of CCP approval, develop and implement a propagation and outplanting program that provides 500 endangered plants per year (e.g., *Clermontia*, *Cyanea*, *Phyllostegia*) and 2,000 native species per year (e.g., pilo, koa, ‘ōhi‘a, pūkiawe) to support restoration activities.
Strategies to achieve objective:
Establish and maintain native plant nursery at field camp site on Mauna Loa to provide plant stock for outplanting activities.
Collect adequate seeds and cuttings to supply plant nursery.
Develop adequate staff (e.g., horticulturist, volunteer coordinator) to assist with administration of propagation program within 7 years.
Develop partnerships to assist with administration of propagation program within 7 years.
Administer volunteer program to support nursery and outplanting program within 7 years.
Rationale: Endangered plant species have become extremely limited in their population and range due to more than 100 years of cattle grazing, pig rooting, loss of pollinators, and limited gene pool. The Refuge can play a vital role in the recovery of more than 10 federally listed threatened and endangered plant species by providing ungulate-free fenced areas. Many of these plants are important food sources for rare birds (e.g., ‘alalā) and invertebrates. The existing facility at the HFU is at a much higher elevation than the KFU. The plant species that are needed for outplanting are different from those of the HFU and the intent of the program will be endangered plant recovery as opposed to the forest restoration program at the HFU. To meet habitat objectives, Refuge staff will need to find or develop a source for the native endangered plants that will be used in management efforts at the KFU. These efforts support Objectives 1.1-1.3. Plant stock may be available from the Volcano Rare Plant Facility from seeds and propagules collected on or near Refuge lands. In addition, the Refuge partners with the Plant Extinction Plant Prevention Program. Through these collaborative partnerships, the Refuge also institutes best management practices, which include incorporating science based genetic information into its outplanting and propagation programs.

Objective 1.5: Investigate and initiate landscape-level habitat conservation measures.
Within 1 year of CCP approval, the Refuge will complete a Land Protection Planning effort in cooperation with other agencies and interested parties to assess and identify land conservation priorities in the vicinity of Refuge units. Potential additions or expansion of Hakalau Forest NWR and examination of various land protection tools will be explored. Land Protection as part of the Refuge System may include fee title acquisition, conservation easements, and/or cooperative agreements. The plan will provide for conservation of supporting habitats, partnership opportunities, and opportunities to adapt Refuge management to impacts from global climate change.
Strategies to achieve objective:
Identify parcels of land that could provide supporting habitat for focal species of the KFU.
Develop strategies for protection and management of supporting habitat.
Work proactively with partners, neighbors, and private landowners where appropriate to meet conservation goals and develop specific project proposals for land acquisition, cooperative agreements, and/or conservation easements as key conservation opportunities arise and willing parties are identified.
Rationale: Through a cooperative effort culminating in the 2006 National Ecological Assessment Team Report, the Service and the U.S. Geological Survey (USGS) outlined a unifying adaptive resource management approach for conservation at "landscape" scales, the entire range of a priority species or suite of species known as "strategic habitat conservation" or SHC. In April 2009, Service leadership established Landscape Conservation Cooperatives (LCCs). The LCCs are conservation-science partnerships between the Service, other Federal agencies, States, Territories, tribes, NGOs, universities, and other entities. They are fundamental units of planning and science capacity to help carry out the functional elements of SHC, biological planning, conservation design, conservation delivery, monitoring, and research, and strategic response to climate change. The Pacific Islands Climate Change Cooperative (PICCC) is the LCC focused on Hawai'i, the Mariana Islands, American Samoa, and central Pacific islands under the U.S. flag. Established in late 2009, it will create the technical capacity, decision support tools, and organizational structure to address landscape-scale conservation issues using SHC. These tools will help managers reach explicit conservation objectives for native species and habitats in the face of climate change and ongoing threats such as fire, land conversion, and invasive species. The Hawaiian and Pacific Islands NWRs anticipate using climate change information provided by the PICCC as foundational products from which to conduct more detailed site-specific and species-specific analyses critical to the preparation of planning documents and to prioritize on-the-ground conservation actions. Currently, the Refuge identifies parcels on a case-by-case basis for protection as they become available from willing sellers. A landscape approach on the slopes of Mauna Loa will allow staff to focus efforts and work with partners to ensure that habitat needs are met over a larger area. In addition, corridors between patches of protected habitat are critical for species migration in response to climate change. Species distribution and abundance is likely to change based upon precipitation patterns, temperature variations, and shifts in mosquito zones. The Refuge will identify landscape-level opportunities to augment the protection currently provided by existing Refuge lands.

2.3.1.2 Goal 2: Protect and maintain lava tube and lava tube skylight habitat throughout the Kona Forest Unit, with special emphasis on their unique and endemic flora and fauna.

Objective 2.1: Protect and maintain lava tube and skylight communities.
Protect and maintain lava tube and skylight communities for all life-history needs of cave-dependent species with the following attributes: • Undisturbed, moist, humid environment; • Relatively constant moderate temperature; • Lack of light; • ʻŌhiʻa and other native plant roots to provide food source and nutrients; • Limited human disturbance; • No ungulates; • No new invertebrate and plant pest species; and • Free of abandoned fence and ranch debris.
Strategies to achieve objective:
Establish protocols to protect lava tube and skylight communities.
Remove existing abandoned fence and other former ranch debris.
Build and maintain ungulate-proof fence as referenced in Obj. 1.1.
Remove all ungulates as well as dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct surveys for pest animals such as ungulates, invertebrates, cats, and dogs.
Control rats, ungulates, and pest invertebrates using appropriate IPM techniques including, but not limited to, trapping, snare, shooting (ground and aerial), and rodenticides (aerial applications and bait stations).
Inventory and map lava tube and skylight communities.
Develop restrictive site-specific access protocols for SUPs to limit human disturbance.
Support additional investigations and research.
Rationale: Lava tubes and skylights are rare, unique habitats that contain an endemic subterranean, invertebrate faunal community. Moisture, moist air, relatively constant moderate temperature, and lack of light are required attributes of these cave systems. Subfossil bird remains found in the detrital soils inside the cave systems are a valuable resource that can be used to document premodern Hawaiian avifauna. Lava tube caves found throughout the Island of Hawaiʻi supported use by Native Hawaiians. Insufficient study has occurred on the Refuge to document archaeological resources. However, there is the potential that cultural resources do exist in Refuge caves.

Invertebrates have evolved in this unique habitat. These mostly blind invertebrates feed on ʻōhiʻa as well as other native plant roots that penetrate the lava tube roof. Trampling, the release of pest species (such as rats), or human disturbance could destroy the entire invertebrate community and destroy subfossil and archaeological resources. Installing fence and implementing the other strategies at the KFU will prevent disturbance and damage from trampling of these fragile invertebrate communities and archaeological resources.

2.3.2 Hakalau Forest Unit

2.3.2.1 Goal 3: Protect, maintain, and restore subtropical rainforest community on the windward slope of Mauna Kea as habitat for all life-history needs of endangered species (e.g., forest birds, ʻōpeʻapeʻa, plants, and invertebrates).

Strategy definitions: ***Reforestation*** focuses on planting koa specifically as appropriate overstory species (though other overstory species can be used as well) to bring habitat into a basic forested condition. ***Restoration*** is the planting of koa to restore forested condition, allowing time for development of a forest canopy, following up with later plantings of native understory shrub species.

Objective 3.1: Protect and maintain native montane wet ʻōhiʻa/uluhe (*Dicranopteris* sp.) forest.
Protect and maintain approximately 7,000 acres of native montane wet ʻōhiʻa/uluhe forest habitat on the HFU for endangered plant and animal species, with special emphasis on endangered plant species, ʻōpeʻapeʻa, and koloa maoli, with the following attributes: • Found from 2,500-4,000 ft; • Upper canopy is composed of scattered mature (100+ years), and medium-stature ʻōhiʻa (30 ft); • Midcanopy zone (10-15 ft) is dominated by hapūʻu (tree fern); • Ground level, up to 6-10 ft is dominated by dense uluhe (matted ferns); • Many *Carex* sp. bogs found scattered throughout the lower elevations; • Plant diversity is low and dominated by open ʻōhiʻa canopy and uluhe understory and ground cover; • No ungulates (e.g., pigs and sheep); • No new invertebrate and plant pest species; • <25% cover of invasive plant species; and • No dogs and cats.
Strategies to achieve objective:
Remove all ungulates as well as dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Install and maintain ungulate-proof fence to protect *Carex* sp. bog habitats where feasible.

Conduct site-specific fencing to protect endangered plant populations.
Conduct annual invasive plant species presence/absence and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, invertebrates, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, and shooting (ground and aerial).
Inventory vegetation communities.
Complete the Wilderness Review by conducting a Wilderness Study within 4 years after the signing of the CCP.
Conduct all management actions utilizing the minimal tools necessary to achieve Refuge purposes while maintaining wilderness character, until a final wilderness determination is made through the Wilderness Study.
Rationale: Low elevation forests are inaccessible by road with steep, deeply incised terrain and would be extremely difficult and prohibitively expensive to fence. Survey and monitoring activities will be conducted, and endangered plant populations protected as needed. In the Wilderness Review conducted for the HFU (Appendix D), lower elevations of the Refuge below 5,000 ft (Inventory Unit B2) met the minimum criteria for a Wilderness Study Area (WSA) designation. Management activities in this unit will be conducted in a manner that maintains the wilderness character by using the minimal tools necessary to achieve Refuge purposes, as required under the Wilderness Act of 1964 and Service policy (610 FW 1-4, Wilderness Stewardship). Should the Wilderness Study, to be conducted subsequent to the CCP, indicate that Unit B2 can be managed under a Wilderness designation without affecting management for Refuge purposes, this unit may be recommended for wilderness designation. If the unit is recommended for wilderness designation through the findings of the Study, and subsequently designated as Wilderness by Congress, the unit will continue to be managed in perpetuity using the minimal tools required for wilderness areas. This unit is depicted in Appendix D.

Objective 3.2: Protect and maintain native montane wet ‘ōhi‘a forest.

Protect and maintain approximately 8,200 acres of native montane wet ‘ōhi‘a forest for endangered plant and animal species, with special emphasis on common and endangered native forest bird species, koloa maoli, and ‘ōpe‘ape‘a with the following attributes:

- Area of high rainfall from 4,000-5,000 ft;
- Upper canopy of this habitat type is dominated by 60-90 ft mature closed canopy ‘ōhi‘a;
- Midcanopy is dominated by a mix of flowering and fruiting tree species (e.g.; ‘ōhi‘a, ‘ōlapa, pilo, kōlea), tree ferns (up to 15 ft), and epiphytes;
- Ground cover is dominated by mixed ferns, *Astelia* (lily), ‘ōhelo, kanawao, pūkiawe, and kāwa‘u;

• Ground level contains downed timber and areas dominated by sphagnum moss; • <25% cover of invasive plants (e.g., English holly, blackberry); • No ungulates (e.g., pigs, cattle); • No nonnative mammalian predators (e.g., mongooses, rats); and • No dogs and cats.
Strategies to achieve objective:
Maintain existing ungulate-proof fence around units 1-8 (Figure 2-1).
Build and maintain ungulate-proof fence (Figure 2-1).
Remove all ungulates, nonnative mammalian predators, and dogs and cats using IPM techniques such as trapping, snares, ground shooting, and aerial shooting.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Outplant native overstory koa and ʻōhiʻa.
Outplant endangered plants.
Conduct site-specific fencing to protect endangered plant populations.
Outplant common understory plants.
Conduct annual invasive plant species presence/absence and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting (ground and aerial), and rodenticides (aerial application and bait stations).
Complete the Wilderness Review by conducting a Wilderness Study within 4 years after the signing of the CCP.
Conduct all management actions utilizing the minimal tools necessary to achieve Refuge purposes while maintaining wilderness character until a final wilderness determination is made through the Wilderness Study.
Rationale: The Refuge's Feral Ungulate Management Plan units are being revised into units A-F to maximize protection of mid-elevation habitats. The revised units will enhance the Refuge's ungulate control capabilities and offer increased protection to forest birds from mosquito-borne diseases because a reduction in ungulates in these units will reduce mosquito breeding habitats. Limiting factors include a lack of native pollinators and several pest species (e.g. ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Native pollinators on the Refuge include native birds and native insects. The habitat improvements outlined in each of the objectives and

strategies are designed to provide suitable habitat that should help increase populations of native pollinators.

Higher densities of pigs at this elevation have disturbed native *Carex* sp. bogs which have converted to nonnative *Juncus* sp. bogs.

In the Wilderness Review conducted for the HFU (Appendix D), lower elevations of the Refuge below 5,000 ft (Inventory Unit B2) met the minimum criteria for a Wilderness Study Area (WSA) designation. Management activities in this unit will be conducted in a manner that maintains the wilderness character by using the minimal tools necessary to achieve Refuge purposes, as required under the Wilderness Act of 1964 and USFWS policy (610 FW 1-4,Wilderness Stewardship). Should the Wilderness Study, to be conducted subsequent to the CCP, indicate that Unit B2 can be managed under a Wilderness designation without affecting management for Refuge purposes, this unit may be recommended for wilderness designation. If the unit is recommended for wilderness designation through the findings of the Study, and subsequently designated as wilderness by Congress, the unit will continue to be managed in perpetuity using the minimal tools required for wilderness areas. This unit is depicted in Appendix D.

Objective 3.3: Restore, and then protect and maintain, native montane wet koa/ʻōhiʻa forest.

Restore and then protect and maintain approximately 5,000 acres of native montane wet koa/ʻōhiʻa forest for endangered plant and animal species, with the following attributes:

- Occurs from 5,000-6,000 ft;
- Mixed age class of koa and ʻōhiʻa-dominated forest;
- Midcanopy is dominated by a mix of flowering and fruiting trees (e.g., ʻōlapa, ʻākala, pilo, pūkiawe, ʻōhelo, kōlea, kāwaʻu), mixed ferns, and epiphytes;
- Ground cover is dominated by native ferns, native shrubs (e.g., ʻōhelo, pūkiawe) and herbs;
- No ungulates (e.g., pigs, cattle);
- <25% cover of invasive plants;
- No nonnative mammalian predators (e.g., mongooses, rats); and
- No dogs and cats.

Strategies to achieve objective:
Maintain existing ungulate-proof fence.
Build and maintain ungulate-proof fence along Middle Maulua tract boundary (unit 9).
Remove all ungulates, nonnative mammalian predators, and dogs and cats using IPM techniques such as trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Control pest insects (e.g., *Vespula* sp.) using IPM techniques including pesticides and biocontrol.
Outplant endangered plants (e.g., *Clermontia* sp., *Cyrtandra* sp.).
Conduct site-specific fencing to protect endangered plant populations.
Conduct annual invasive plant species presence/absence surveys and percent cover monitoring using established survey transects.

Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25% occurrence of invasive plant species.
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, invertebrates, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Rationale: Management actions to control and prevent access of ungulates, eradicate invasive plants, and reestablish endangered plants will provide improved habitat conditions for forest birds and support recovery of threatened and endangered species.

Objective 3.4: Protect and maintain native montane mesic koa forest.
Protect and maintain approximately 3,500 acres of native montane mesic koa forest for endangered plant and animal species, with special emphasis on koloa maoli, ʻōpeʻapeʻa, and endangered plants, with the following attributes: • A mixed age class of koa-dominated forest; • Occurs from 6,000-6,600 ft; • Midcanopy is dominated by a mix of flowering and fruiting trees (e.g. ʻākala, pilo, ʻōhelo, kōlea, māmane, naio), mixed ferns, and epiphytes; • Ground cover is dominated by native ferns and herbs; • <25% cover of invasive plants (<50% for nonnative grasses); • No ungulates (e.g., pigs, cattle); • No nonnative mammalian predators (e.g., mongooses, rats); • No dogs and cats; and • No increase of the impact from wildland fires.
Strategies to achieve objective:
Maintain existing ungulate-proof fence (45 miles) with 25 ft fuel break.
Remove all ungulates, nonnative mammalian predators, and dogs and cats using IPM techniques such as trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Control pest insects (e.g., *Vespula* sp.) using IPM techniques including pesticides and biocontrols.
Outplant endangered plants (e.g. *Clermontia* sp., *Cyrtandra* sp.).
Conduct site-specific fencing to protect endangered plant populations.
Conduct annual invasive plant species presence/absence surveys and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25% occurrence of invasive plant species (<50% for nonnative grasses) over 15-year plan period.
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, invertebrates, cats and dogs.

Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Conduct hazardous fuels treatments (e.g., prescribed fire, mechanical removals, herbicides) to reduce the threat from wildland fires, giving special attention to invasive species that increase fire risk (e.g., gorse).
Maintain a system of fuels breaks by mowing roadways and areas around buildings.
Establish a fire prevention program that includes signage, education, and area fire closure criteria.
Rationale: This habitat type contains a mixed-age class of koa-dominated forest and occurs from 6,000-6,600 ft. The midcanopy is dominated by a mix of flowering and fruiting trees and shrubs (e.g., ‘ōlapa, ‘ākala, pilo, pūkiawe, ‘ōhelo, kōlea, kāwa‘u), mixed ferns, and epiphytes. Ground cover is dominated by mixed ferns, nonnative and native grasses, and herbs. A diverse native bird community occurs in this habitat type, primarily above the mosquito zone and in a more diverse forest plant community. Other species of conservation and management concern include the koloa maoli, ‘ōpe‘ape‘a, and endangered plants. The windward east-facing HFU receives northeasterly tradewind-dominated rainfall throughout the year. This habitat type receives approximately 23 ft of rainfall annually. More rainfall occurs between the months of October-March. Mountain slopes are moderate. Soils are aged, eroded, volcanic in origin, and typically poorly drained. The ground surface is bisected by numerous streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep sided, providing protection to native and endangered plants from grazing ungulates. Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Native pollinators on the Refuge include native birds and native insects. The habitat improvements outlined in each of the objectives and strategies are designed to provide suitable habitat that should help increase populations of native pollinators. A total of 3,500 acres of high-value montane mesic koa forest habitat exists at this elevation. Refuge lands at this elevation are former ranch lands dominated by nonnative grasses, which have been partially reforested over the past 25 years. Varying amounts of the approximately 2,500 acres of nonnative grassland-dominated habitat remaining are scheduled for reforestation and/or restoration in Objective 3.5.

Objective 3.5: Restore/reforest native montane mesic koa forest.
Restore/reforest, and then maintain and protect 2,500 acres of native montane mesic koa forest for endangered plant and animal species, with special emphasis on the endangered and native forest birds (e.g., ‘akiapōlā‘au, Hawai‘i ‘ākepa, Hawai‘i creeper), and endangered plants (e.g., *Clermontia* sp. *Phyllostegia* sp.), with the following attributes: • Occurs from 6,000-6,600 ft; • Mixed age koa canopy (1-30 years);

• Closed canopy on plantings over 6 years old; • Emergence of fern ground cover within 15 years; • Midcanopy composed of mixed native tree species (e.g., ‘ōhi‘a, pilo, kōlea, ‘ōlapa); • Koa density of 200-300 per acre; • Mixed tree density of 400-500 per acre; • No increase of the impact from wildland fires; • No ungulates (e.g., pigs, cattle); • <25% cover of invasive plants; • No nonnative mammalian predators (e.g., mongooses, rats); and • No dogs and cats.
Strategies to achieve objective:
Maintain existing ungulate-proof fence.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Prepare site(s) for outplanting by reducing grass competition by chemical or mechanical (e.g., dozer) means.
As nurse crop, outplant 300 koa per acre (12 ft x 12 ft).
Use excluder device to control the impact of turkeys on koa seedlings to improve survival of plantings.
Outplant native understory species and ‘ōhi‘a at 150 per acre.
Outplant 100-300 endangered plants (e.g. *Clermontia* sp., *Cyrtandra* sp.).
Conduct site-specific fencing to protect endangered plant populations.
Conduct annual invasive plant species presence/absence surveys and percent cover monitoring using established survey transects.
Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving <25% occurrence of invasive plant species over 15-year plan period.
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, invertebrates, cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Conduct hazardous fuels treatments (e.g., prescribed fire, mechanical removals, herbicides) to reduce the threat from wildland fires, giving special attention to invasive species that increase fire risk (e.g., gorse).
Maintain a system of fuels breaks by mowing roadways and areas around buildings.
Establish a fire prevention program that includes signage, education, and area fire closure criteria.
Rationale: Prior to Refuge ownership, this area was in commercial cattle ranching. The effect of the ranching activities, logging, and fire was destruction of the naturally occurring forest ecosystem. The area was an open, nonnative, grassland pasture with few remaining native trees, primarily located in gulches. The grassland was maintained by cattle grazing and pig rooting.

Starting in 1987, the Refuge has been actively reforesting the native koa/ʻōhiʻa forest at HFU. The first steps were to fence and remove the ungulates that were continuing to inhibit forest regeneration, and controlling pest plants. Using koa seeds from the area, volunteers planted approximately 20,000 seedlings per year. After experimenting with a variety of site preparation methods, such as fire, discing, and herbicide, Refuge personnel prepared the planting sites through soil scarification with bulldozer scrapes.

Once the koa provides a closed canopy, ʻōhiʻa and understory species such as kōlea, ʻōlapa, ʻōhelo, and pūkiawe are planted under the protection of the canopy. The canopy cover provides protection from frost and excess sunlight. The koa serves as the "forest engineer" by ameliorating temperatures, adding moisture through fog condensation, and adding soil nutrients and organic matter. This koa forest restoration provides roosting, feeding, and nesting areas for native forest birds.

The end result of the restoration efforts will be a healthy koa/ʻōhiʻa forest as described below. This habitat type contains a mixed-age class of koa-dominated forest and occurs from 6,000-6,600 ft. The midcanopy is dominated by a mix of flowering and fruiting trees (e.g. ʻōlapa, ʻākala, pilo, pūkiawe, ʻōhelo, kōlea, kāwaʻu), mixed ferns, and epiphytes. Ground cover is dominated by mixed ferns, nonnative and native grasses, and herbs.

A diverse native bird community occurs in this habitat type, primarily above the mosquito zone and in a more diverse forest plant community. Other species of conservation and management concern include the koloa maoli, ʻōpeʻapeʻa, and endangered plants.

The forest restoration program has outplanted approximately 382,000 native trees, including koa, ʻōhiʻa, pilo, kōlea, ʻōlapa, māmane, naio, and other natives on approximately 1,700 acres.

Native forest birds currently occur in this habitat at greatly reduced numbers and diversity when compared to nearby intact forest communities, though populations are increasing as forest restoration occurs. Nēnē are found throughout the current habitat. Species of conservation and management concern include the native forest birds, ʻōpeʻapeʻa, and endangered plants.

Objective 3.6: Maintain and enhance propagation and outplanting program.

Develop and implement a propagation and outplanting program that provides native common and endangered species to support restoration activities, with the following attributes:

- Approximately 10,000 koa seedlings per year (or enough for approximately 70 acres per year) for the first 5 years, then 5,000 annually for the next 10 years;
- 300-1,200 endangered plants per year (e.g., *Clermontia lindseyana*, *Clermontia peleana*, *Clermontia pyrularia*, *Cyanea shipmanii*, *Phyllostegia racemosa*);
- 8,000-10,000 non-koa common native plants per year.

Strategies to achieve objective:

Expand native plant nursery at administration site on Mauna Kea to adequately provide plant stock for outplanting program.

Collect adequate seeds and cuttings to supply plant nursery.

Outplant koa seedlings, understory plants, and T&E plants.
Develop partnerships to assist with administration of propagation program.
Rationale: Endangered plants have become extremely limited in their population and range because of more than 100 years of cattle grazing, pig rooting, loss of pollinators, and limited gene pool. The Refuge can play a vital role in the recovery of more than 10 federally listed threatened and endangered plant species by providing ungulate-free fenced areas. Many of these plants are important food resources for native forest birds and invertebrates. Plant stock is available from the Refuge greenhouse facility at HFU from seeds and propagules collected on or near Refuge lands. The Refuge volunteer program helps to support plant rearing and planting activities. These efforts support Objectives 3.1-3.5. Plant stock may also be available from the Volcano Rare Plant Facility from seeds and propagules collected on or near Refuge lands. In addition, the Refuge partners with the Plant Extinction Plant Prevention Program. Through these collaborative partnerships, the Refuge also institutes best management practices, which include incorporating science based genetic information into its outplanting and propagation programs. Number of outplantings is used as a measure of annual capability rather than “acres planted” due to terrain, soil, competition with invasive grasses, and habitat quality variables, as well as elevation-related factors such as extreme differences in precipitation and frost mortality.

2.3.2.2 Goal 4: Protect and maintain wetland and aquatic habitats (e.g., streams and their associated riparian corridors, ponds, and bogs) on the Hakalau Forest Unit.

Objective 4.1: Protect and maintain streams and stream corridors at HFU.
Protect and maintain existing streams and stream corridors that support native plant communities, and endangered plant and animal species, with special emphasis on common and endangered native forest bird species, koloa maoli, and ‘ōpe‘ape‘a with the following attributes: • Stable banks with native fern and native sedge with less than 50 percent occurrence of nonnative grasses; • No ungulates; • Reduced invasive plant cover; • Water with reduced levels of disease, sediments, contaminants (e.g., fecal coliform); • No nonnative mammalian predators (e.g., mongooses, rats); and • No dogs and cats.
Strategies to achieve objective:
Maintain ungulate-proof fence.
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct annual invasive plant species presence/absence surveys and percent cover monitoring using established survey transects.

Based on results of annual invasive species transect monitoring, control invasive plant species with the goal of achieving reduced occurrence of invasive plants over 15-year plan period.

Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, and cats and dogs.

Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, and shooting (ground and aerial).

Inventory streams and stream corridors.

Rationale:
Streams cross through various habitat types, being intermittent at higher elevations, and perennial at lower elevations. Some streams with steep walls protect endangered and native plants from grazing by ungulates. Fauna within the streams and riparian areas at lower elevations are unstudied and unknown. Although unstudied at higher elevations, the fauna is thought to be exclusively invertebrate. Other species of conservation and management concern include native forest birds, koloa maoli, and endangered plants.

Glacial meltwater created ravines during the Pleistocene era. Rainfall and runoff currently maintain stream habitats.

Invasive gorse can degrade ecological integrity of stream corridors by displacing native riparian vegetation communities and reducing surface water availability. Gorse seeds can wash downstream from highly infested lands above the Refuge via stream corridors.

Ungulates and rats degrade water quality through soil disturbance and feces deposition. Lack of groundwater retention due to upstream human disturbance (e.g., grazing, soil compaction) can lead to flash floods. Streams also transport and disperse pest plant seeds.

Objective 4.2: Protect and maintain semipermanent natural ponds.

Protect and maintain semipermanent natural ponds for opportunistic breeding and loafing by koloa maoli and migratory shorebirds, with the following attributes:

- Shallow, less than 4 ft, open water with shoreline emergent vegetation (e.g.; *Carex*);
- Presence of endemic invertebrates (e.g., damselflies and dragonflies);
- No nonnative mammalian predators (e.g., mongooses, rats); and
- No dogs and cats.

Strategies to achieve objective:

Maintain exterior management unit ungulate fencing (45 miles).

Conduct surveys for pest animals such as nonnative mammalian predators and cats and dogs.

Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting, and rodenticide (aerial and bait stations).

Rationale:
All of the natural and manmade ponds are above the mosquito elevation so there is no concern about these features providing potential mosquito breeding areas.

Previous ranching operations built and maintained ponds as a source of water for cattle. These manmade ponds are used rarely by koloa maoli as nesting areas. Migratory birds occasionally use

the ponds for feeding and loafing. These ponds, which have already begun to be filled in by vegetation consisting of emergent *Carex* and nonnative *Juncus* species, will remain as is and allowed to progress naturally. While the nonnative *Juncus* has outcompeted *Carex* at lower elevations, it is used by koloa and has limited impacts in this habitat type. In order to support waterbirds and migratory shorebirds, the semipermanent natural ponds will be maintained according to the attributes identified above. No water quality testing will be done for these aquatic habitats.

Objective 4.3: Protect and maintain *Carex* bogs within the montane wet ʻōhiʻa/uluhe forest.
Protect, maintain, and allow natural regeneration of existing *Carex* bogs within the montane wet ʻōhiʻa/uluhe habitat, with special emphasis on koloa maoli, with the following attributes: • Found from 2,500-4,000 ft; • Many *Carex* sp. bogs found scattered throughout the lower elevations; • Native plant diversity is low and dominated by *Carex* sp.; • Surrounded by open ʻōhiʻa canopy, uluhe understory, and ground cover; • No nonnative mammalian predators (e.g., mongooses, rats); and • No dogs and cats.
Strategies to achieve objective:
Build and maintain ungulate-proof fence to protect *Carex* sp. bog habitats where feasible.
Conduct surveys for pest animals such as cats and dogs and nonnative mammalian predators.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting, and rodenticide (aerial and bait stations).
Survey extent and number of bogs.
Rationale: Bogs naturally occur in flat areas and are dominated by sedges and rushes. Limited areas of open water also occur. Bogs are primarily located below 4,500 ft. While sphagnum exists in these bogs, it is unclear whether it is native. Faunal use of bogs is primarily by invertebrates; however, koloa maoli are known to use bogs. Other species of conservation and management concern include native forest birds, nēnē, and endangered plants. The conversion of *Carex* sp. to *Juncus* sp. has occurred due to the rooting activities of pigs. Enhanced soil erosion from ungulate activities also has increased the eutrophication of bogs.

2.3.2.3 Goal 5: Protect and maintain grassland habitat to support nēnē population recovery.

Objective 5.1: Maintain managed grassland for foraging nēnē.
Maintain approximately 65 acres of managed grassland for nēnē foraging with the following attributes: • Grass height < 6 inches; • Native (e.g., *Deschampsia* sp.) and nonnative grasses (e.g., *Holcus* sp.); • <25% cover of invasive plants; • No nonnative mammalian predators (e.g., mongooses, rats); and

• No dogs and cats.
Strategies to achieve objective:
Build and maintain ungulate-proof fence.
Use mowing to maintain fuel breaks and fence corridors in short grass (< 6 inches).
Use mowing except during peak nesting (October-April).
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct surveys for pest animals such as nonnative mammalian predators and cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting, and rodenticide (aerial and bait stations).
Rationale: Fuel breaks have been constructed and will be maintained creating short grass habitat that is incidentally used by nēnē. Nēnē graze the grasses of the fuel breaks, helping to maintain them. In addition, the 15-acre administrative site (located near Hakalau Cabin) is kept mowed and provides incidental nēnē habitat for foraging. Annually mowing 50 acres of fuel breaks and 15 acres around the administrative site would maintain the Refuge's focus on maximizing forest bird habitat by reforesting and restoring the maximum amount of nonnative, high-elevation grasslands.

Objective 5.2: Maintain grassland habitats for nēnē nesting.
Maintain approximately 15 acres of managed grassland habitat for nēnē nesting with the following attributes: • Composed of primarily native grasses with limited nonnative grasses and scattered native shrubs and trees; • Reduced nest predators to levels that do not impact breeding success during nesting season; and • No ungulates.
Strategies to achieve objective:
Maintain ungulate-proof fence.
Establish a predator-proof fence on15-acre grassland breeding site away from administrative sites on the Pua ʻĀkala Tract.
Remove all ungulates, nonnative mammalian predators, and dogs and cats using IPM techniques such as trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).
Use IPM techniques including physical/mechanical, biological, and chemical to eradicate or control invasive plants (see Appendix G).
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, and cats and dogs.
Control pest animals using appropriate IPM techniques including, but not limited to, trapping, snares, shooting (ground and aerial), and rodenticide (aerial and bait stations).

Rationale:
Currently, nēnē nest throughout the existing grasslands that are being restored to forest. These grasslands are located in the upper elevations (approximately 6,000-6,500 ft). As the forest develops and matures, nēnē nesting will occur primarily on lands adjacent to the Refuge.

In this area of Hawaiʻi, nēnē typically use mid- to high-elevation native and nonnative shrubland and early successional grasslands, native alpine grasslands and shrublands, and open native and nonnative alpine shrubland-woodland community interfaces. The areas nēnē inhabit typically have less than 7.5 ft of annual rainfall.

Nēnē nests, eggs, and young are vulnerable to predation. On the Refuge, they are susceptible to mongooses, rats, and cats. Exclosures and predator control (during nesting season) have helped to maintain the Refuge population.

During the breeding season, nēnē feed mainly on berries and other plant items found on lava flows near their nest sites, although some birds supplement their berry diet by feeding in grasslands, depending on berry density. During the pre- and non-breeding season, their principal foods are cultivated grasses (Black et al. 1994). Nēnē select habitats with food plants high in protein. The presence of standing or flowing water is not necessary for successful breeding, although observations of nēnē in the lowland coastal regions of Hawaiʻi Island and Kauaʻi indicate that when standing water is present, it is readily utilized for drinking and bathing. Bodies of water may also be used to escape from predators when goslings have not yet fledged, and when adults molt their primary flight feathers. Standing water is generally sparse in most nēnē habitats, and water is obtained primarily from their diet. Nēnē are more terrestrial than most other waterfowl species, having evolved in habitats with limited freshwater availability.

During the nēnē nesting period (October-April), Service interns monitor nēnē nests and control predators (mongooses, cats, and rats) near nesting areas. Monitoring of nēnē nests and predator control would also be expanded to include the new 15-acre breeding site as needed.

Objective 5.3: Investigate and initiate landscape-level habitat conservation measures.

Within 1 year of CCP approval, the Refuge will complete a Land Protection Planning effort in cooperation with other agencies and interested parties to assess and identify land conservation priorities in the vicinity of Refuge units. Potential additions or expansion of the Hakalau Forest NWR and examination of various land protection tools will be explored. Land Protection as part of the Refuge System may include fee title acquisition, conservation easements, and/or cooperative agreements.

The plan will provide for conservation of supporting habitats, partnership opportunities, and opportunities to adapt Refuge management to impacts from global climate change.

Strategies to achieve objective:

Identify parcels of land that could provide supporting habitat for focal species of the HFU.

Develop strategies for protection and management of supporting habitat.

Work proactively with partners, neighbors, and private landowners where appropriate to meet conservation goals and develop specific project proposals for land acquisition, cooperative agreements, and/or conservation easements as key conservation opportunities arise and willing parties are identified.

Rationale:
Through a cooperative effort culminating in the 2006 National Ecological Assessment Team Report, the Service and USGS outlined a unifying adaptive resource management approach for conservation at "landscape" scales, the entire range of a priority species or suite of species known as "strategic habitat conservation" or SHC. In April 2009, Service leadership established Landscape Conservation Cooperatives (LCCs). The LCCs are conservation-science partnerships between the Service, other Federal agencies, States, Territories, tribes, NGOs, universities, and other entities. They are fundamental units of planning and science capacity to help carry out the functional elements of SHC, biological planning, conservation design, conservation delivery, monitoring, and research, and strategic response to climate change.

The Pacific Islands Climate Change Cooperative (PICCC) is the LCC focused on Hawaiʻi, the Mariana Islands, American Samoa, and central Pacific islands under the U.S. flag. Established in late 2009, it will create the technical capacity, decision support tools, and organizational structure to address landscape-scale conservation issues using SHC. These tools will help managers reach explicit conservation objectives for native species and habitats in the face of climate change and ongoing threats such as fire, land conversion, and invasive species. The Hawaiian and Pacific Islands NWRs anticipate using climate change information provided by the PICCC as foundational products from which to conduct more detailed site-specific and species-specific analyses critical to the preparation of planning documents and to prioritize on-the-ground conservation actions.

Currently, the Refuge identifies parcels on a case-by-case basis for protection as they become available from willing sellers. A landscape approach on the slopes of Mauna Kea will allow staff to focus efforts and work with partners to ensure that habitat needs are met over a larger area. In addition, corridors between patches of protected habitat are critical for species migration in response to climate change. Species distribution and abundance is likely to change based upon precipitation patterns, temperature variations, and shifts in mosquito zones. The Refuge will identify landscape-level opportunities to augment the protection currently provided by existing Refuge lands.

2.3.3 Both Hakalau Forest and Kona Forest Units

2.3.3.1 Goal 6: Collect scientific information (inventories, monitoring, research, assessments) necessary to support adaptive management decisions on both units of Hakalau Forest NWR.

Objective 6.1: Conduct high-priority inventory and monitoring (survey) activities that evaluate resource management and public use activities to facilitate adaptive management.

These surveys contribute to the enhancement, protection, use, preservation, and management of wildlife populations and their habitats on and off Refuge lands. Specifically, they can be used to evaluate achievement of resource management objectives identified under all goals. These surveys have the following attributes:

- Data collection techniques would have minimal animal mortality or disturbance and minimal habitat destruction;
- Minimum number of samples (e.g., water, soils, vegetative litter, plants, macroinvertebrates, vertebrates) to meet statistical analysis requirements would be collected for identification

and/or experimentation in order to minimize long-term or cumulative impacts; • Proper cleaning of investigator equipment and clothing as well as quarantine methods, where necessary, would minimize the potential spread or introduction of invasive species; and • Projects will adhere to scientifically defensible protocols for data collection, where available and applicable.
The following is an initial list of survey activities to support resource management decisions on the Refuge. Please note this list will continue to evolve during the 15 year life span of the CCP:
Continue annual Hawaiʻi Forest Bird Surveys.
Monitor nesting density and success of nēnē.
Monitor species and habitat response to management actions (Goals 1-5) by conducting annual transect surveys.
Develop an updated vegetation cover map of HFU and KFU (for use in GIS and monitoring).
Inventory endemic species in all forest habitats (Goals 1 and 3).
Inventory plants, invertebrates, and vertebrates occurring at HFU and KFU.
Institute early detection and rapid response monitoring to identify new or spreading invasive plant problems on the Refuge.
Monitor plant and animal diseases (e.g., ʻōhiʻa rust, koa wilt, avian malaria, avian pox).
Inventory endemic species, subfossil remains, and cultural resources associated with lava tube and skylight systems (Goal 2).
Inventory endemic species in all aquatic habitat types (Goal 4).
Monitor global climate change parameters (e.g., temp, CO_2, etc.).
Survey water quality for reduced levels of disease, sediments, contaminants (e.g., fecal coliform).
Monitor public uses (e.g., disturbance).
Rationale: The Administration Act requires each refuge to "… monitor the status and trends of fish, wildlife, and plants in each refuge." Surveys would be used primarily to evaluate resource response to assess progress toward achieving refuge management objectives derived from the Refuge System mission, refuge purpose(s), and maintenance of biological integrity, diversity, and environmental health (601 FW 3). Determining resource status and evaluating progress toward achieving objectives is essential to implementing adaptive management on Department of the Interior lands as required by policy 522 DM 1. Specifically, results of surveys would be used to refine management strategies, where necessary, over time in order to achieve resource objectives. Surveys would provide the best available scientific information to promote transparent decisionmaking processes for resource management on refuge lands.

Objective 6.2: Conduct high priority research projects that provide the best science for habitat and wildlife management on and off the Refuge.
Scientific findings gained through these projects would expand knowledge regarding life-history needs of species and species groups, as well as identify or refine habitat and wildlife management actions. Research also will reduce uncertainty regarding wildlife and habitat responses to Refuge management actions in order to achieve desired outcomes reflected in resource management objectives and to facilitate adaptive management. These research projects have the following attributes: • Adhere to scientifically defensible protocols for data collection, where available and applicable, in order to develop the best science for resource management; • Data collection techniques would have minimal animal mortality or disturbance and minimal habitat destruction; • Collect the minimum number of samples (e.g., water, soils, vegetative litter, plants, macroinvertebrates, vertebrates) to meet statistical analysis requirements for identification and/or experimentation in order to minimize long-term or cumulative impacts; • Utilize proper cleaning of investigator equipment and clothing as well as quarantine methods, where necessary, to minimize the potential spread or introduction of invasive species; and • Often result in quality, peer-reviewed articles in scientific journals and publications and/or symposiums.
The following is an initial list of research projects to support resource management decisions on the Refuge. Please note this list will continue to evolve during the 15 year life span of the CCP:
Investigate and monitor endangered plant propagation and outplanting strategies.
Identify methods for forest regeneration and reforestation techniques.
Identify pest plant and animal species presence, distribution, abundance, and trends.
Conduct research to determine arthropod abundance.
Conduct research to determine species-specific thresholds for disturbances from Refuge uses such as outplanting and bird watching activities.
Conduct an investigation to identify and quantify avian and plant disease issues.
Research demography, life-history, carrying capacity, and competition for native forest birds.
Research population dynamics and viability of ‘ākepa and other species: influences of management, environmental factors, and potential nonnative competitors.
Investigate foraging ecology and competition among native and nonnative forest bird species.
Identify avian disease distribution and climate change.
Rationale: Research projects on Refuge lands would address a wide range of natural and cultural resource as well as public-use management issues. Examples of research projects can include habitat use and life-history requirements for specific species/species groups, practical methods for habitat

management and restoration, extent and severity of environmental contaminants, techniques to control or eradicate pest species, effects of climate change on environmental conditions and associated habitat/wildlife response, identification and analyses of paleontological specimens, wilderness character, modeling of wildlife populations, and assessing response of habitat/wildlife to disturbance from public uses. Projects may be species-specific, refuge-specific, or evaluate the relative contribution of the refuge to larger landscape (e.g., ecoregion, region, flyway, national, international) issues and trends. Like monitoring, results of research projects would expand the best available scientific information and potentially reduce uncertainties to promote transparent decision-making processes for resource management over time on Refuge lands. In combination with results of surveys, research would promote adaptive management on Refuge lands. Quality, scientific publications resulting from research on Refuge lands will help increase the visibility of the Service as a leader in the development of the best science for resource conservation and management.

A research facility of the University of Hawaiʻi is located on the administrative site of the HFU. This site is used as a base of operations for researchers from a variety of institutions and agencies. Use of the site is governed by a Memorandum of Agreement between the Service and UH. A compatibility determination for this facility and the research associated with it is included in Appendix B.

The scientific community from Hawaiʻi and beyond has historically had a good deal of interest in conducting research on Hakalau Forest NWR. The native forest birds and the habitat restoration efforts that occur here lend themselves well to research questions. In addition, research can help to assess the effectiveness of management activities and help to adapt management over time. Scientific research requires staff and management time for review of proposed studies, oversight of access and facility issues, permitting, and use of supporting infrastructure, and thus places a strain on both the Refuge resources and the staff that are required to administer Refuge access and research activities. It is not possible to permit all of the research requests that are received by Refuge staff. Research will be reviewed and permitted on a case-by-case basis, according to Refuge purpose and goals, best available information using an objective review process, and according to established research priorities.

Forest Bird Workshop: The Service sponsored a workshop in October 2008 including most of the prominent researchers knowledgeable about Hawaiian forest bird biology, ecology, and population status. During this workshop, Refuge managers met with researchers to hear about some of the latest research and gain insight into researchers' perspectives about forest bird research priorities. A summary of the workshop is included as Appendix E.

Forest bird researchers at the 2008 workshop identified potential research priorities for Hakalau Forest NWR. The list (in priority order) is (1) monitoring and background data; (2) predation, especially from rats; (3) invasive plants and potential biocontrols; (4) impacts from grazers/browsers; (5) invasive plants, more efficient control methods and registration of herbicides; (5) determine the effects of global climate change at the Refuge; (6) develop more effective cat control techniques and determine effects of ectoparasites on non-endangered bird populations; and (8) experimental control of Japanese white-eyes.

We expect to refine these priorities as new information arises. The process used at the Hilo workshop was most inclusive and objective and may well serve us in the future as new management challenges develop.

Additional research projects for consideration are also listed in Appendix C.

Objective 6.3: Conduct scientific assessments to provide baseline information to expand knowledge regarding the status of Refuge resources to better inform resource management decisions.
These scientific assessments will contribute to the development of Refuge resource objectives. They would also be used to facilitate habitat restoration through selection of appropriate habitat management strategies based upon site-specific conditions. The assessment attributes are: • Utilize accepted standards, where available, for completion of assessments; and • Scale and accuracy of assessments would be appropriate for development and implementation of Refuge habitat and wildlife management actions.
The following is an initial list of scientific assessments to support resource management decisions. Please note this list will continue to evolve during the 15 year life span of the CCP:
Conduct surveys to determine role of predators in native flora and fauna abundance.
Support research to determine ecological parameters for ʻōpeʻapeʻa.
Complete global climate change impacts assessment for the Refuge.
Develop a soil survey map.
Rationale: In accordance with policy for implementing adaptive management on refuge lands (522 DM 1), appropriate and applicable environmental assessments are necessary to determine resource status, promote learning, and evaluate progress toward achieving objectives whenever using adaptive management. These assessments would provide fundamental information about biotic (e.g., vegetation data layer) as well as abiotic processes and conditions (e.g., soils, topography) that are necessary to ensure that implementation of on-the-ground resource management achieves resource management objectives identified under Goals 1-5.

2.3.3.2 Goal 7: Visitors, with a special emphasis on experience gained through volunteer work groups and local residents, understand and/or value the native forest environment and management practices at Hakalau Forest NWR.

Objective 7.1: Establish compatible wildlife observation and photography opportunities.
Maintain and enhance compatible wildlife observation and photography opportunities at Hakalau Forest NWR focusing on HFU, with the following attributes: • Highlights the Refuge's purposes and management practices; • Provides opportunities to view and photograph native forests and endangered and native forest birds and plants; • Provide locations for prime viewing opportunities (e.g., wildlife observation trails); and • Maintain or increase visitor use levels at the Refuge as appropriate.

Strategies to achieve objective:
Work with Friends of Hakalau Forest to develop interpretive brochures.
Develop a 0.3- 0.5-mile wildlife trail with interpretive signs and associated parking area on the Upper Maulua Tract.
Rationale: Compatible wildlife observation programs receive priority consideration in Refuge planning and management, secondary to the needs of fish and wildlife. High quality wildlife viewing will continue to be provided on the Refuge. Wildlife viewing opportunities will be provided for an estimated 1,500 visitors per year. The HFU opportunities, to accommodate high visitor demand, would require new trails to provide quality wildlife viewing opportunities and access to a variety of habitat types, while minimizing wildlife disturbance and providing sufficient wildlife sanctuary. Quality wildlife observation is defined by several elements including: (1) opportunities exist to view wildlife in their habitat and in a natural setting; (2) observation opportunities promote public understanding of Hakalau Forest NWR resources and its role in managing and protecting those resources; (3) observations occur in places with the least amount of disturbance to wildlife; (4) facilities are safe, fully accessible, and available to a broad spectrum of the public; (5) viewing opportunities are tied to interpretive and educational opportunities; and (6) observers have minimal conflict with other visitors or Refuge operations. Compatible wildlife photography is also one of six priority wildlife-dependent recreational uses of the Refuge System. Photographic opportunities promote public understanding and increase public appreciation for America's natural resources and incorporate a message of stewardship and conservation. The Refuge will provide a high-quality photography program where compatible with sound principles of fish and wildlife management, other objectives, and other compatible uses.

Objective 7.2: Promote and enhance the volunteer program at Hakalau Forest NWR.
Maintain the existing HFU volunteer program (35-40 weekends), develop seasonal volunteer program, and establish and promote a volunteer program at KFU within 7 years after the CCP is approved, with the following attributes: • Begins after fence construction and ungulate removal (KFU); • Over 7,500 hours contributed per year (HFU); • Appreciation and understanding of Refuge management efforts gained; • Increase public involvement to cultivate feelings of ownership and empowerment through various activities, such as tree planting, habitat restoration, weed control, surveys, historic building restoration, construction, bird walk guiding, plant propagation; • Creates ambassadors of environmental stewardship practices and ethic; • Ecovolunteer program supports the Refuge habitat management program; and • Provide a range of volunteer opportunities for individuals with a variety of skills and abilities, and support the Service's "Connecting People with Nature" priority.
Strategies to achieve objective:
Maintain volunteer program at HFU by providing 35-40 weekend-long service opportunities with partner organizations to visit the Refuge, assist with habitat restoration, and observe native forest birds.
Develop a seasonal volunteer program to supplement staffing and weekend programs.

Develop volunteer program at KFU.
Rationale: The existing volunteer program would continue, with emphasis on service weekends by groups interested in Refuge enhancement activities. Volunteer programs are vital to Refuge management by providing additional labor for management programs that could not be accomplished by Refuge staff alone. While volunteer programs require administration and coordination, the benefits far outweigh these costs.

Objective 7.3: Support existing outside programs for on and off site environmental education and develop interpretive opportunities at Hakalau Forest NWR.
Support existing outside programs for off site and compatible on site environmental education opportunities that are administered by NGOs and where appropriate develop interpretive opportunities with the following attributes: • Includes 168 participants annually; • Based on Refuge and endangered species recovery management programs; • Provides hands-on stewardship opportunities for teachers and students; • Actively promote the Service's "Connecting People with Nature" priority; • Accommodates six volunteer sessions that target students; and • Provides information about and serves as a conduit to past uses and connections to the land.
Strategies to achieve objective:
Interpretive wildlife walks available at the annual HFU open house. Rely on SUP process to allow commercial guides, teachers, and NGOs to continue compatible outreach activities.
Coordinate with County, State, and NGO partners for off site environmental education opportunities, including Kīpuka 21.
Develop and expand interpretive programming relative to cultural resources and historic sites.
Rationale: Compatible environmental education and interpretation are priority wildlife-dependent public uses of the Refuge. In addition, they provide opportunities to reach local community members who may not otherwise learn about Refuge resources and management programs. The Refuge is in a unique position to offer local education agencies, teachers, and students opportunities to study endangered species and engage in natural resource management and conservation issues in an outdoor setting. Since its establishment, educators and youth professionals have been using the Refuge as an outdoor classroom to enhance course curricula. The existing program serves approximately 75 students per year. Groups using the Refuge for environmental education purposes would be required to obtain a SUP or work through the Refuge volunteer program. To meet student needs, the Refuge is committed to working with schools to teach students about Refuge resources, including wildlife, habitat conservation, and cultural resources. These could be

one-time activities such as planting, or long-term involvement including planning, design, and actual on-the-ground implementation for a restoration site. Interpretation opportunities about the history of the area, ties to Native Hawaiian cultural practices, and historical use of Refuge resources should be offered.

Objective 7.4: Enhance outreach targeting local communities to promote appreciation of and generate support for the KFU.
Enhance outreach targeting local communities to promote appreciation of and generate support for the KFU and its resources. The outreach efforts will focus on accomplishing the following: • Build awareness and support amongst local communities, with special emphasis on Native Hawaiians; • Build positive name recognition for both units of Hakalau Forest NWR specifically and the Refuge System in general; and • Maintain and expand partnerships with conservation organizations, adjacent landowners, other Federal, State, and County agencies, Native Hawaiian groups, high schools (including Hawaiian charter schools), colleges, businesses, civic clubs, hunting organizations, and the interagency Navigating Change educational partnership.
Strategies to achieve objective:
Work with existing partners (Friends of Hakalau Forest NWR, Three Mountain Alliance, Imi Pono no ka ʻĀina) to promote awareness and appreciation.
Develop and cultivate new partners and outreach efforts.
Rationale: Outreach to local communities would allow the Refuge to reach populations that may not otherwise learn about Refuge resources and management programs.

2.3.3.3 Goal 8: Protect and manage cultural resources and historic sites for their educational and cultural values for the benefit of present and future generations of Refuge users and communities.

Objective 8.1: Increase identification, monitoring, protection and restoration of all cultural resources and historic sites, while increasing staff and public support and appreciation.
Increase identification, monitoring, protection and restoration of all cultural resources and historic sites, while increasing staff and public support and appreciation. These efforts will focus on accomplishing the following: • Build Refuge capacity and understanding for cultural and historic sites to assist with management; and • Expand knowledge for the public related to Refuge cultural and historic resources.
Strategies to achieve objective:
Evaluate known/potential Refuge cultural resources and historic sites.

Obtain Section 106, Hawaiian cultural, and diversity training for Refuge staff to enhance protection and appreciation of cultural resources.
Within 1 year develop guidelines for approval of and a compatibility determination for Native Hawaiian cultural activities on the Refuge.
Identify Native Hawaiian groups or cultural practitioners within the Refuge ahupuaʻa lands to cultivate an understanding of important historic sites and cultural resources.
Conduct a comprehensive cultural resources investigation of both units.
Develop interpretive programming relative to cultural and historic sites; including developing interpretive products in partnership with Native Hawaiian groups.
Rationale: The Refuge contains cultural/historic resource sites that have been inventoried in areas where management actions could have impacted cultural/historic sites. This inventory will continue to ensure protection of these important resources. The Refuge allows cultural/historic resource investigations of sites by universities, researchers, students, and/or cultural practitioners. This information adds to our understanding of sites on Refuge lands. Within 1 year, Refuge staff will develop guidelines for approval of and a compatibility determination for Native Hawaiian cultural activities on the Refuge, including collecting medicinal plants, visiting/utilizing caves with cultural and spiritual significance, and performing traditional ceremonies. Refuge staff will coordinate with Regional staff, the DOI solicitor's office, Office of Hawaiian Affairs, and interested parties in development of these guidelines. Refuge volunteers gain appreciation and respect for Native Hawaiian culture by helping to preserve the culture and land through restoration projects. In a traditional Native Hawaiian context, there is no division between nature and culture. The land, water, and sky were the foundation of life and the source of the spiritual relationship between people and their world. Native Hawaiian traditions express the attachment felt between the Native Hawaiian people and the earth around them. "Native traditions describe the formation (literally the birth) of the Hawaiian Islands and the presence of life on and around them in the context of genealogical accounts. All forms of the natural environment–from the skies and mountain peaks, to the watered valleys and plains, to the shoreline and ocean depths–are the embodiments of Hawaiian gods and deities" (Maly 2001). The land divisions known as ahupuaʻa were claimed by the king and chiefs in the Mahele of 1848. Seldom visited, except by travelers between ahupuaʻa, bird feather collectors, hunters, and canoe makers, the ahupuaʻa highlands were generally undeveloped in architectural terms. The ahupuaʻa for HFU are Maulua Nui, Honohina, Hakalau, Makahanaloa, Pāpaʻikou, and Paukaa. For KFU, the ahupuaʻa are Kalāhiki and Hoʻokena. The ʻōhiʻa-koa zone was used by Native Hawaiians for specialized resources including bark for making fishing nets and māmaki to make kapa cloth. Native Hawaiians may have used the area for temporary camps while collecting natural resources or en route to a higher elevation adze quarry and associated surface work sites. Native Hawaiians had knowledge of shelter caves, overhangs, and water sources. In the dry māmane woodland, pili grass may have been collected as a special resource for thatching structures, as well as māmane wood for making adze handles, house posts, and hōlua sleds. Within or above the māmane zone, nēnē, ʻuʻau, and koloa maoli may have been

used as a source of meat. Radio carbon dating of bird bones from caves located in the saddle region between Mauna Loa and Mauna Kea indicate that Native Hawaiians were obtaining juvenile ‘ua‘u and collecting bird feathers between 1000-1450 A.D. (Dougherty and Moniz-Nakamura 2006).

By interpreting Native Hawaiian practices that occurred on Refuge lands, we will provide the public with a better understanding of these sites and enhance the Refuge experience.

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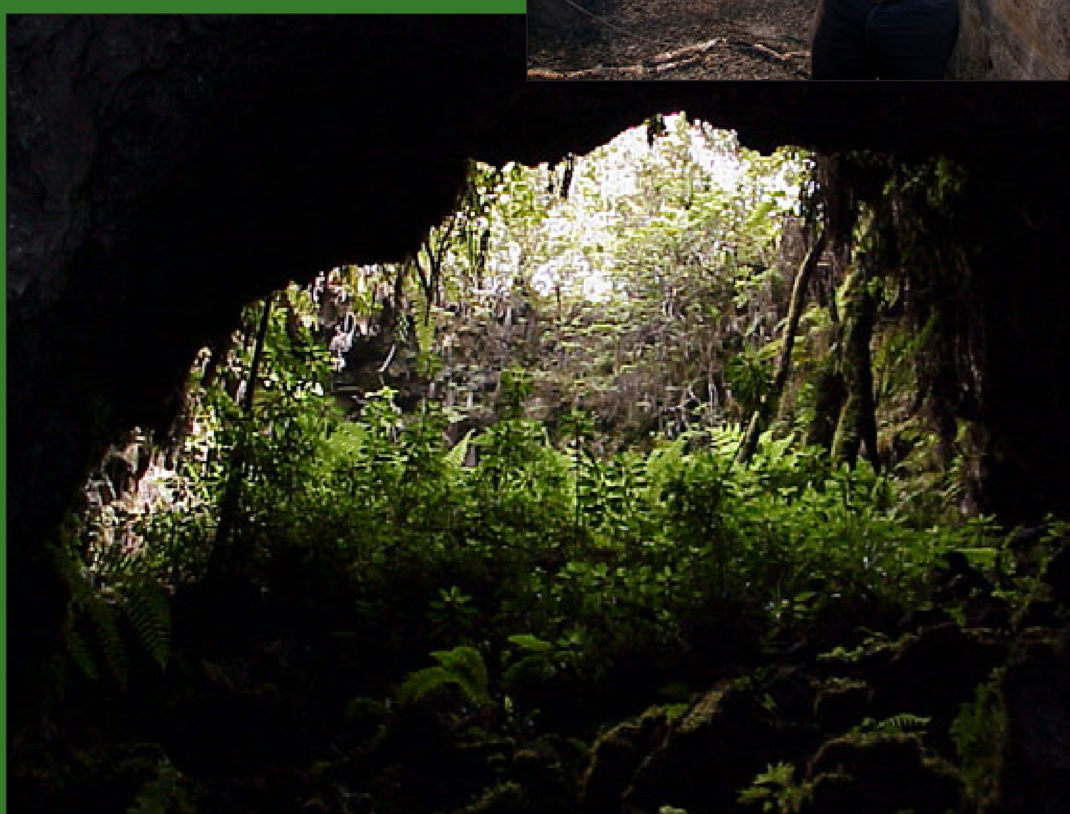
Chapter 3. Physical Environment

Above: ‘Ākepa/Jack Jeffrey Photography
Right: The FWS Horticulturist and his volunteers raise thousands of rare native plants in the Hakalau Forest NWR greenhouse /Roy Lowe



Kona Forest Unit/USFWS

Chapter 3. Physical Environment

3.1 Climate

Located approximately 2,400 miles (mi) southwest of the nearest continental landmass, the Hawaiian Islands are the most isolated archipelago in the world. The climate of Hawaiʻi is generally constant throughout the year, with only minor periods of diurnal and seasonal variability. In general, temperatures during the summer season (May-September) are warm, conditions are dry, and trade winds originate from the northeast direction. The winter season (October-April) is characterized by cooler temperatures, higher precipitation, and less equable winds (Juvik and Juvik 1998).

The trade winds also produce differences within the two physiographic provinces, windward and leeward zones, as a result of orographic rainfall. Moisture is carried from the ocean to the island by the northeasterly trade winds. Orographic rainfall is rain generated when moist air rises against steep slopes, cools, and forms rain producing clouds. As the air descends on the opposite side of the slope, it becomes warmer and less moist, resulting in less rain. Orographic rainfall patterns strongly influence the climate of the two zones. On the windward side, climatic conditions are relatively wet, while the leeward areas experience decreased winds, less rain, and are subject to southerly Kona (leeward) storms (Juvik and Juvik 1998).

Episodic oceanic and atmospheric events also influence climate in the islands during specific intervals. The El Niño Southern Oscillation (El Niño) usually results in light trade winds in the western Pacific and drier conditions (Duffy 1993). During El Niño years in Hawaiʻi, average rainfall has dropped below historical records (USFWS 2002a). Hurricanes result in intense rain and wind. The two major hurricanes that most affected Hawaiʻi Island, Hurricanes Fico (July 18-20, 1978) and Estelle (July 22, 1986), had peak gusts of 58 and 55 miles per hour (mph), respectively (HDBEDT 2007). These climate differences determine vegetation patterns, which in turn can affect local hydrological movements of surface and especially ground water (Sack and Frole 2006).

Climatic conditions on the Island of Hawaiʻi vary dramatically due to its large size and elevation range. Clouds form against the windward mountain slopes creating drier conditions around the high mountains of Mauna Kea and Mauna Loa. Annual rainfall fluctuates from 10 in on the leeward coast to 270 in in the windward forests (Mitchell et al. 2005).

Other moisture-producing mechanisms, besides the orographic effect, include convection, Kona storms, and fog drip. Kona storms are low pressure areas which bring southerly winds and rain. These storms typically occur during the winter months when trade winds are light (Juvik and Juvik 1998). Fog drip occurs when clouds gather along mountain slopes and condensation causes the moisture on vegetation to drip to the ground. Fog drip usually develops in late winter and early spring during the afternoon (USFWS 1996a, 2008a). In addition to rainfall, the summits of Mauna Kea and Mauna Loa on Hawaiʻi Island also receive snow in the winter months (Juvik and Juvik 1998).

A particularly unique aspect of the climate in Hawaiʻi is the trade wind temperature inversion. This layer occurs from 5,000 - 10,000 ft where rising air meets sinking air and warmer air exists above cooler air. The temperature inversion layer prevents warm, moist surface air from rising to form rain clouds. Because humid moist air cannot reach high altitudes, a cloud ceiling is formed, causing the climate above the layer to be clearer, drier, and less humid than below the temperature inversion. Orographic rain does not occur above the layer because air flows around the high elevation mountains, rather than over the mountains. The temperature inversion is prevalent during the summer months (Juvik and Juvik 1998).

Prevailing ocean currents surrounding the island also influence weather patterns by moderating the surrounding surface air temperatures as a result of differential heat absorption and advection of heat. Ocean currents in the Hawaiian Islands are moderated by the north Pacific anticyclone, a clockwise gyre that extends from the tropics to the North Pacific (Juvik and Juvik 1998, Lau and Mink 2006). The east-to-west-flowing North Equatorial Current splits at the Island of Hawai‘i, creating a northern branch current that is 65 mi wide called the North Hawaiian Ridge Current.

3.1.1 Hakalau Forest Unit Climate

Climatic conditions at the HFU are largely shaped by elevation. Microclimatic shifts have also occurred at and adjacent to the unit as a result of changing land use patterns. Clearing and grazing of native vegetation allowed for the creation of large open grasslands. These areas increase wind speed, reduce moisture, and result in more extreme temperature fluctuations (USFWS 1996b, USFWS 2002a).

Overall, the HFU is generally characterized by moderate temperatures and wet conditions. In lower elevation areas, daily atmospheric temperatures are higher, with a mean annual temperature of approximately 65°F. Higher elevation areas have lower temperatures around 53°F. At the upper portion of the Refuge around 6,440 ft, temperatures have reached a maximum of 75°F. Night temperatures during the winter can fall to 25°F, causing frost and soil ice (DHHL and USFWS 2003). Generally, winds at the HFU arrive from the south southeast direction. Wind speed is approximately 5 mph (USFWS 2002a). Hawaiian Electric Company (2004) notes that mean annual wind speeds in the area are less than 12.3 miles per hour (mph).

The windward HFU receives northeasterly tradewind-dominated rainfall. Rainfall varies along an elevation gradient, with areas above 5,000 ft receiving less rainfall than lower elevation portions of the Refuge. In the lower regions, annual rainfall is approximately 300 inches, compared to 210 inches at the upper elevations. Rainfall averages also vary within the upper elevations. The area near the Hakalau Cabin at 6,100 ft receives about 20 percent less rain than at Pua ‘Ākala located at 6,300 ft elevation. Between 1989-1994, the average total rainfall at Pua ‘Ākala was 124.19 inches, while Hakalau Cabin received 85.67 inches between 1990-2000 (USFWS 2002a). In general, increased precipitation occurs between October-March (USFWS, unpubl.).

In addition to elevation and wind patterns, episodic events and vegetation differences also influence rainfall variations. At HFU, El Niño years caused average rainfall to drop below historical records, with an average of 55.57 inches each year (USFWS 2002a). Six drought periods (1992-93, 1995, 1998, 2000, and 2008-2010) have been recorded at HFU. Rainfall during these years ranged from 40–68 inches (DHHL and USFWS 2003).

Fog drip is estimated to account for approximately 35 percent of moisture amounts (USFWS 2002a). Fog and mist are consistently present in the afternoons due to the inversion layer (Scowcroft et al. 2000). On the Hilo side of Hawai‘i, the average relative humidity remains fairly constant, ranging from 77-81 percent throughout the year (Juvik and Juvik 1998). At HFU, average daily relative humidity during the winter months is about 70 percent. In the spring and summer months, daily humidity increases to about 85 percent. Daily differences in humidity are also present, with the strongest humidity in the late afternoon and early evening (USFWS 2002a).

3.1.2 Kona Forest Unit Climate

Compared to the HFU on windward Mauna Kea, the climate on the Kona side (leeward) of Hawai'i Island is drier. In particular, South Kona is considered one of the most drought-prone regions in the Hawaiian archipelago (USFWS 2008a). The moisture patterns in the area are driven primarily by daytime surface heating and upslope winds that yield convective rainfall from roughly 2,000 - 5,900 ft. Unlike most areas in the State, the rainy season in Kona occurs during the summer months, with peaks in June-September and low periods from November-February (Juvik and Juvik 1998).

Rainfall clearly decreases with elevation at KFU. Areas above 5,000 ft and below 2,000 ft elevation are generally dry (Atkinson et al. 2005). Average annual rainfall at the lower and upper area of KFU can differ by 39 in (USFWS 2008a). Between April 1995-November 1998, the average annual rainfall varied from 5.63 inches at 2,000 ft to 2.05 inches at 6,000 ft. The climatic differences between the elevations affect the types of species present and species distributions. Seasonal fluctuations have also been observed at the Refuge. Annual and monthly rainfall averages are listed in Table 3-1.

Table 3-1. Average Monthly Rainfall (inches) at the Kona Forest Unit, April 1995-November 1998.

Month	Elevation				
	2,000 ft	**3,000 ft**	**4,000 ft**	**5,000 ft**	**6,000 ft**
January	3.31	2.80	3.00	2.78	2.73
February	1.61	2.07	2.25	1.71	0.82
March	5.28	6.12	6.09	5.42	4.08
April	3.89	4.40	3.26	2.57	1.64
May	4.76	5.77	4.04	2.15	1.30
June	8.45	8.19	7.06	4.74	3.17
July	6.94	5.45	4.10	3.17	1.95
August	6.99	6.48	4.02	2.29	1.73
September	12.2	9.89	6.19	3.07	2.35
October	6.16	4.79	2.19	2.03	1.25
November	3.11	2.85	2.10	1.79	1.42
December	2.37	4.25	4.15	4.01	2.71
Annual Ave.	**5.63**	**5.39**	**4.05**	**2.93**	**2.05**

Source: USFWS, unpubl.

Rain is the primary moisture source at elevations from 2,000 - 2,700 ft, while areas above this elevation also receive moisture from fog drip. The maximum amount of fog drip occurs from 3,000-6,500 ft. Fog density peaks at about 5,000 ft (USFWS 2008a). “Vog”, volcanic gases and particulates emitted from Kīlauea volcano, is another aspect of the climate on the Island of Hawai'i. Vog forms a distinctive haze and has been implicated in causing decreased rainfall and plant damage in Kona forests (USFWS 2008a).

Prevailing trade winds are weak along the Kona coast because the winds are blocked by Mauna Loa and Hualālai (Juvik and Juvik 1998). Mean annual wind speeds in the area are less than 12.3 mph (HECO 2004).

3.2 Geology and Soils

The Hawaiian Islands were formed by a series of volcanic eruptions that occurred at various hotspots beneath the Earth's crust. As the tectonic plate slowly drifted, magma welled up from fixed spots creating a linear chain of islands. Hawai‘i Island is the largest and youngest island in the Hawaiian chain and encompasses a total land area of 4,028.2 mi^2. The landmass was formed when five volcanoes of varying ages (Kohala, Mauna Kea, Hualālai, Mauna Loa, and Kīlauea) joined together (Juvik and Juvik 1998).

Dated at 430,000 years, the extinct Kohala volcano is the oldest on Hawai‘i Island. Found on the northeastern portion of the island, this volcano is deeply eroded on the windward side. Mauna Kea is a dormant, postshield volcano with the oldest lavas estimated to be roughly 250,000 years old and the most recent approximately 4,500 years old (Juvik and Juvik 1998). The elevation of Mauna Kea is 13,796 ft; however, when measured from the submarine base to its peak, Mauna Kea is considered the world's tallest mountain, with a height of 33,480 ft (HDBEDT 2007). Hualālai is an active, postshield volcano on the western side of Hawai‘i Island. Although Hualālai last erupted in 1801, alkalic basalt eruptions generally occur every few hundred years so its core is still active (Juvik and Juvik 1998). Mauna Loa is an active shield volcano with an elevation of 13,679 ft (HDBEDT 2007). Embedded in the eastern flanks of Mauna Loa is Kīlauea, the youngest and most active of the volcano on the Island of Hawai‘i. Since January 1983, Kīlauea has continuously erupted, discharging lava and occasionally ash deposits (Juvik and Juvik 1998).

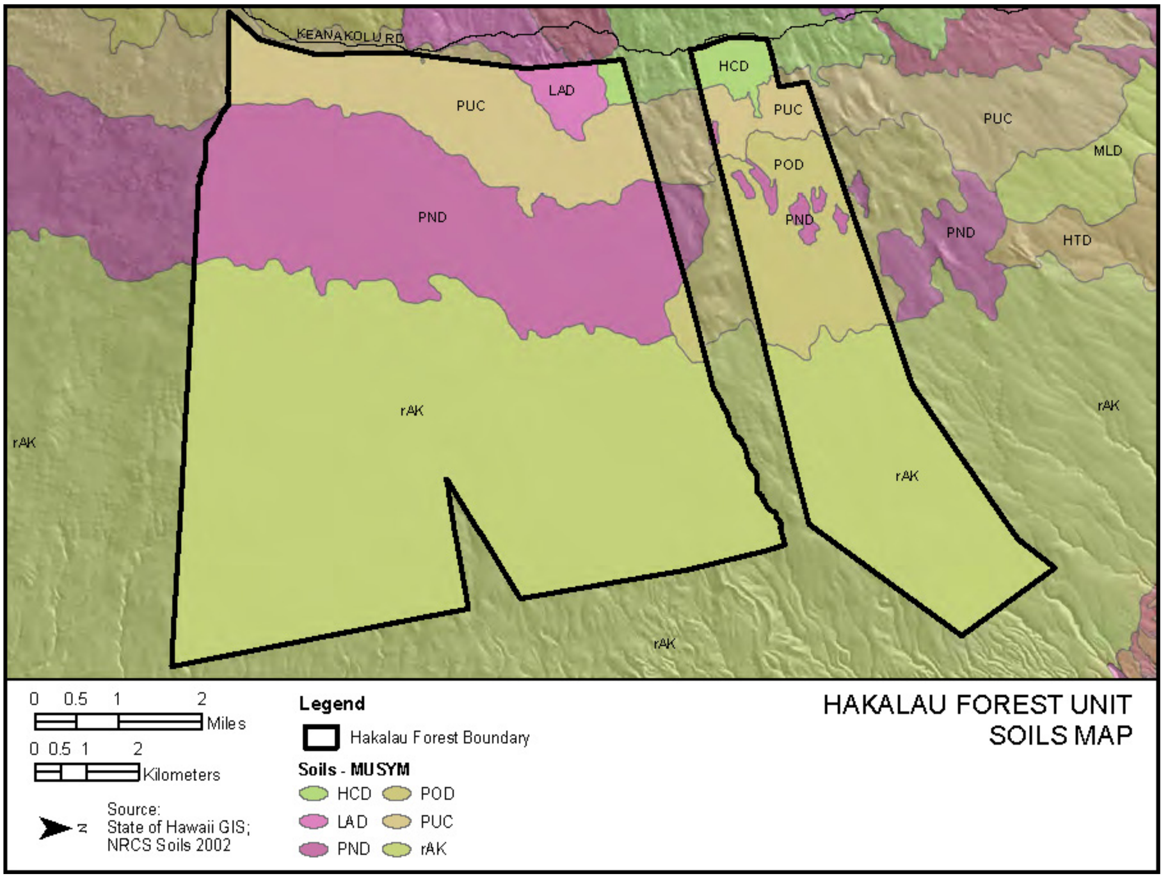
As the basaltic lavas and volcanic ash from the volcanoes weathered and decomposed, various soil types developed throughout the island (Juvik and Juvik 1998). Soils on the Island of Hawai‘i were classified by the U.S. Department of Agriculture (USDA) Soil Conservation Service (Foote et al. 1972). Soil types are mapped in Figures 3-1 and 3-2. Key characteristic of the soils found within the units are listed in Tables 3-2 and 3-3.

3.2.1 Hakalau Forest Unit Geology and Soils

The majority of the unit is covered in Laupāhoehoe Volcanics from a Mauna Kea lava flow ranging between 11,000-64,000 years old. Laupāhoehoe Volcanics in the Maulua Tract of the Refuge are younger, primarily dated between 5,000-11,000 years old. Smaller areas of Hāmākua Volcanic from the Pleistocene epoch (dated between 64,000 and 300,000 years old) occur in the southwestern and northwestern corners of HFU.

All of the soil series present in the HFU were formed from volcanic ash. In the upper elevations of the unit above 5,000 ft, the soil is classified as well-drained silt loams, while lower portions of the Refuge are composed of silty clay loams. The USDA Soil Conservation Service has identified the following soil types:

Figure 3-1. Soil map of the Hakalau Forest Unit.



Pu'u 'O'o silt loam, 6-12 percent slopes (PUC):
Located on uplands of the windward side of Mauna Kea between 5,000 - 6,500 ft, soils in the Pu'u 'O'o series are gently sloping to moderately steep. The surface layer is dark reddish-brown and very dark gray silt loam. This layer is approximately 6 in thick and can be strongly acid (pH 5.1 - 5.5) to very strongly acid (pH 4.5 - 5.0). The subsoil, which is about 21 in thick, is very dark brown to dark reddish-brown silty clay loam. Material underlying the subsoil is dark yellowish-brown and dark-brown sandy clay loam. These layers range from strongly acid to extremely acid (pH below 4.5).

Laumai'a silt loam, 6-20 percent slopes (LAD):
The Laumai'a series are undulating soils located on high elevations above 5,500 ft of the windward side of Mauna Kea and are gently sloping to moderately steep. The surface of the Laumai'a silt loam is a 12 in thick layer of very dark brown and dark-brown silt loam that is exceptionally stony in certain areas. The subsoil is roughly double in thickness and is very dark grayish-brown and dark brown silt loam. The degree of acidity ranges from medium acid (pH 5.6 - 6.0) at the surface layer to strongly acid at the subsoil.

Hanipoe very stony loam, 12-20 percent slopes (HCD):
The Hanipoe series is found from 5,000 - 6,500 ft in elevation. Hanipoe very stony loam is composed of a 20-30 in layer over fragmental 'a'ā lava.

Pi'ihonua silty clay loam, 6-20 percent slopes (PND):
The Pi'ihonua series, located from 4,500 - 6,500 ft on the windward side of Mauna Kea, consists of well-drained silty clay loams that have a banded appearance. The surface layer is about 6 in thick and comprised of very dark brown silty clay loam that is extremely stony in certain areas. The subsoil is dark-brown to dark-red silty clay loam about 44 in thick, while a weakly cemented layer of volcanic ash occurs at a depth of 17-25 in. Acidity varies between very strongly acid to extremely acid.

Pi'ihonua extremely stony silty clay loam, 6-20 percent slopes (POD):
In addition to the characteristics of Pi'ihonua silty clay loam, 6-20 percent slopes, stones cover 3-15 percent of the surface in this soil.

'Akaka soils (rAK):
The 'Akaka series consists of moderately well-drained silty clay loams that formed from volcanic ash. These are gently sloping to steep soils on upland rain forests ranging from 1,000 - 4,500 ft. On the HFU, these soils are found in the mid- to lower-portion of the Refuge and comprise the majority of the Refuge area. 'Akaka soils typically have a slope between 3-20 percent, but are dissected by small steep drainages, with slopes between 40-50 percent. Small, swampy areas of shallow soils underlain by pāhoehoe bedrock also occur in the soil type.

Table 3-2. Soil Types Found Within the Hakalau Forest Unit and Key Characteristics.

	Permeability	Runoff	Erosion Hazard
PUC	Moderately rapid	Slow	Slight
LAD	Moderately rapid	Medium	Moderate
HCD	--	Slow	Slight
PND	Rapid	Slow	Slight
POD	Rapid	Slow	Slight

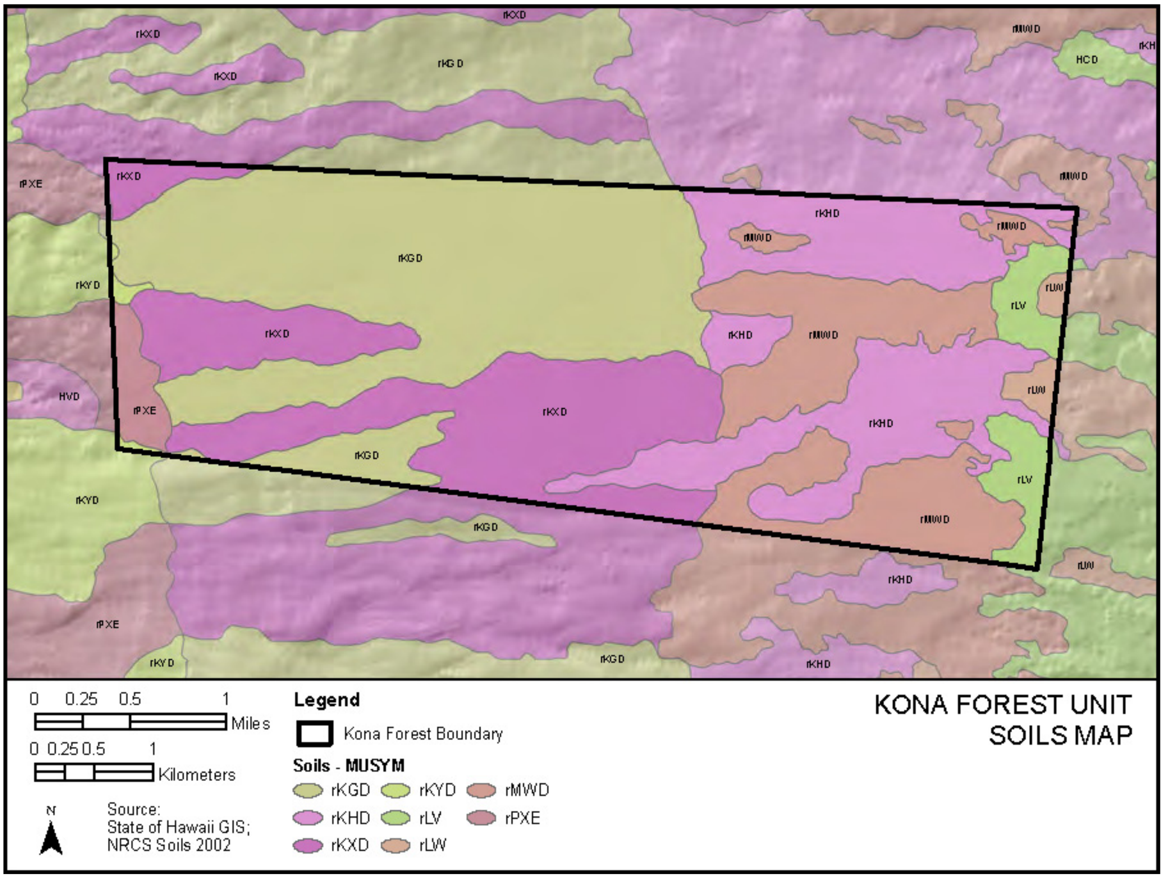
The Natural Resources Conservation Service (NRCS) operates a soil moisture and temperature station at Pua 'Ākala at 6,394 ft. This station, which has been operating since February 2005, records soil moisture and temperature to a depth of 27 inches.

3.2.2 Kona Forest Unit Geology and Soils

The surface of the KFU is covered in a sheath of Mauna Loa lava flows of the Ka'ū Basalt series. Lava flows in the northern two-thirds of the unit are older ranging between 1,500 - 3,000 years old, while the younger southern portion is estimated between 750-1,500 years old. A small area in the central region of the Refuge is composed of Ka'ū Basalt flows between 3,000 - 5,000 years old. South of the KFU, more recent twentieth century lava flows are present (USFWS 2008a).

A thin layer of organic soil covers the highly permeable basalt that remains from the lava flows. The following eight soil types have been identified within the KFU:

Figure 3-2. Soil map of the Kona Forest Unit.



Lava flows, ʻaʻā (rLV):
ʻAʻā lava flows are found along the northern boundary of the KFU. This lava is rough, clinkery, and "piled in tumbled heaps." Only a thin layer of soil covers the lava allowing minimal vegetation growth such as mosses, lichens, ferns, and scattered ʻōhiʻa trees.

Lava flows, pāhoehoe (rLW):
Pāhoehoe lava generally has a smooth, glassy surface compared to ʻaʻā lava. Pāhoehoe is hotter, contains more trapped gasses, and flows faster than ʻaʻā. This lava is lacking any soil covering supports mainly mosses and lichens with scattered ʻōhiʻa trees, ʻōhelo, and ʻaʻaliʻi in cracks and crevices.

Kēkake extremely rocky muck, 6-20 percent slopes (rKHD):
The Kēkake series are well-drained, thin organic soils underlain by pāhoehoe lava bedrock on uplands between 3,500 - 7,000 ft. Approximately 25-50 percent of the surface area is rock outcrops. The soil surface layer is black muck about 4 inches thick and strongly acid.

Māwae extremely stony muck, 6-20 percent slopes (rMWD):
The Māwae series consists of well-drained, thin organic soils over fragmented ʻaʻā lava. This muck is undulating on mountains between 3,500 - 7,000 ft. The surface layer is black extremely stony muck about 5 in thick with a medium acidity.

Kīloa extremely stony muck, 6-20 percent slopes (rKXD):
The Kīloa series is located at intermediate elevations on Mauna Loa and Hualālai between 1,000 - 4,000 ft. Kīloa extremely stony muck consists of a 10 in thick layer of well-drained, very dark brown, extremely stony organic muck over fragmental ʻaʻā lava. Slightly weathered ash and cinders occur in the voids of the lava. The Kīloa series is strongly acid.

Keʻei extremely rocky muck, 6-20 percent slopes (rKGD):
Located between 1,000-3,500 ft on Mauna Loa and Mauna Kea, the Keʻei series consists of well-drained, thin organic soils overlying pāhoehoe lava bedrock. The strongly acid surface layer is very dark brown muck about 10 in thick. Between 25-50 percent of the surface is occupied by rock outcrops.

Puna extremely stony muck, 3-25 percent slopes (rPXE):
The Puna series is found between 1,000-3,500 ft in elevation on Mauna Loa and Hualālai. This soil is well-drained, very dark brown, extremely stony organic muck. The soil is about 5 in thick and underlain by fragmental ʻaʻā lava. This soil is gently sloping to moderately steep and neutral (pH 6.6-7.3).

Kona extremely rocky muck, 6-20 percent slopes (rKYD):
The Kona series also occurs between 1,000 - 3,500 ft on Mauna Loa and Hualālai. About 25-50 percent of the surface is covered by rock outcrop and the surface soil layer is well-drained, very dark brown muck. The slightly acid surface layer is approximately 5 in and underlain by pāhoehoe lava bedrock.

Table 3-3. Soil Types Found Within the Kona Forest Unit and Key Characteristics.

Soil Type	Permeability	Runoff	Erosion Hazard
rLV	Rapid	Slow	Slight
rLW	Rapid	Slow	Slight
rKHD	Rapid	Medium	Slight
rMWD	Rapid	Slow	Slight
rKXD	Rapid	Slow	Slight
rKGD	Rapid	Medium	Slight
rPXE	Rapid	Slow	Slight
rKYD	Rapid	Medium	Slight

3.3 Hydrology

The hydrologic processes that occur in the Hawaiian Islands are unique compared to continental landmasses or temperate zones. Drainage basins are typically small and streams are characterized by steep longitudinal profiles and numerous waterfalls (Lau and Mink 2006). In addition, hydrology is largely influenced by geological features associated with lava flows. Many streams in Hawaiʻi have lengthy dry reaches under natural conditions due to the nature of the underlying rock (Stearns and Macdonald 1947, Macdonald and Abbot 1970).

Similar to other oceanic islands, rainfall is the greatest source of freshwater on the Island of Hawaiʻi. Rainfall contributes roughly 8,000 million gallons per day (mgd) to the water budget of Hawaiʻi Island (Lau and Mink 2006, TMA 2007). This rainwater recharges two vital water resources: groundwater and surface water.

Groundwater, which occurs beneath the surface, is the primary water resource in Hawaiʻi. Groundwater can occur as thin basal lens, as well as high-level aquifers that do not float on seawater (Juvik and Juvik 1998). Unlike older islands in the archipelago, Hawaiʻi Island does not have sedimentary coastal plain or caprock. Lack of a caprock allows fresh water to outflow and the seawater to intrude the freshwater lens. As a result, basal water levels throughout the island are low (Bauer 2003).

Surface water is water flowing in stream channels. This water originates from surface runoff derived from rainfall, groundwater seepage, and channel water that seeps into the banks during high stream stages (Lau and Mink 2006). Streams are classified as intermittent or perennial based on flow conditions. Perennial streams are streams that normally have surface flow throughout the year, at least in some part of the course (Hawaiʻi Cooperative National Park Studies Unit 1990). Perennial streams, which are generally sustained by groundwater in high level aquifers, are usually restricted to the windward sides of islands that receive more rain (Nishimoto and Kuamoʻo 1997, Juvik and Juvik 1998). The largest perennial stream on Hawaiʻi Island (and in the State) is Wailuku River. This river is 22.7 mi long and discharges 180 mgd (HDBEDT 2007).

Water on the island is primarily derived from groundwater rather than surface water (TMA 2007). In 2000, the County of Hawaiʻi used 44.55 mgd of groundwater and 8.86 mgd of surface water (HDBEDT 2007). Major water systems are located in the Kona, Kaʻū, and Puna areas. Water is supplied to these systems from wells, springs, and roof catchments (TMA 2007). Hawaiʻi Island consumes a relatively small percentage of the State's water. In 2006, the County of Hawaiʻi consumed 11.9 percent of the total freshwater consumption of the State of Hawaiʻi (HDBEDT 2007).

Wetlands are critical components of an area's hydrology and provide a variety of ecological functions. The Service defines wetlands as "lands transitional between terrestrial and aquatic system where the water table is usually at or near the surface or the land is covered by shallow water" (Erickson and Puttock 2006). According to this definition, unvegetated areas including beaches, mudflats, and ponds are considered wetlands. Hydrology, vegetation, and soil type are used as indicators to determine the presence of a wetland (Erickson and Puttock 2006). Although small, isolated wetlands occur on the Refuge, they would not be under the jurisdiction of the U.S. Army Corps of Engineers as waters of the U.S. because they are not connected or adjacent to navigable waters (USFWS 2008a).

Flooding is common in certain areas of the island due to ponding, surface runoff, high seas, storm surge, and tsunami inundation. Hawaiʻi Island is particularly vulnerable to flooding because it is relatively young and water courses are generally not well-defined (County of Hawaiʻi 2006). The Federal Emergency Management Agency's National Flood Insurance Program has prepared Flood Insurance Rate Maps (FIRM) that depict flood hazard areas through the State. The maps classify land into four zones depending on the expectation of flood inundation. The entire Hakalau Forest NWR is within Zone X, defined as areas outside of the 100 and 500 year floodplains. In addition, the County General Plan (2005) lists flood prone areas. Statewide flood control is managed by the Department of Land and Natural Resources' Engineering Branch, Land Division.

The use of water resources in the Hawaiian Islands is regulated by the State Water Code, Chapter 174C and governed by the State Commission on Water Resource Management (CWRM). This agency issues permits to regulate the use of surface and ground water. Between 1988-1989, water users in Hawai‘i were required to register their water sources and declare their water uses to CWRM (CWRM 1992). A water right is a legal entitlement to use a certain amount of water from a particular source for a beneficial use. Outside designated water management areas landowners have the right to “reasonable use” of underlying groundwater and riparian water, providing it does not harm the uses of other users (Miike 2004). Specific water rights for descendants of Native Hawaiians who inhabited the Hawaiian Islands prior to 1778 are discussed in Section §174C-101 of the State Water Code.

3.3.1 Hakalau Forest Unit Hydrology

The presence of gulches and ravines allows for intermittent surface water flow following periods of heavy or continuous rain (USFWS 2002a). Some of the streams within the Refuge boundaries are considered perennial at lower elevations. Nonnative ungulates and other mammals (rats) degrade water quality of the intermittent streams through soil disturbance and feces deposition. In addition, disturbance in the upper reaches can result in lack of groundwater retention. Table 3-4 lists stream and tributaries identified within the boundaries of the Refuge.

Table 3-4. Streams and Tributaries on the Hakalau Forest Unit.

Stream	Tributaries
Hakalau	
Honoli‘i	Pōhakupuka
Kapue	
Kawainui	
Kolekole	
Maulua	Makahiloa
Nanue	Painui
Pāhoehoe	Pāhoehoe
Pōhakupuka	
Umauma	Nauhi Gulch, Honohina Gulch
Waikaumalo	
Wailuku	‘Āwehi, Nukupahu Gulch

Source: Hawai‘i Office of Planning GIS Data.

As required under the State Water Code, the Refuge filed Declaration of Water Use for 12 perennial streams in May 1989. These streams included: Kalohewahewa, ‘Āwehi, Honoli‘i, Kapue, Kawainui, Kolekole, Hakalau, Umauma, Painui, Waikaumalo, and Pōhakupuka (CWRM 1989, 1992). The Refuge continuously uses the water in these streams to maintain the riparian community and protect habitat for native aquatic insects and crustaceans. This type of use is considered a category two instream water use because the water remains in the stream channel, rather than being transported outside the channel (CWRM 1989).

Natural and constructed ponds exist along the upper slopes of the HFU. The constructed water features were former stock ponds built for cattle, but several still hold water. Many of the naturally occurring pond and waterholes referenced in historical documents no longer exist. This is likely due to drier conditions and changes in the microclimate. One natural pond, known as Frog Pond, occurs between the Honohina and Hakalau Tracts at about 5,600 ft (Tomonari-Tuggle 1996).

A baseline water resource assessment and stream fauna assessment has not been conducted at the HFU (USFWS 2007). However, numerous surveys have been conducted at the lower elevations of streams that pass through the Refuge. The lower reaches of these streams support native fishes and invertebrates (Tate 1996, Nishimoto and Kuamo‘o 1997). Although unstudied, stream fauna at higher elevations within the HFU are believed to be exclusively invertebrate.

According to the Water Resources Protection Plan (USFWS 2005), the HFU is located in the Pa‘auilo, Hakalau, and Onomea hydrological units. These aquifers have a sustainable yield of 60, 150, and 147 mgd, respectively. The size of these systems shows that a large amount of potable basal groundwater can be developed in the area (Yuen and Associates 1990).

3.3.2 Kona Forest Unit Hydrology

Due to the extremely permeable lava and well-drained soils, there are no perennial surface waters or drainages on the KFU. As a result, no standard water resource assessments have been performed (USFWS 2007). The closest permanent surface water is the Lumiawai waterhole, located about 0.5 mi south of the southeast corner (Rayond and Valentine 2007). Ki‘ilae Stream, which is south of Hōnaunau, is the closest stream (Yuen and Associates 1990).

The Water Resources Protection Plan (USFWS 2005) depicts the KFU within the Ka‘apuna hydrological unit. Groundwater in this region is primarily composed of a thin basal lens that is not protected by caprock. The aquifer in the Ka‘apuna hydrological unit has a sustainable yield of 50 mgd (Yuen and Associates 1990). The Refuge area functions as an important groundwater recharge area for Kona as a result of the porous substrate and high moisture conditions (USFWS 2008a).

South Kona is vulnerable to flooding due to the combination of intense storms, lack of drainages, steep terrain, permeable soils, and urban land uses (County of Hawai‘i 2006, TMA 2007). No records of flooding on the unit have been found.

3.4 Topography

The Island of Hawai‘i is considered the highest oceanic island in the world. However, similar to other volcanic islands, summit heights are constantly changing due to erosion, lava deposition, and isostatic compensation (Jordan et al. 2003). Hawai‘i Island is characterized by high elevation areas and gentle slopes. The majority of Hawai‘i Island (88 percent) is above 500 ft (HDBEDT 2007). Furthermore, almost 70 percent is above 2,000 ft (Mitchell et al. 2005, HDBEDT 2007). The highest point on the island, Mauna Kea, reaches 13,796 ft. Although Hawai‘i Island has some of the highest peaks in the State, the inclines are relatively mild. Approximately 70 percent of Hawai‘i Island has a slope of less than 10 percent (HDBEDT 2007).

3.4.1 Hakalau Forest Unit Topography

The relatively young Mauna Kea volcano does not contain deep valleys and high cliffs that are distinctive on other volcanoes. As a result, the topography at the HFU is relatively gentle. The lower elevation areas have deeper gulches and steeper slopes than higher elevation portions. The prevailing aspect of the slopes is east. Cinder cones, built by lava fountains or erupting magma foam, are scattered throughout the area (Stearns 1966, USFWS 1996b).

3.4.2 Kona Forest Unit Topography

The rectangular-shaped KFU slopes toward the west-southwest. The entire area has an average slope of 20 percent, with slopes of less than 10 percent at the upper elevations (USFWS 2002b). The surface of the entire parcel is rocky, irregular, and undulating (USFWS 2008a). Lava tubes and shallow gulches also dissect the overlapping ‘a‘ā and pāhoehoe lava flows, creating uneven topography (Rayond and Valentine 2007).

3.5 Environmental Contaminants

The Agency for Toxic Substances and Disease Registry, a Federal bureau of the U.S. Department of Health and Human Services, defines a contaminant as “a substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects” (ATSDR 2002). Contaminants commonly include pesticides and their residues, industrial chemicals, fertilizers, metals, and other toxic substances. By altering biological or physical processes, contaminants may produce adverse and even detrimental effects to an ecosystem (USFWS 2005a).

No contaminated sites have been identified on the Refuge units (USFWS 2007). However, Hawai‘i Island is exposed to high sulfur dioxide (SO_2) levels from Kīlauea volcano emissions (vog), as well as traces of metals such as mercury. Sulfur dioxide is an irritant gas that may cause acute and chronic changes in human health, such as eye and respiratory system irritation (Michaud et al. 2005).

The National Priorities List (NPL), compiled under authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (United States Code, Title 42, Chapter 103), provides an inventory of the Nation’s most contaminated hazardous waste sites. No sites are identified on the island.

3.5.1 Hakalau Forest Unit Contaminants

Level I Environmental Site Assessment was conducted on the property prior to acquisition (Woodward, pers. comm.). Potential on- and off-site contamination sources that have been identified on or adjacent to the HFU include accidents and spills, agricultural livestock, forestry silviculture, pesticide application, and recreation (USFWS, unpubl.).

3.5.2 Kona Forest Unit Contaminants

An updated Level I Environmental Site Assessment was conducted on the property in March 1997. The assessment was based on previous contaminants surveys that were conducted in November 1995 and July 1994, as well as supplemental interviews and surveys conducted in 1996 and 1997. Contaminants surveys consisted of interviews with people familiar with area, site inspections by foot and vehicle, and a 24-minute aerial survey. No hazardous substances or other environmental problems were evident on the property during any of these surveys. Small amounts of debris (a single 55-gallon drum and 5 water storage tanks) and localized oil staining associated with the 3 water pumps were noted; however, these were not determined to be significant contaminant problems (Harper 1997).

3.6 Land Use

This section presents an overview of land uses within and adjacent to the units of the Hakalau Forest NWR that currently influence or have the potential to influence Refuge conditions. Relevant local and regional land use designations and policies affecting land use are also discussed.

Both units of the Hakalau Forest NWR were acquired and are continuously managed under a variety of legislative acts, administrative orders, and legal authorities. The Endangered Species Act provides for the conservation of threatened and endangered species of fish, wildlife, and plants. The Service used the legislative authority of the ESA to establish both of the Refuge units and continues to use the ESA to guide management of the endangered species and their habitats. The general purpose of both units is "… to conserve (A) fish or wildlife which are listed as endangered species or threatened species…or (B) plants…" (16 U.S.C. §§ 1534 ESA).

The primary land use at the Refuge is maintenance to restore and benefit native species. Biological research and monitoring is also an important aspect of the units. Roughly 34 research studies were conducted throughout the Refuge in 2007 (USFWS 2007) and 17 studies in 2006 (USFWS 2006).

In addition, limited public use is permitted. The Administration Act identifies six wildlife-dependent visitor uses on refuges: hunting and fishing, wildlife observation and photography, and environmental education and interpretation. All recreational activities must be compatible with the primary purpose of the refuge.

3.6.1 Local Land Use Designations: Hakalau Forest Unit

The HFU, located on the windward side of Mauna Kea, is situated 13 mi northwest of Hilo (Figure 1-1). It spans portions of both the North Hilo District and the South Hilo Districts. The 32,733 ac HFU is comprised of four tracts, including Maulua, Honohina, Hakalau, and Pua ʻĀkala. These tracts are further divided into subunits. The HFU is surrounded by various sections of the Hilo Forest Reserve to the north, east, and south. Along the northern boundary of the Refuge, north of the Maulua tract, the Refuge is bordered by the Laupāhoehoe Section of the Hilo Forest Reserve and the Laupāhoehoe Natural Area Reserve. The Hilo Watershed Forest Reserve abuts the property to the south, while the Pīhā (Game Management Area) Section of the Hilo Forest Reserve splits the

Honohina and Maulua tracts. The HFU is accessed by taking Mauna Kea Summit Road to Keanakolu Road, which is an unpaved road that follows the upper elevation boundary of the Refuge.

The HFU was established on October 29, 1985. The current acreage was purchased over a series of years from various entities including W.H. Shipman LTD, The Nature Conservancy, Liliʻuokalani Trust, Robertson, and the World Union. In addition, a 1.65 ac easement was purchased from the Department of Hawaiian Homelands (DHHL).

The specific purpose of HFU is "to assure the perpetuation of native forest habitats of the Upper Hakalau Forest for the protection of a number of endangered animals and plants endemic to the area." The environmental assessment for Refuge acquisition states that the purpose "is to sustain the naturally evolving mid-elevation rain forest of this area and, as necessary, allow for the management of this forest and its assemblage of native and non-native plants and animals" (Stine 1985). Furthermore, the 500 ac Pua ʻĀkala Ranch portion of the Refuge unit was added to the unit in 1995 in order "to protect and rehabilitate significant native forest habitat, provide for recovery of endangered and threatened species, and to establish a Refuge boundary that would improve management capabilities."

Historically, the Refuge area above 6,000 ft was used as rangeland. This area encompasses 4,950 ac. Domestic grazing occurred in the Upper Honohina Tract (Liliʻuokalani Trust) until April 1996. This 1,034-acre area was leased by Parker Ranch. A private landowner leased 500 acres known as Pua ʻĀkala Ranch until 1997.

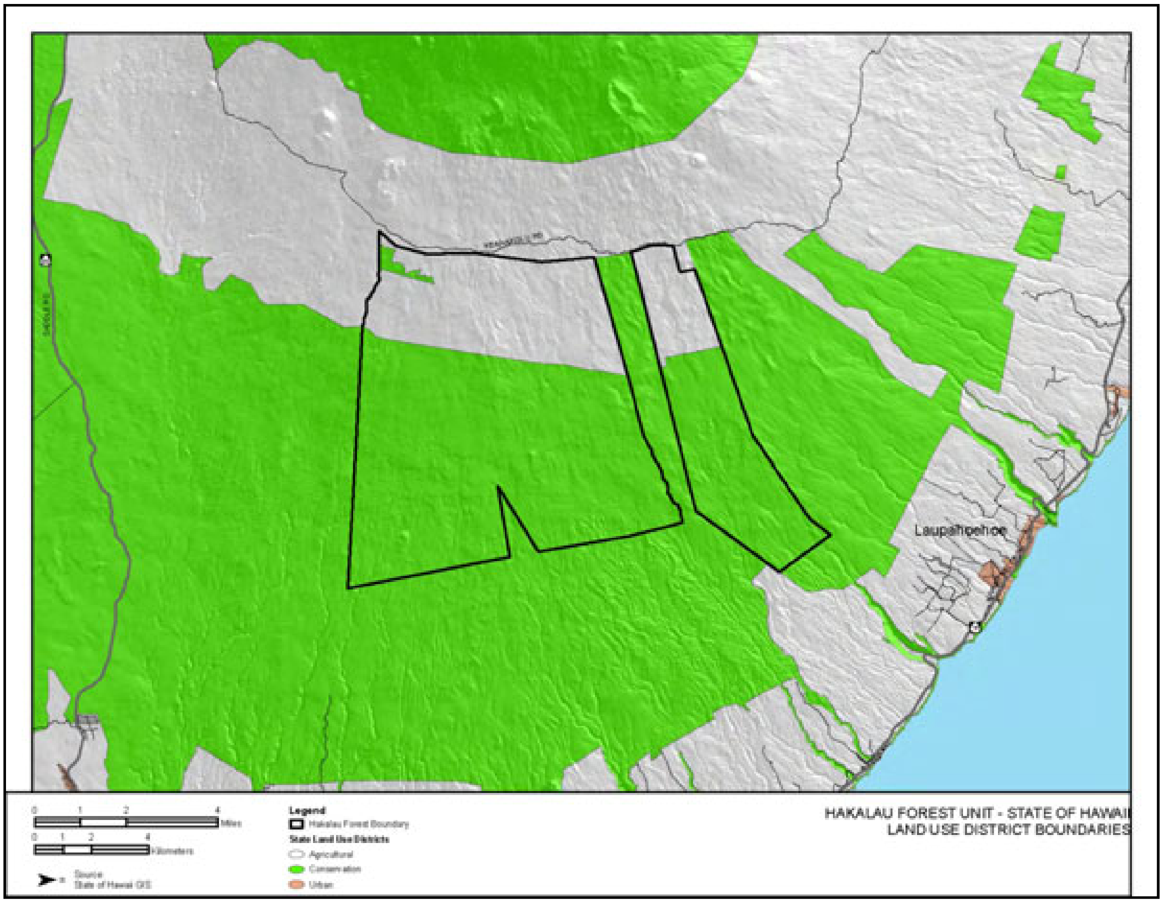
Currently, DHHL and the Hawaiʻi Division of Forestry and Wildlife (DOFAW) are two adjacent land owners of the HFU. DHHL owns the land bordering the west boundary of the Refuge, including the 514 ac Kanakaleonui corridor. Domestic grazing no longer occurs on the land. In a partnership between the Refuge and DHHL in the area immediately adjacent to and above the Refuge (195 ac), DHHL is pursuing a koa forest restoration project that was designed to plant koa to contain the spread of the gorse infestations. At the northwestern corner of the Upper Maulua tract, a 40 ac parcel and two 40 ac parcels are owned by two private landowners.

The DOFAW owns and manages the Forest Reserves and Natural Area Reserves adjacent to the Refuge. Land uses on the Laupāhoehoe Natural Area Reserve include hiking, wildlife observation, and hunting (HAR § 13-209-3). The adjacent sections of the Forest Reserve System are utilized by the public for camping, collecting, commercial harvesting, hunting, and other special uses (HAR § 13-209-3). The Pīhā Section of the Hilo Forest Reserve, located between the Honohina and Maulua tracts, is primarily used by the public for hunting.

More distant land areas include the Mauna Kea Forest Reserve and Mauna Kea Ice Age Natural Area Reserve, located west of the property at the summit of Mauna Kea. In addition, Puʻu Oʻo Ranch is located south of the Pua ʻĀkala area and Parker Ranch is located west of the Refuge boundary.

The Districts of North and South Hilo encompass 174,377 and 252,960 ac, respectively. Almost 69 percent of the North Hilo District is defined as Conservation by the State of Hawaiʻi Land Use District Boundaries Map, while 67 percent of the South Hilo District is considered Conservation (County of Hawaiʻi 2007). The majority of the upper portion of the HFU is designated as Agriculture by the State of Hawaiʻi Land Use District Boundaries Map. The lower portions of the Refuge, as well as the southwestern corner of the Refuge, are classified as Conservation. Areas in the immediate vicinity are also classified as Conservation and Agriculture along a similar elevational gradient (Figure 3-3). Conservation District designations are under the jurisdiction of DLNR, while all other land use designations (such as Agriculture, Urban, and Rural) come under the County of Hawai‘i. There is no Special Management Area for HFU according to State Coastal Zone Management.

Figure 3-3. Land Use District Boundaries - Hakalau Forest Unit.



3.6.2 Local Land Use Designations: Kona Forest Unit

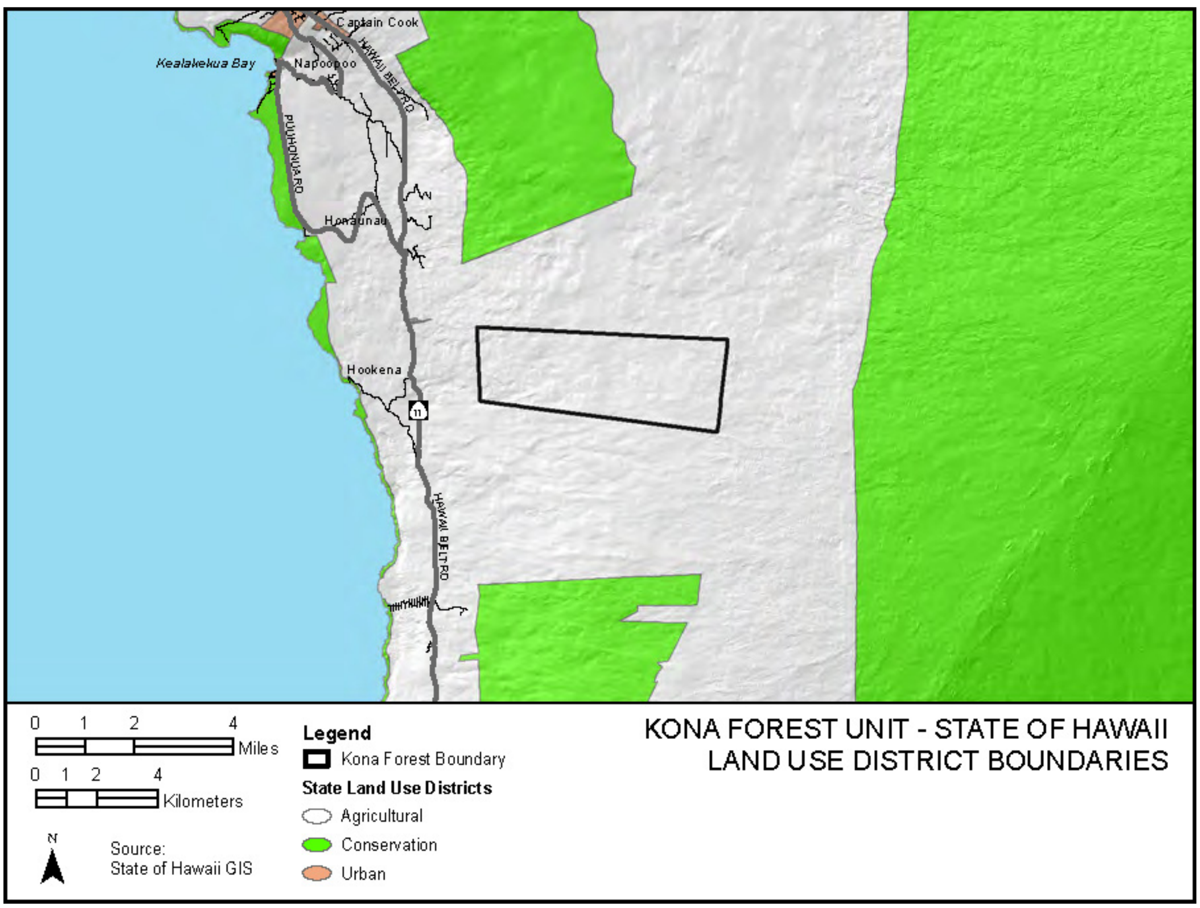
The KFU is situated in the District of South Kona on the leeward slope of Mauna Loa (Figure 1-1). It is located roughly 8 mi from the town of Captain Cook and 23 mi south of Kailua-Kona. Other communities in the vicinity of the Refuge are Kealakekua, Kainaliu, and Hōnaunau. The unit is accessed through a 17 ac permanent easement across private property. Keālia Ranch borders the property to the north and McCandless Ranch lies near the southern boundary.

The KFU of the Hakalau Forest NWR was purchased in 1997. Approximately 5,300 ac were acquired from the Kai Malino Ranch section (Les Marks Trust) of the former McCandless Ranch, a private cattle ranch. Two easements were purchased from the Les Marks Trust in March 2005. As part of the Hakalau Forest NWR, the KFU is administered and managed by the Refuge according to the Administration Act. According to the Final EA for the Proposed KFU of the Hakalau Forest

NWR (1997), the KFU was established "... to protect, conserve, and manage a portion of the native forest in south Kona, primarily for the benefit of the ʻalalā and other endangered and threatened species."

Until 2003, the Refuge maintained dedicated staffing and a local office across Māmalahoa Highway near the KFU; however, due to prolonged access disputes and pending resolution of legal issues, staffing was discontinued on the unit. The KFU is currently unstaffed and is managed from the Refuge complex office in Hilo, 2.5 hours away. Adjacent land uses in the vicinity include ranching, farming, residences, and ecotourism ventures. Keālia Ranch is located approximately 3 mi north of the KFU, and McCandless Ranch is found to the south of the Refuge. The KFU is 4 mi from the Waiea Transfer Station, managed by the County's Department of Environmental Management, Soil Waste Division. This station was selected as one of six sites prioritized for coqui frog control on the island due to its potential to threaten high-value resource areas (ISCs, AIS Team & CGAPS 2005). Various kuleana lands are present immediately outside the Refuge. Other land uses adjacent to the Refuge include Kalāhiki cemetery and Hoʻokena School. The South Kona Forest Reserve and Kīpāhoehoe Natural Area Reserve are to the south of the Refuge.

Figure 3-4. Land Use District Boundaries- Kona Forest Unit.



The South Kona District encompasses 146,685 ac. This district is primarily classified as Agricultural by the State of Hawaiʻi and zoned as Agricultural by Hawaiʻi County (County of Hawaiʻi 2007). The KFU is designated as Agricultural by the State of Hawaiʻi Land Use District Boundaries Map. Areas in the immediate vicinity are also classified as Agricultural (Figure 3.4). According to the ordinances from the County of Hawai‘i, the unit is zoned as Agricultural. The General Plan Land Use Pattern Allocation Guide Map shows the unit as a "Conservation Area." This land use is defined as "forest and water reserves, natural and scientific preserves, areas in active management for conservation purposes, areas to be kept in a largely natural state, with minimal facilities consistent with open space uses, such as picnic pavilions and comfort stations, and lands within the State Land Use Conservation District" (County of Hawai‘i 2006).

3.7 Global Climate Change

The Intergovernmental Panel on Climate Change (IPCC) recognizes that small island groups are particularly vulnerable to climate change. The following characteristics contribute to this vulnerability: small emergent land area compared to the large expanses of surrounding ocean; limited natural resources; high susceptibility to natural disasters; and inadequate funds to mitigate impacts (IPCC 2001). Thus, Hawai‘i is considered to have a limited capacity to adapt to future climate changes. The Pacific Islands Regional Integrated Science and Assessment program is working to develop tools dealing with climate risk management in the Pacific region. Furthermore, the Hawai‘i Climate Change Action Plan (1998) offered initial recommendations to reduce GHGs, and the Pacific Islands Climate Change Cooperative is developing a strategy to deal with climate change throughout the State.

Similar to the rest of the world, temperatures in Hawai‘i are rising. The EPA has estimated that the average surface temperature in Honolulu, Hawai‘i, has increased by 4.4°F over the last century (EPA 1998). In particular, nighttime temperatures are notably warmer, increasing by about 0.5°F per decade over the past 30 years (Arakawa 2008). Recent studies have shown that this rising average night temperature is greater at high elevation sites than lower areas (Giambelluca 2008). Sea surface temperature near the islands has been increasing recently, showing a 0.72°F rise between 1957 - 1987 (Giambelluca et al. 1996). Sea level around the Hawaiian Islands is rising by 6-14 in per century (EPA 1998). Over the last 90 years, precipitation has also decreased by approximately 20 percent (EPA 1998).

As a result of these shifts, Hawai‘i is developing means to reduce its GHG emissions. In 1990, it is estimated that 15,985,225 tons of carbon dioxide (CO_2) were emitted in Hawai‘i. Other major GHGs released that year include 75,736 tons of methane (CH_4) and 690 tons of nitrous oxide (N_2O). These estimates do not include fuels that were exported, used on international aircraft or ship operations, or used by the military in the State. International, military, and overseas CO_2 emissions were estimated to be 7,363,261 tons in 1990 (DBEDT and DOH 1998). In 2007, the State of Hawai‘i enacted Act 234, which set the goal to reduce GHG emissions to 1990 levels by 2020.

Global and regional predictive climate simulations may not capture unique and important features of the Hawaiian climate. Existing large-scale models show large variability and uncertainty for the Hawaiian Islands; thus, applying these models to predict local conditions must be done with caution until more fine-scaled models are developed (Timm 2008). Models from the IPCC and the climate model of the United Kingdom's Hadley Centre suggest that by 2100 annual temperatures in Hawai‘i could increase by 3°F, with a slightly higher increase in fall. Other estimates predict a 5 - 9°F rise by the end of the 21st century (TenBruggencate 2007). Future changes in precipitation are uncertain, dependent largely on shifts in El Niño/La Niña events. Some predictions forecast an additional rise of 17-25 inches by 2100 (EPA 1998), while others suggest decreased precipitation.

Climate Change Effects on Water Resources

The impact of climate change on water resources is dependent on shifts in precipitation amounts, evaporation rates, storms, and events such as the El Niño Southern Oscillation (ENSO). The ENSO is an ocean-atmosphere phenomenon in which the normal oceanic and atmospheric circulation patterns of the Pacific Ocean temporarily collapse. During normal years, strong tradewinds move counterclockwise in the southern hemisphere and clockwise in the northern hemisphere, causing surface water to move westward. These winds also produce upwelling that brings high nutrient waters to the surface. During an ENSO event, tradewinds in the western Pacific stop and the warm mass of water in the west moves eastward, causing shifts in the location of evaporation. As a result, heavy rains occur in normally dry areas such as the central Pacific islands. In addition to more precipitation, these winds upwell warm water, which is devoid of nutrients. This causes productive communities to collapse and subsequent death of fish and birds (Duffy 1993).

Although ENSO events have increased in intensity and frequency over the past decades, some longer-term records have not found a direct link to global warming (Cobb et al. 2003) and do not predict significant changes in ENSO; however, a majority of climate forecasts do suggest an evolution toward more “El Niño-like” patterns (Buddemeier et al. 2004). Most climate projections reveal that this trend is likely to increase rapidly in the next 50 years (Walther et al. 2002). However, other models predict more “La Niña-like” conditions in the Hawaiian Islands (Timm 2008).

A trend toward ENSO patterns will impact sea levels, sea temperatures, rainfall amounts, evaporation rates, and the occurrence of hurricanes; however, the exact impact of climate change on water resources is difficult to predict due to spatial variability. On a global scale, mean precipitation is anticipated to increase. Current climate models project that tropical Pacific and high-latitude areas will experience increasing precipitation amounts, while precipitation is likely to decrease in most subtropical regions (Parry et al. 2007; Solomon et al. 2007). A current trend toward this increase is supported by lowered salinity levels in both the mid- and high-latitude oceanic waters (Solomon et al. 2007). If the opposite effect takes place, decreasing precipitation or increasing evaporation will further stress meager surface and groundwater resources. Lack of rain could lower the amount of freshwater lens recharge and decrease available water supplies. Reduced rainfall or increased evaporation will cause a corresponding increase in the demand for residential, commercial, or agricultural water (Giambelluca et al. 1996).

Most climate projections suggest that more intense wind speeds and precipitation amounts will accompany more frequent tropical typhoons/cyclones and increased tropical sea surface temperatures in the next 50 years (Solomon et al. 2007; Walther et al. 2002). The Third Assessment of the IPCC (2001) has concluded with “moderate confidence” that the intensity of tropical cyclones is likely to increase by 10-20 percent in the Pacific region when atmospheric levels of CO_2 reach double preindustrial levels (McCarthy et al. 2001). One model projects a doubling of the frequency of 4 in per day rainfall events and a 15-18 percent increase in rainfall intensity over large areas of the Pacific (IPCC 2001). Solomon et al. (2007) states that it is “more likely than not” that the rise in intense tropical cyclones is due to anthropogenic activity.

An increase in heavy storms and surf will result in increased flood risks, sedimentation, and impeded drainage in Hawaiʻi (DBEDT and DOH 1998). Change in rainfall patterns will affect the success of forest restoration as well as existing protected habitats and stream resources (e.g., may cause movement of or degradation of these resources). In particular, the low-elevation Refuge areas will be vulnerable to changes in storm frequency, intensity, and directionality. These events have the potential to denude vegetation and impact habitat for wildlife and plants.

Ecological Responses to Climate Change

Evidence suggests that recent climatic changes have affected a broad range of individual species and populations in both the marine and terrestrial environment. Organisms have responded by changes in (1) phenology (timing of seasonal activities) and physiology; (2) range and distribution; (3) community composition and interaction; and (4) ecosystem structure and dynamics (Walther et al. 2002). The reproductive physiology and population dynamics of amphibians and reptiles are highly influenced by environmental conditions such as temperature and humidity. For example, sea turtle sex is determined by the temperature of the nest environment; thus, higher temperatures could result in a higher female to male ratio (Baker et al. 2006). In addition, increases in atmospheric temperatures during seabird nesting seasons will also have an effect on seabirds and water birds (Duffy 1993).

Warming has also caused species to shift toward the poles or higher altitudes and changes in climatic conditions can alter community composition. For example, increases in nitrogen availability can favor those plant species that respond to nitrogen rises (Vitousek 1994). Similarly, increases in CO_2 levels can impact plant photosynthetic rates, decrease nutrient levels, and lower herbivore weights (Ehleringer et al. 2002). Although there is uncertainty regarding these trajectories, it is probable that there will be ecological consequences (Walther et al. 2002).

Climate change has the potential to influence two important ecological issues in the State of Hawaiʻi: endangered species and invasive species. An overwhelming majority of U.S. endangered species are found in the State of Hawaiʻi. Species declines have resulted from habitat loss, introduced diseases, and impacts from invasive species. Changes in climate will add an additional threat to the survival of these species (DBEDT and DOH 1998). For example, warmer night temperatures can increase the rate of respiration for native vegetation, resulting in greater competition from nonnative plants (Giambelluca 2008). Of particular concern are native forest birds. Climate change may raise the elevational gradient in which mosquitoes can live. Consequently, current elevations free of mosquitoes (which protect native forest birds that do not have resistance to avian diseases carried by mosquitoes) may disappear, leaving forest birds with no mosquito safe habitats.

Furthermore, climate change may enhance existing invasive species issues because alterations in the environment may increase the dispersal ability of flora or fauna. Species response to climate change will depend on the life cycle, distribution, dispersal ability, and reproduction requirements of the species (Middleton 2006). However, for invasive weed species on Hawaiʻi Island, climate change may increase their range and expansion into native habitats. In addition to degrading native habitat, a more concerning result of this effect may be increased wildfires as many of these invasive species have evolved with fire and require fire for their life-history. This issue is of particular concern for the drier Kona side where the KFU is located. Such an increase in fuel loads would be detrimental to forest habitats and the species dependent on them.

The Service is supporting the development of regional Landscape Conservation Cooperatives that will integrate local climate models with models of climate change responses by species, habitats, and ecosystems. Cooperatives will collectively plan and design appropriate conservation actions at a landscape scale, monitor responses to climate change, and assess the effectiveness of management strategies. The regional version of these Landscape Conservation Cooperatives is the Pacific Islands Climate Change Cooperative (PICCC), headquartered in Honolulu, Hawai'i, but working across the Pacific. By working with PICCC, the Refuge will identify additional mitigation measures for climate change.

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Chapter 4. Refuge Biology and Habitats

Above: ‘Alalā/USFWS
Left: *Cyanea shipmanii*/Barry Stieglitz

‘Akiapōlā‘au/Jack Jeffrey Photography

Chapter 4. Refuge Biology and Habitats

This chapter addresses the biological resources and habitats found on Hakalau Forest National Wildlife Refuge. The chapter begins with a discussion of biological integrity and moves on to focus on the presentation of pertinent background information for each of the conservation targets designated under the CCP. Background information includes a description, location, condition, and trends associated with wildlife or habitats, key ecological attributes, and stresses and sources of stress (collectively, "threats") to the target. The information presented was used as the CCP team developed goals and objectives for each of the conservation targets.

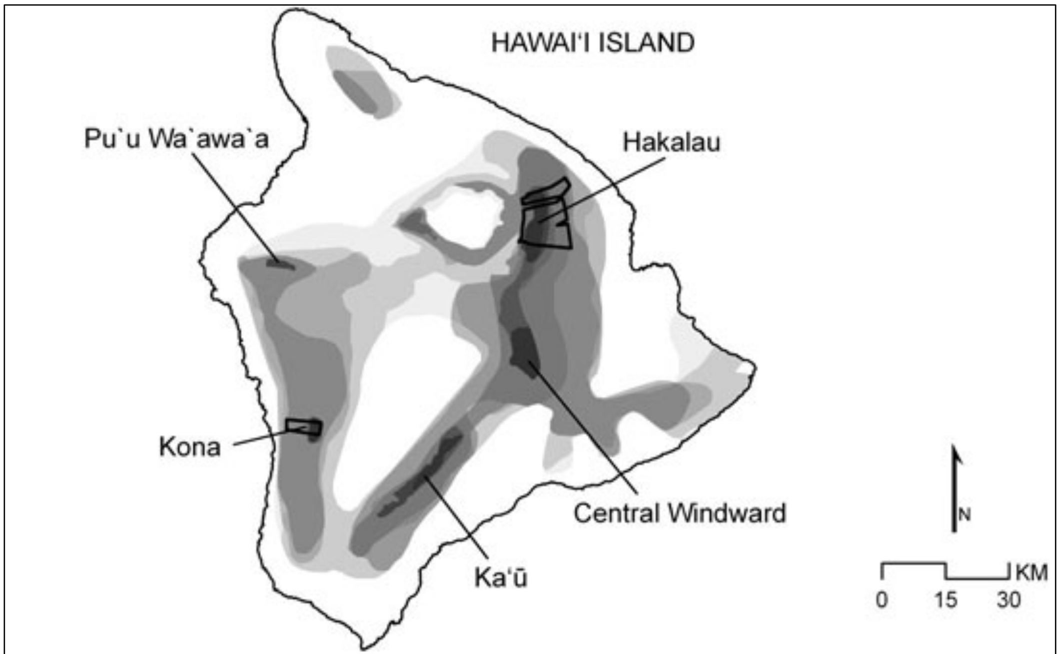
4.1 Biological Integrity Analysis

The National Wildlife Refuge System Improvement Act of 1997 (amendment to the Administration Act) directs the Service to ensure that the biological integrity, diversity, and environmental health (BIDEH) of the Refuge System are maintained for the benefit of present and future generations of Americans. Elements of BIDEH are represented by native fish, wildlife, plants, and their habitats as well as those ecological processes that support them. The Service"s policy 601 FW 3 also provides guidance on consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges, and associated ecosystems that represent BIDEH on each refuge.

The Refuge is adjacent to the Hilo Forest Reserve and Laupāhoehoe Natural Area Reserve (both State-owned and managed areas by the Division of Forestry and Wildlife), as well as State-owned and managed lands by the Department of Hawaiian Home Lands above the upper elevation (Figure 1-1). The Refuge"s lower elevation boundary lines are adjacent to private properties. The majority of DOFAW lands are forested and range from intact native forest to more degraded (nonnative) forest. Both DHHL land and some private lands are grazed completely with little to no forest, while other private lands (particularly the lower boundary in the southeastern corner) are heavily forested with native species. Of particular note is the section of the Hilo Forest Reserve that bisects the HFU. This State parcel is also a game management area. Differing land uses by these adjacent landowners can impact Refuge lands via invasive species, feral ungulates, and mammalian predator encroachment.

The Refuge includes various native forest habitat types as well as subterranean habitats such as lava tubes and skylights. The HFU has intermittent streams as well. However, due to former land use practices (e.g., cattle ranching, logging, and sheep grazing), areas of the Refuge in both units have nonnative habitats that are composed of grasses and invasive weeds. Such areas at HFU are actively being restored through outplantings of native plants in order to regenerate the native forest habitats. The HFU in particular is a shining example of an area that gives hope to the perpetuation of native forest bird species. A study by the USGS-BRD (Figure 4-1) indicates many of the native forest bird species are stable or increasing at Hakalau Forest NWR, which is a stark contrast to the other areas included in the survey. This finding supports continuing the forest restoration activities undertaken by Refuge staff during the past 25 years.

Figure 4-1. Native forest bird trends on Hawai‘i Island.



	Hakalau Forest NWR	Central Windward	Ka‘ū	Kona Forest Unit HFNWR	Pu`u Wa`awa`a Wildlife Sanctuary
‘Elepaio	▲	▼?	▼?	▼?	▼?
‘Ōma‘o	S or ▲	▼?	S	X	X
Hawai‘i ‘Amakihi	S	S	S	▲?	▲?
‘Akiapōlā‘au	▲	▼?	▼?	X	X
Hawai‘i Creeper	▲	?	▼	X	▼
Hawai‘i ‘Ākepa	S or ▲	▼?	▼	▼	▼
‘I‘iwi	S	S	▼?	▼?	▼?
‘Apapane	S	▲?	▲	▲	S?

S=Stable; triangles indicate upward or downward trends. Source: Camp et al. 2010.

The biological integrity of the area is high relative to much of the Island of Hawai„i. The conservation targets and focal habitats were chosen specifically as an attempt to return this portion of the landscape to its natural state. The greatest challenges are threats from nonnative species: plants, ungulates, and mammalian predators as well as diseases such as avian malaria.

4.2 Conservation Target Selection and Analysis

Early in the planning process, the CCP team cooperatively identified priority species, groups, and communities for this Refuge, as recommended under the Refuge System‟s Habitat Management Planning policy (620 FW1). These priorities, called conservation targets, frame the CCP actions for wildlife and habitat. The conservation targets are species, species groups, or communities that the Refuge will actively manage to conserve and restore over the life of the CCP. Potential management actions will be evaluated on their effectiveness in achieving Refuge goals and objectives for the conservation targets. Additionally, management of these species and habitats will also benefit and support many other native species that are present on the Refuge. Negative features of the landscape, such as invasive plants, may demand a large part of the Refuge management effort, but are not designated as conservation targets. Through the consideration of the BIDEH, the Refuge will provide for or maintain all appropriate native habitats and species. These species and habitats can be found in Appendix F.

Table 4-1. Refuge Conservation Targets.

Species, Species Group, or Habitat	Hawaiian Name, Common Name	Supporting Habitat Type(s) and/or Specie(s)	Life-History Requirement(s)
Birds*			
Anas wyvilliana	Koloa maoli, Hawaiian duck	Riparian corridors, ponds	Foraging, nesting, loafing, feeding, roosting, all life-history requirements
Branta sandvicensis	Nēnē, Hawaiian goose	Grasslands, ponds	Foraging, nesting, loafing, feeding, all life-history requirements except roosting
Fulica alai	„Alae ke„oke„o, Hawaiian coot	Ponds	Foraging, loafing
Buteo solitarius	„Io, Hawaiian hawk	Montane wet „ōhi„a, and mesic and dry koa/„ōhi„aforest, Montane wet „ōhi„a/*Dicranopteris* sp. forest grasslands	Foraging, nesting, roosting, feeding, all life-history requirements
Corvus hawaiiensis	„Alalā, Hawaiian crow	Montane wet „ōhi„a and mesic koa/„ōhi„aforest, Montane mesic koa forest, Montane dry koa/„ōhi„a/māmane forest	Feeding, nesting, breeding, roosting. All life-history requirements
Psittirostra psittacea	„Ō„ū	Montane wet „ōhi„a and mesic koa/„ōhi„aforest	Feeding, nesting, breeding, roosting. All life-history requirements
Hemignathus munroi	„Akiapōlā„au	Montane wet „ōhi„a and mesic koa/ „ōhi„aforest, Montane dry koa/„ōhi„a/māmane forest	Feeding, nesting, breeding, roosting. All life-history requirements
Oreomystis mana	Hawai„i creeper	Montane wet „ōhi„a and mesic koa/„ōhi„aforest, Montane dry koa/„ōhi„a/māmane forest	Feeding, nesting, breeding, roosting. All life-history requirements
Loxops c. coccineus	Hawai„i „ākepa	Montane wet „ōhi„a forest and mesic koa/„ōhi„aforest, Montane dry koa/„ōhi„a/māmane forest	Feeding, nesting, breeding, roosting. All life-history requirements
Mammal			
Lasiurus cinereus semotus	„Ōpe„ape„a, Hawaiian hoary bat	Montane wet „ōhi„a and mesic koa/„ōhi„aforest, grasslands, Montane dry koa/„ōhi„a/māmane forest	Foraging, birthing, breeding, all life-history requirements

Species, Species Group, or Habitat	Hawaiian Name, Common Name	Supporting Habitat Type(s) and/or Specie(s)	Life-History Requirement(s)
Invertebrate			
Drosophila heteroneura	Picture-wing fly	Montane wet „ōhi„a and mesic koa/„ōhi„aforest [4]	All life-history requirements
Habitats**			
Montane wet „ōhi„a/ *Dicranopteris* sp. forest	N/A	Native forest birds	All life-history requirements
Montane wet „ōhi„a forest	N/A	Native forest birds	All life-history requirements
Montane wet koa/„ōhi„aforest	N/A	Native forest birds	All life-history requirements
Montane mesic koa/„ōhi„aforest	N/A	Native forest birds	All life-history requirements
Montane mesic koa forest	N/A	Native forest birds	All life-history requirements
Dry koa/„ōhi„a /māmane forest	N/A	Native forest birds	All life-history requirements
Lava tubes and skylights	N/A	Invertebrates	All life-history requirements
Aquatic habitats (e.g., intermittent streams and ponds)	N/A	Invertebrates and waterbirds	All life-history requirements
Carex bogs	N/A	Invertebrates, koloa maoli	All life-history requirements
Grasslands	N/A	Nēnē	All life-history requirements
Plants***			
Asplenium peruvianum var. *insulare*	No common name	Montane wet „ōhi„a and mesic koa/„ōhi„aforest	n/a
Clermontia lindseyana	„Oha wai	Wet „ōhi„a and mesic koa/„ōhi„a forest[5]	n/a
Clermontia peleana	„Oha wai	Montane wet „ōhi„a forest[5]	n/a
Clermontia pyrularia	„Oha wai	Montane wet „ōhi„a and mesic koa/„ōhi„aforest[5]	n/a
Cyanea hamatiflora[2]	Hāhā	Montane wet „ōhi„a and mesic koa/„ōhi„aforest[4]	n/a
Cyanea platyphylla[2]	„Aku„aku	Montane wet „ōhi„a forest[5]	n/a
Cyanea shipmannii	Hāhā	Montane wet „ōhi„a and mesic koa/„ōhi„aforest[5]	n/a
Cyanea stictophylla	Hāhā	Montane wet „ōhi„a and mesic koa/„ōhi„aforest	n/a
Cyrtandra tintinabula	Ha„iwale	Wet koa/„ōhi„a forest[5]	n/a
Nothocestrum breviflorum[3]	„Aiea	Montane wet „ōhi„a and mesic koa/„ōhi„aforest	n/a
Phyllostegia floribunda[1]	No common name	Wet koa/„ōhi„a forest	n/a

Species, Species Group, or Habitat	Hawaiian Name, Common Name	Supporting Habitat Type(s) and/or Specie(s)	Life-History Requirement(s)
Phyllostegia racemosa	No common name	Montane wet „ōhi„a and mesic koa/„ōhi„aforest[5]	n/a
Phyllostegia velutina	No common name	Montane wet „ōhi„a and mesic koa/„ōhi„aforest [5]	n/a
Portulaca sclerocarpa[3]	Po„e	Dry koa/„ōhi„a/māmane forest	n/a
Sicyos macrophyllus	„Anunu	Montane wet „ōhi„a forest, mesic koa/„ōhi„aforest	n/a
Silene hawaiiensis[1]	No common name	Dry koa/„ōhi„a/māmane forest	n/a

Notes:
* Species appear in taxonomic order.
** Habitat types follow Jacobi et al. (1989).
*** Species appear in alphabetical order.
[1] Specimen found on Refuge currently pending verification.
[2] No individuals are known from the Refuge.
[3] Plants known from adjacent area but not currently known from Kona Forest Unit.
[4] Critical habitat has been designated for these species at Kona Forest Unit.
[5] Critical habitat has been designated for these species at Hakalau Forest Unit.

4.3 Habitats

Both the HFU and KFU are montane communities located between 1,640-8,900 ft. This community type is further divided based on annual rainfall; montane dry communities receive less than 48 in per year, montane mesic communities receive between 48-100 inches of rainfall per year, and montane wet communities are defined as areas receiving more than 100 inches annually (Wagner et al. 1999). These plant communities are then defined based on the vegetation cover. For example, a community that has greater than 25 percent of the upper vegetation layer covered by trees is defined as a forest (Wagner et al. 1999).

On the Island of Hawai„i, montane forests have been severely altered by a variety of factors, including land use changes and invasive species introductions. In particular, introduced mosquitoes transmit avian diseases that have resulted in declines in native bird populations and ungulates have removed native plant species. Conservation and restoration efforts are needed to improve habitat conditions at both units of the Hakalau Forest NWR.

4.3.1 Hakalau Forest Unit

The habitats at the HFU are defined according to gradients of elevation, temperature, and rainfall. In addition topography, soils, and geological substrate play a role in influencing these zones. The montane habitats at HFU have been transformed by years of cattle ranching and logging, creating isolated areas of relatively undisturbed forest and highly modified open woodland (VanderWerf 1993). The native species dominated habitats within the HFU are described below, from lowest to highest elevation as well as several nonnative species dominated communities, including stands of eucalyptus and sugi pines, as well as former pasture lands that are still dominated by nonnative grass species. Figure 4-2 shows the main vegetation types found on the HFU.

Montane wet ‘ōhi‘a/uluhe forest, including *Carex* bogs

This habitat type is found between 2,500-4,000 ft in elevation. The topography of the montane wet „ōhi„a/uluhe forest is gently sloping; however, numerous steep-sided streams bisect the surface. The volcanic soils are aged, eroded, and typically poorly drained (USFWS, unpubl.).

The upper canopy of this habitat type is composed of scattered mature „ōhi„a (over 100 years old), as well as medium stature „ōhi„a approximately 30 ft in height. The midcanopy zone, between 10-15 ft, is dominated by hāpu„u. The ground cover is composed mostly of dense mats of uluhe that make access difficult. Numerous native *Carex* bogs can be found scattered throughout the lower elevations of this habitat. These bogs occur naturally in flat areas where a limited amount of open water is retained in a clay-layered depression. Sphagnum moss also exists in these bogs. The bogs at the HFU range from 8-12 ft deep (Tomonari-Tuggle 1996).

The steep topography of the montane wet „ōhi„a/uluhe forest provides protection for native and endangered plants from grazing ungulates. For example, the bogs are used by rare invertebrates and possibly the koloa maoli (USFWS, unpubl.).

Although endangered flora and fauna do occur in this habitat type, the montane wet „ōhi„a/ uluhe forest in the HFU is the most exposed to invasive species from lower elevations. Limiting factors in the montane wet „ōhi„a/uluhe forest include invasive species such as ungulates, rats, mice, slugs, mosquitoes, and nonnative plants. In particular, native bird densities are curbed by avian diseases, which are transmitted by mosquitoes that are able to breed up to 4,500 ft in elevation. Native plant and invertebrate diversity is also assumed to be low and native pollinators are lacking. Eutrophication and elimination of *Carex* bogs is occurring due to pig activity. As a result, the bogs are primarily invaded by nonnative rushes. Limited historical and current anthropogenic disturbance occurs within the montane wet „ōhi„a/uluhe forest (USFWS, unpubl.).

Montane wet ‘ōhi‘a forest

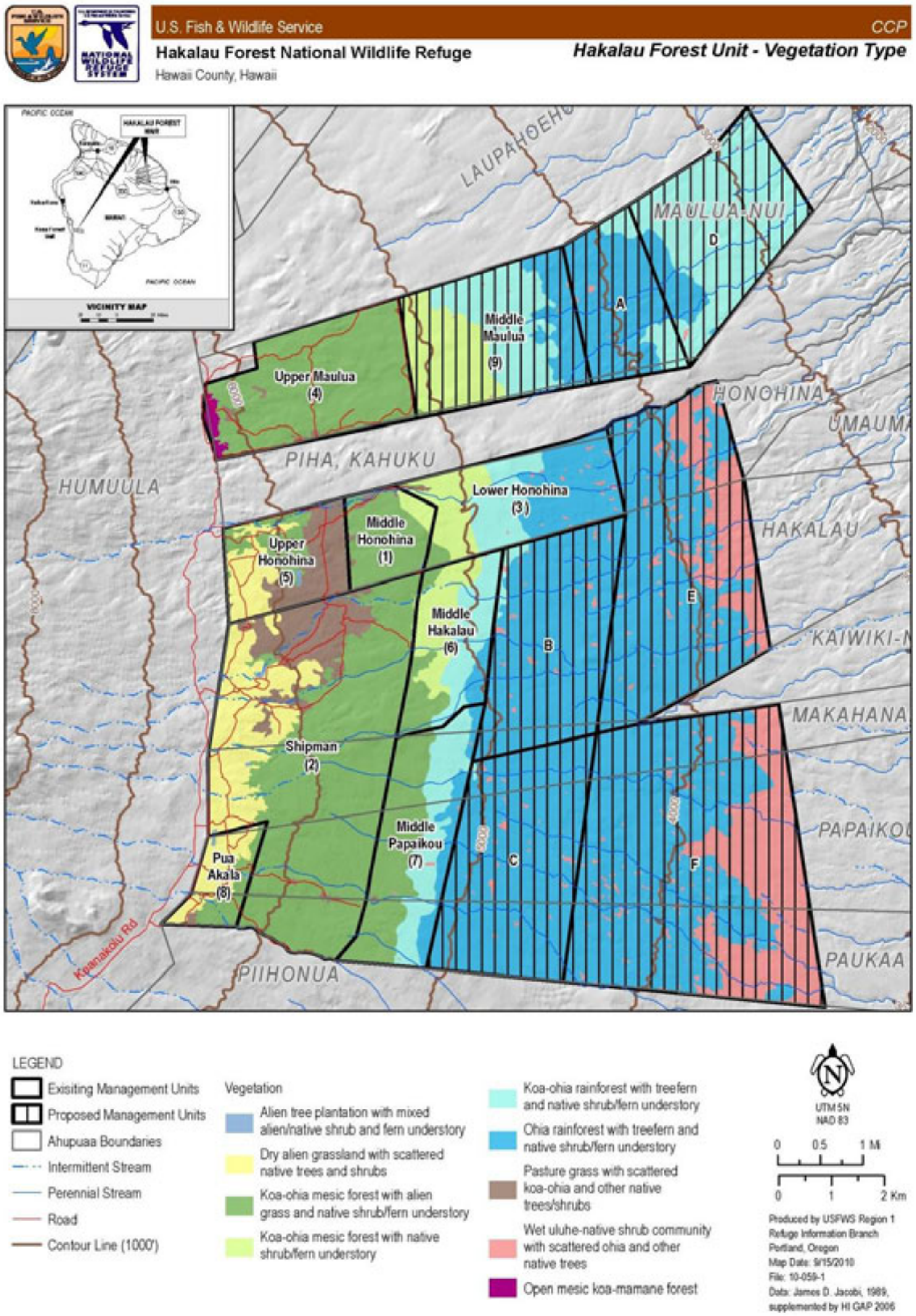
This habitat type is found upslope of the montane wet „ōhi„a/uluhe forest, between 4,000-5,000 ft. The montane wet „ōhi„a forest within the HFU maintains a more diverse plant and native bird community than the lower elevation habitat due to the location above the mosquito zone (USFWS, unpubl.).

The upper canopy of the wet „ōhi„a forest is dominated by a mature closed canopy of „ōhi„a that reach 60-90 ft. Midcanopy species include „ōhi„a, „ōlapa, pilo, kōlea, epiphytes, and tree ferns reaching up to 15 ft. The ground cover is dominated by mixed ferns, *Astelia* lilies, „ōhelo, kanawao, pūkiawe, and kāwa„u. Downed timber and sphagnum moss are also dominant in this habitat at the ground level. Slopes are moderate (USFWS, unpubl.).

Rare native forest birds, such as the „akiapōlā„au, Hawai„i creeper, and Hawai„i „ākepa, are found in montane wet „ōhi„a forest at the HFU. The area also provides potential habitat for *Clermontia peleana* subsp. *peleana* and other rare native plants.

Similar to the montane wet „ōhi„a/uluhe forest, invasive species and lack of native pollinators are also a problem within the montane wet „ōhi„a forest (USFWS, unpubl.).

Figure 4-2. HFU vegetation type.



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Montane wet koa/ ‘ōhi‘a forest

Located between 5,000-6,000 ft, the montane wet koa/„ōhi„aforest habitat type is comprised of mixed age class koa and „ōhi„a. Various flowering and fruiting trees can be found at the midcanopy level including: „ākala, „ōlapa, pilo, pūkiawe, „ōhelo, kōlea, kāwa„u. Mixed ferns and epiphytes can also occur in the midcanopy. The ground cover in the montane wet koa/„ōhi„a forest is dominated by fern species such as *Dryopterus* sp. (Tomonari-Tuggle 1996). Slopes in this habitat are moderate.

A diverse assemblage of native and endangered plants and animals occurs in this habitat type. This includes the koloa maoli and the „ōpe„ape„a (USFWS, unpubl.).

In addition to habitat threats present in other areas of the HFU, the montane wet koa/„ōhi„a forest has been exposed to greater human disturbance, especially cattle grazing. Areas previously forested in koa and „ōhi„a that have been exposed to browsing have largely been converted to grasslands, suggesting that the habitat type cannot tolerate this land use (Stine 1985, Tomonari-Tuggle 1996).

Montane mesic koa forest

The montane mesic koa forest habitat type can be found at the highest elevation of the unit between 6,000 - 6,600 ft. Koa is the dominant vegetation cover in this area and the trees are mixed ages. Characteristic midcanopy species within this forest include „ōlapa, „ākala, pilo, pūkiawe, „ōhelo, kōlea, kāwa„u, ferns, and epiphytes.

A low concentration of native forest birds currently occurs in this habitat. Nēnē are found throughout the habitat. This habitat preference is likely biased since captive-bred birds are released in this area. „Ōpe„ape„aand the „io have been recorded in the montane mesic koa forest. Various native and endangered plants and a single native grass, *Deschampsia nubigena*, are also present here.

This forest shares similar threats as other habitats within the HFU. The historical area of mesic koa forest was reduced to nonnative grassland by grazing, timber harvest, and fires; however, the Refuge is working to restore this habitat by outplanting native species. Nonnative grasses include various species of *Anthoxanthum*, *Holcus*, *Pennisetum*, and *Ehrharta*.

Aquatic habitats (streams, ponds, *Carex* bogs)

Several streams are located within the HFU. Streams start as intermittent in higher elevations and for some become perennial at lower elevations of the Refuge (Figure 4-2). Some streams are found in gulches or with steep walls, thereby providing better protection for endangered and native plants from grazing by ungulates. Fauna within the streams are unknown and unstudied, but invertebrates are believed to be the main users of this habitat. Threats to these habitats include gorse, which can displace native riparian vegetation, and ungulates and rats, which can affect water quality through soil disturbance and feces deposition.

The Refuge also has manmade and semipermanent natural ponds. These habitats are seasonal and the manmade ponds will not be maintained by Refuge staff as they have transitioned to *Carex* and *Juncus* vegetation, which can be used by koloa maoli.

Carex bog habitat is discussed previously under montane wet „ōhi„a/uluhe forest.

Grasslands

Grasslands for nēnē foraging are created as part of the maintenance of fuel breaks (50 acres) as well as an existing 15-acre site (for nesting) maintained near the administrative site at Hakalau cabin. Currently these grasslands are a combination of native and nonnative grasses. Nēnē typically use mid- to high-elevation native and nonnative shrubland and early successional grasslands, native alpine grasslands and shrublands, and open native and nonnative alpine shrubland-woodland community interfaces. Threats to this habitat type are wildfire.

4.3.2 Kona Forest Unit

The habitat types within the KFU are influenced by rainfall, elevation, and historical volcanism. In addition, human activities such as logging and cattle ranching have impacted the wet, mesic, and dry habitat types throughout the KFU (Figure 4-3). As in the HFU, former pasture land, dominated by nonnative grasses, as well as a large section of lowland wet/mesic forest dominated by nonnative tree and shrub species (e.g., Christmas berry and strawberry guava species) are found within the KFU.

Montane wet ʻōhiʻa forest

The montane wet „ōhi„aforest occurs in two elevational bands: a lower gradient between 2,000-3,000 ft and an upper gradient between 3,500-4,500 ft. Both the lower and upper gradients have an upper tree canopy that is dominated by a closed canopy of mature „ōhi„a The canopy is between 60-80 ft high.

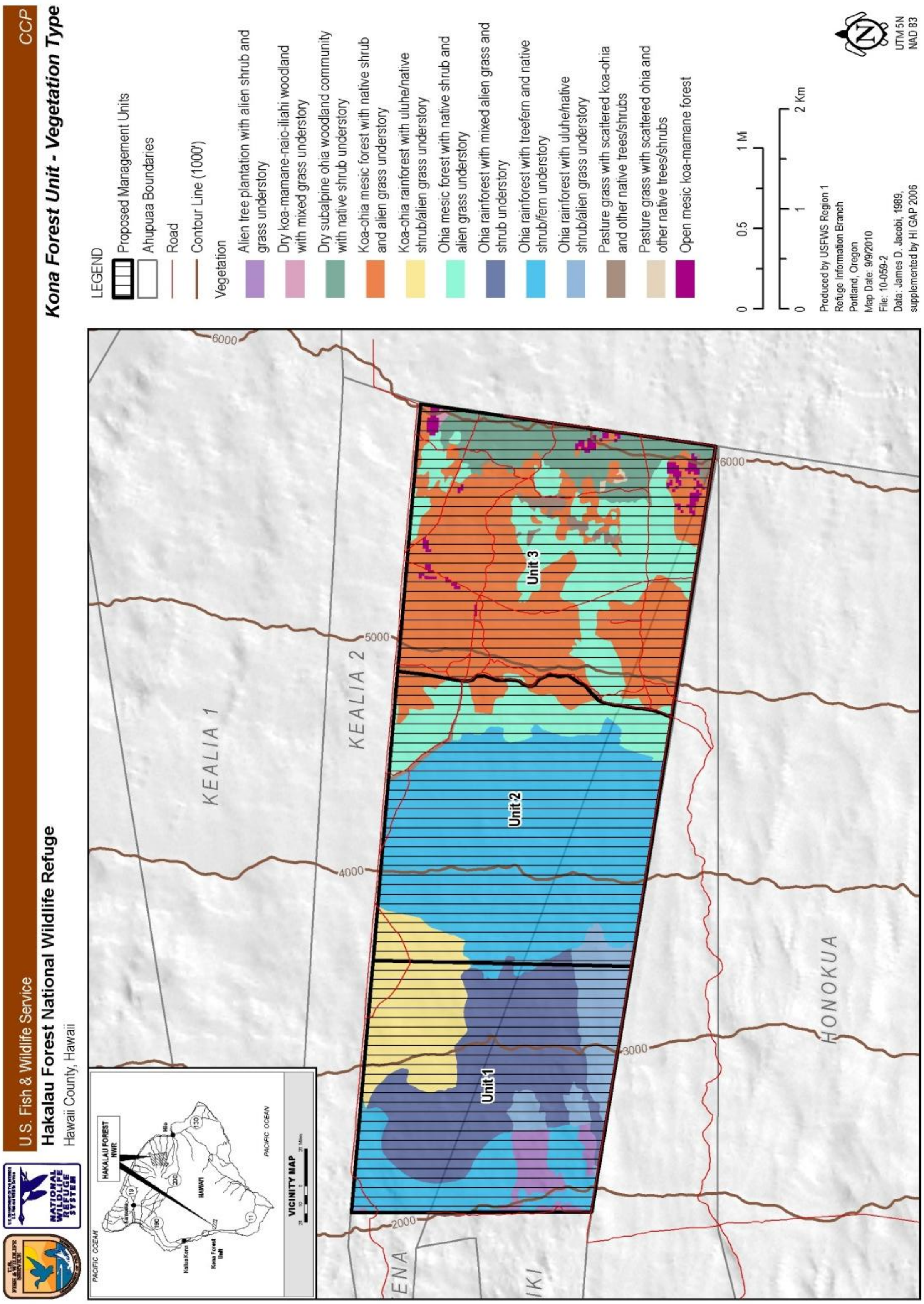
In the lower gradient, midcanopy species include a mix of introduced species such as Christmas berry and strawberry guava, as well as the native hame, „ie„ie, kōlea, hāpu„u, „ōhi„a, and various epiphytes. The groundcover in the lower gradient is dominated by introduced Koster‟s curse and thimbleberry, as well as a mix of introduced and native ferns. In the upper gradient, the midcanopy contains „ōhi„a, pilo, C*lermontia* sp., „ōlapa, kāwa„u, kōlea, pūkiawe, hāpu„u, „ie„ie, and epiphytes. Ferns (both introduced and native species) and introduced grasses are the primary groundcover.

There are three primary differences between the upper and lower elevation gradients in montane wet „ōhi„a forest habitat type at the KFU. Compared to the lower gradient, the upper gradient has higher plant diversity in the midcanopy. The ground cover in the upper canopy is dominated by grasses, while the ground cover in the lower gradient is mostly herbaceous. In addition, the lower elevation gradient of this habitat type receives more rainfall annually than the upper gradient.

As a result of the lack of mosquitoes and increased plant diversity, the upper gradient of this habitat type supports a diverse native bird community. The „ōpe„ape„a and various endangered plants also occur in these areas.

Invasive species, such as ungulates, rats, mice, slugs, mosquitoes, and plants, threaten the montane wet „ōhi„aforest at the KFU. In addition, plants are limited due to a lack of native pollinators. Farming, ranching, and fires have also affected the native landscape, transforming native forests into grasslands.

Figure 4-3. KFU vegetation type.



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Montane mesic koa/‘ōhi‘a forest

The habitat between 4,500-5,800 ft is defined as a montane mesic koa/„ōhi„aforest. It is primarily composed of mixed age trees of both species. The midcanopy is dominated by a mix of flowering and fruiting trees such as *Clermontia* sp., pilo, pūkiawe, „ōhelo, kōlea, kāwa„u. Tree ferns, mixed ferns, and epiphytes also occur in the understory.

The mesic koa/„ōhi„aforest is potential habitat for several endangered species, such as the „alalā, „ōpe„ape„a, picture-wing flies, and various plants. It also provides foraging and nesting areas for native forest birds.

Wildfires are a serious threat to the mesic forests above 5,000 ft in elevation due to nonnative grass fuel. The montane mesic koa/„ōhi„a forest is threatened by ungulates. Sheep, which do not exist in the wet „ōhi„a forest, exist in the montane mesic koa/„ōhi„a forest above 5,000 ft. A lack of native pollinators also threatens this habitat.

Native dry koa/‘ōhi‘a/māmane forest

This native dry koa/„ōhi„a/māmane forest is located at the upper elevation of the KFU between 5,800-6,100 ft. Abandoned pastures, skid trails, and mill sites are present in this zone.

The upper canopy of this forest is composed of koa, „ōhi„a, and māmane, while the understory consists of iliahi, kukainene, naio, pilo, pūkiawe, „ōhelo, and mixed ferns.

The dry koa/„ōhi„a/māmane forest is potential habitat for the „alalā, „ōpe„ape„a, endangered plants, and endangered invertebrates. Native forest birds (such as „akiapōlā„au, Hawai„i „ākepa, and Hawai„i creeper) are also found in this habitat.

This forest shares similar threats as other habitats within the Refuge, such as invasive species and lack of native pollinators.

Lava tube and lave tube skylight

Lava tubes are subterranean channels that were created by flowing molten lava, particularly pahoehoe lava. This type of basaltic lava is warmer, faster moving and less viscous than „a„ā lava (Howarth 1973). Because pahoehoe lava does not fuse with the existing surface, extensive horizontal spaces and vesicle-like channels develop. When the surface crust of a lava flow cools, the underlying flow is insulated, allowing it to travel for many miles without losing its heat energy. As the volcanic eruption ceases, the molten lava drains from the channel, leaving an empty passage or lava tube. In Hawai„i, tubes formed in pahoehoe lava can reach up to 40.7 ft in length (Howarth 1983, Kauahikaua et al. 2004).

Sections of lava tube roofs often collapse naturally creating skylights, which are vertical-walled openings. Typically, skylights form on sloped terrain shortly after lava tube formation (Kauahikaua et al. 2004). Skylights are exposed to the surface environment of rainfall, sunlight, and temperature fluctuations. Due to the steep walls, skylights also serve as natural refugia where endangered or rare plants can persist without being damaged by herbivores (USFWS, unpubl.).

Moist air, relatively constant moderate temperature, and lack of light are attributes of these cave systems. In general, lave tubes can be divided into four zones – entrance, twilight, transition, and true dark. The entrance zone is the opening of the lava tube and is generally rich in resources. Green vegetation lessens in the twilight zone where light is reduced. In the transition zone, no light is present, but surface environmental conditions are not absent. Finally, the true dark zone is characterized by constant darkness and has steady environmental conditions (Howarth 1973).

4.4 Endangered Hawaiian Forest Birds

Over two-thirds of the remaining native forest birds in Hawai„i are federally listed under the ESA. The isolation of the Hawaiian Islands has contributed both to the endemism of the forest birds and to their potential for endangerment. Isolation has made them particularly vulnerable to diseases such as avian malaria and pox, one of the most critical threats to native forest birds. The endangered species present in Hakalau Forest NWR include three families of birds: Fringillidae (honeycreepers), Corvidae (crows) and Accipitridae (hawks). The majority are Hawaiian honeycreepers (Fringillidae: Drepanidinae) and include the „akiapōlā„au, Hawai„i „ākepa, Hawai„i creeper, and „ō„ū. The „alalā and „io are the two other species of concern. All species are endemic to the Island of Hawai„i, with the exception of the „ō„ū, which formerly occurred on all the main Hawaiian Islands but may now be extinct.

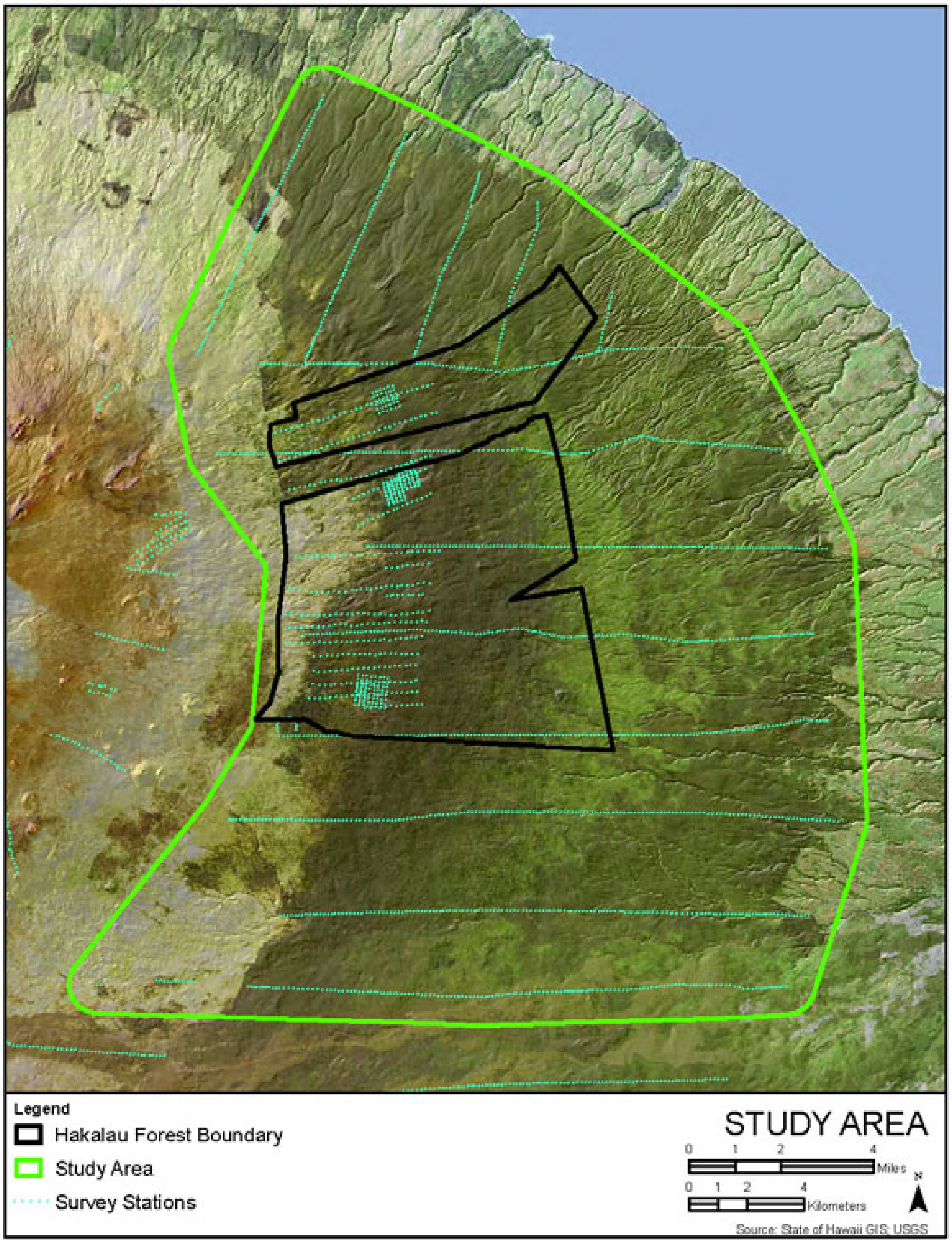
Statewide surveys of the distribution, abundance, and habitat occurrences of native forest birds began in 1976 (Scott et al. 1986). These efforts were followed up by annual surveys that allow for monitoring and the examination of trends in forest bird densities over time, particularly of the endangered Hawaiian forest birds. Long-term data are available for two areas on the Island of Hawai„i in particular: the North Hāmākua study area and the central windward region of Hawai„i Island. These two areas are described in detail below.

The North Hāmākua area (160,230 ac) is located on the eastern flank of Mauna Kea, from 1,000-8,000 ft elevation (Figure 4-4). This area includes the HFU and surrounding public and private lands. The study area is steeply dissected by ridges and erosion gullies, with frequent major tree falls (Camp et al. 2003).

Most surveys within the North Hāmākua study area were conducted in the montane forest, which has a canopy dominated by old growth „ōhi„a and koa. „Ōlapa, pūkiawe, „ōhelo, „ākala, and hāpu„u are the most common subcanopy trees and shrubs. Vegetation at low elevations (0-1,970 ft) consists of nonnative trees, shrubs, and grasses in agriculture and urban/exurban settings. Vegetation at middle elevations (1,970–6,230 ft) is dominated by native „ōhi„a and koa/„ōhi„a forest, whereas the highest elevations (more than 6,230 ft) are comprised of pasture, subalpine native shrubland, and māmane and koa woodland. Nonnative plant species may be found throughout parts of the native forest at all elevations (Camp et al. 2003).

The central windward region of Hawai„i Island includes approximately 166,300 ac of mid- to high-elevation rainforest on the windward slopes of Mauna Loa Volcano, between 2,300-6,890 ft. It was divided into four study areas: Kūlani-Keauhou, „Ōla„a, Mauna Loa Strip, and East Rift (Gorresen et al. 2005).

Figure 4-4. North Hāmākua study area.



The Kūlani-Keauhou study area (elevation 3,280-4,920 ft) and surrounding region is comprised of wet ʻōhiʻa and koa dominated forests. The clearing of forest and ranching largely ceased in the 1990s, and the region is now managed mainly as native forest. Recent management has included removal of livestock, tree planting, and in some areas removal of ungulates and weed control. The ʻŌlaʻa study area (elevation 3,280-4,920 ft) is comprised of wet ʻōhiʻa and hāpuʻu forests.

Management actions include the eradication of pigs and control of nonnative plants (Gorresen et al. 2005).

Management of the Mauna Loa Strip study area (elevation approximately 3,280-4,920 ft) by the Hawai„i Volcanoes National Park includes the exclusion of ungulates (cows, goats, pigs, and sheep) and the control of nonnative plants. The East Rift study area (1,640-3,280 ft) is comprised of wet „ōhi„a-dominated forests. The portion of the study area that lies within the Hawai„i Volcanoes National Park has received ungulate control. The adjacent area (i.e., Kahauale„a Natural Area Reserve) has received no nonnative plant or ungulate control. The forest surrounding and including parts of the study area have been extensively disturbed by lava flows, fire, and „ōhi„a dieback (Gorresen et al. 2005).

Figure 4-5 shows the configuration of Forest Bird Survey Transect lines established at the Hakalau Forest Unit (HFU) for annual bird surveys.

4.4.1 'Akiapōlā'au (*Hemignathus munroi*)

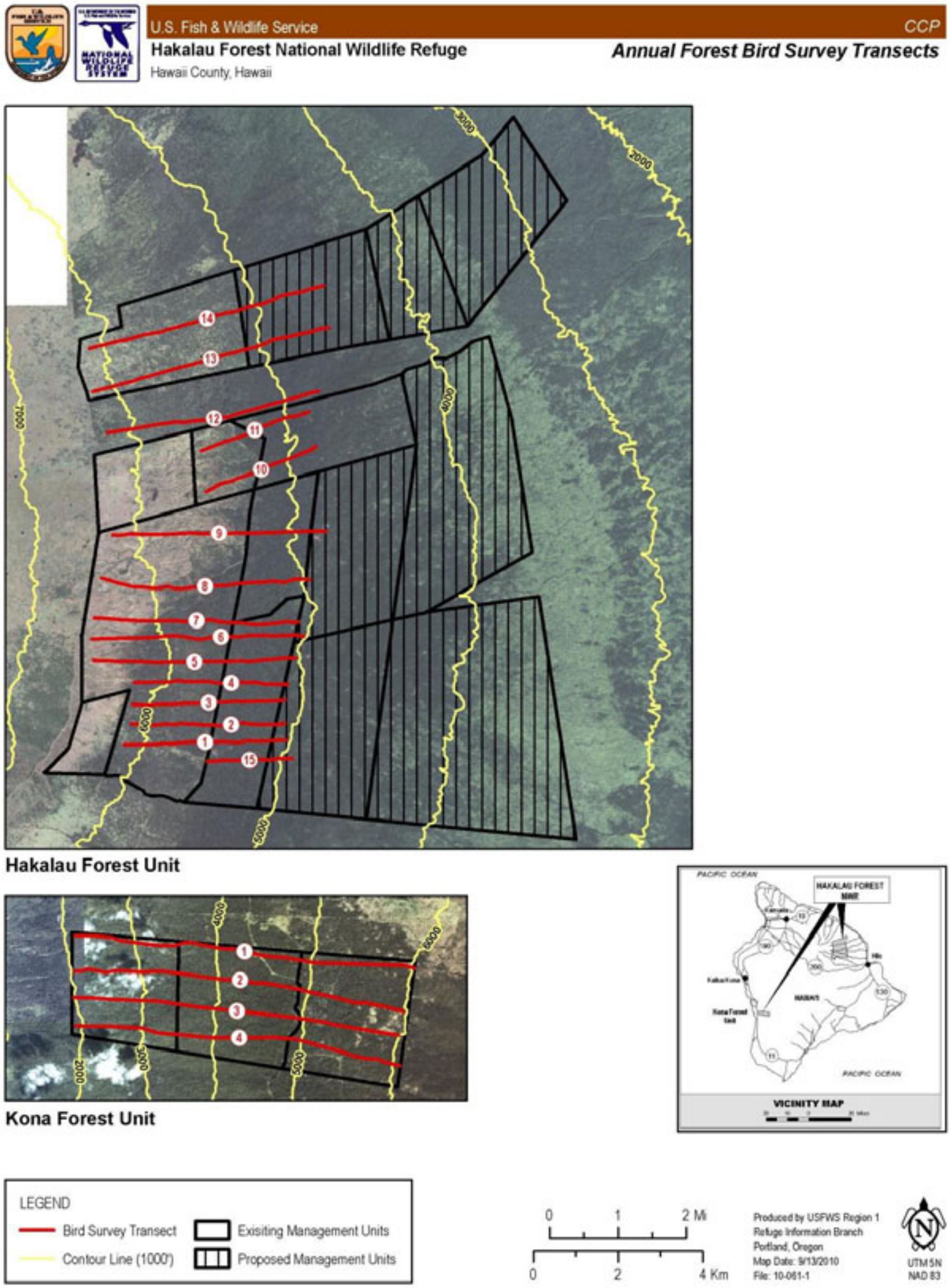
The „akiapōlā„au is a medium-sized, stocky, short-tailed Hawaiian honeycreeper. Its bill has a long, sickle-shaped upper mandible and a short, straight lower mandible that is only half as long as the upper. Males are larger and heavier than females and have a slightly longer bill. Adult males have a bright yellow head and underparts, a greenish back and wings, and black lores. Adult females differ in color, with a yellowish-white chin, throat, and upper breast that contrasts with a pale yellowish-gray lower breast and belly. Fledglings have a mottled yellowish-gray or green plumage with pale underparts.

The „akiapōlā„au is endemic to the Island of Hawai„i. Historically, the „akiapōlā„au was much more common and widespread than it is today, being found virtually islandwide in native forest. In the early 1900s, these forest birds were reportedly abundant, occurring in forests as low as 1,650 ft near Hilo. In the 1940s, they were still present above 5,500 ft in Hawai„i Volcanoes National Park, but by 1970 they had disappeared from the Park and were less common elsewhere (Pratt et al. 2001a).

In the 1970s, „akiapōlā„au were found in five disjunct populations with a total estimated population size of 1,500 ± 400 birds (confidence interval (CI) =95 percent) (Scott et al. 1986). Four of these populations inhabited koa-dominated montane forests in Hāmākua south to the upper Waiākea kīpuka, Kūlani, and Keauhou, in Ka„ū and Kapāpala, in southern Kona, and in central Kona. A fifth population occupied subalpine dry forest on Mauna Kea. Originally these populations were all connected, but they have since been isolated by clearing of forest, mainly due to grazing.

The most recent population estimate, based on islandwide surveys from 1990-1995, is 1,163 birds, with a 90 percent CI of 1,109-1,217 birds (Fancy et al. 1995). However, more recent surveys indicate that the population size might be greater.

Figure 4-5. Annual forest bird survey transects.



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The largest population has long been thought to occur in the Hāmākua region. As of 2000, approximately 1,600 (± 44 standard error (SE)) „akiapōlā„au were estimated to occur in the North Hāmākua area. The HFU currently protects 50 percent of the „akiapōlā„au population in the study area (approximately 800 „akiapōlā„au). In this Unit, a positive trend in „akiapōlā„au density was observed for the 24-year study period (1977-2000); no trends in „akiapōlā„au densities were detected for the 14-year study period (1987-2000). The density of birds for the 14-year study period in the HFU was estimated to be 0.44 birds per acre (standard deviation (SD) = 0.39) (Camp et al. 2003).

In the Ka„ū/Kapāpala area, the population had reportedly decreased from an estimated 533-544 individuals since the 1970s (Fancy et al. 1995), but a more recent and intensive survey revealed a population in this region of more than 1,000 birds (USGS, unpubl.).

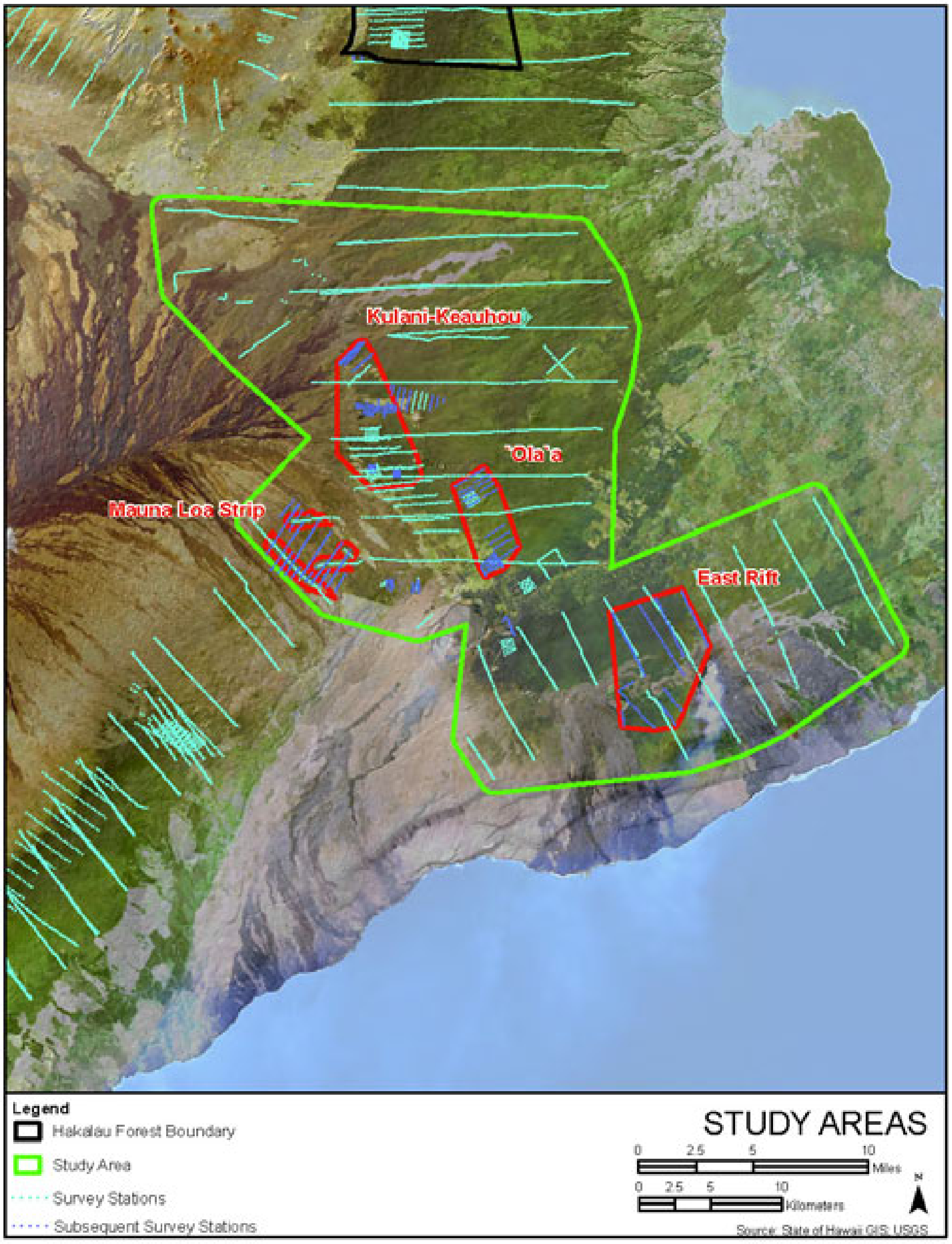
In the central windward region of Hawai„i (Figure 4-6), a 1972-1975 survey of Keauhou Ranch and the Kīlauea Forest Reserve recorded an overall „akiapōlā„au density of 0.2 birds per acre. Subsequent surveys in 1977, the 1990s, and 2000s detected densities of only 0.04 birds per acre. A 2002 survey of the Upper Waiākea Forest Reserve directly north of the Kūlani-Keauhou study area did not record „akiapōlā„au in areas in which they had been detected during the 1977 survey (Gorresen et al. 2005, USFWS 2006b). The range of the „akiapōlā„au also no longer includes the „Ōla„a Tract and „Ōla„a Forest Reserve from which the species were recorded as late as the 1960s. These results may indicate the species" range has contracted upslope. Despite the apparent decline in „akiapōlā„au density, the assessment of trend remains inconclusive. However, regenerating koa in degraded or deforested areas on Kamehameha Schools" Keauhou Ranch and the Kapāpala Forest Reserve recently has been observed to support relatively high densities of „akiapōlā„au (Pratt et al. 2001a, Pejchar 2004).

Three „akiapōlā„au remained in the māmane forest on Mauna Kea in 2000, but all three of these birds are now gone. In the late 1970s, a relict population of 20 birds remained in the koa/„ōhi„a forests of central Kona. „Akiapōlā„au were last detected in central Kona in the mid-1990s (USFWS 2006b) and recent field surveys did not detect „akiapōlā„au in the area (USFWS 2008). The current status of the birds in southern Kona is unknown (USFWS 2006b).

At the HFU, „akiapōlā„au are found in montane wet „ōhi„a and mesic koa/„ōhi„a forest and montane dry koa/„ōhi„a/māmane forest. „Akiapōlā„au attained highest densities in the upper elevation in areas with a koa component and heterogeneous habitats along the forest margins (Camp et al. 2003). „Akiapōlā„au are positively associated with koa and closed canopy, and „akiapōlā„au density is significantly and positively associated with „ōhi„a, high-stature forest and negatively associated with grass and presence of banana poka. Recent observations of „akiapōlā„au have been in montane mesic and wet forest dominated by koa and „ōhi„a or in subalpine dry forest dominated by māmane and naio.

Males and females remain together in pairs most of the time. From the limited data available, breeding occurs year-round (Pratt et al. 2001a). The home range size of both sexes varies from approximately 12-100 ac. Territories are defended, and there is little evidence of daily or seasonal movements. Habitat types influence the size of home ranges, with larger ranges occurring in open forest and smaller ranges in koa plantation; home ranges vary from 56.8 ± 17.8 ac in open forest to 30.4 ± 17.8 ac in closed forests, and 28.9 ± 10.6 ac in young koa plantations. Furthermore, home ranges overlapped more in koa plantations (41.2 percent), than in closed forest (22.6 percent) or open

Figure 4-6. Central windward study area.



forest (9.2 percent). This results in even higher population densities in koa plantations (13 pairs per 247 acres), than in closed forest (10 pairs per 247 acres) or open forest (5 pairs per 247 acres) (Pejchar 2005).

Moth larvae are the most common food item in ‘akiapōlā‘au fecal samples, followed by spiders and longhorned beetle larvae (Ralph and Fancy 1996). Koa, kōlea, māmane, and naio are the moths’ preferred forage plant species, while „ōhi„a is not favored. The foraging behavior of „akiapōlā„au is very specialized compared with that of other forest birds, and foraging sites and food may be limiting. This species rarely takes nectar from flowers, but it recently has been discovered to drink sap from small wells it drills in the bark of „ōhi„a trees.

Only a few trees in a bird‟s territory are used for this purpose, and they are defended against other „akiapōlā‟au. On average, sap trees are larger, have thinner bark, greater sap flow, and tend to occur on convex slopes with more light (Pejchar and Jeffrey 2004).

„Akiapōlā„au often join mixed-species foraging flocks, perhaps to enhance detection of predators. In montane mesic forests, they most frequently associate with Hawai„i creeper and „ākepa, whereas in subalpine dry forest they are found with Hawai„i „amakihi and palila. The importance of these flocks to „akiapōlā„au has not been studied but may prove relevant to the conservation of this species and the need to maintain intact, functioning ecosystems (USFWS 2006b).

„Akiapōlā„au are limited by habitat loss and degradation, predation, and introduced diseases. Due to its low reproductive rate, this species may be particularly vulnerable to these threats and slow to recover. Other factors, such as competition from introduced avian and arthropod insectivores may also limit the range of the species (USFWS 2006b).

The impact of habitat loss and degradation, particularly in mesic and dry forest, also threaten „akiapōlā„au. Dry high elevation māmane-naio forest habitat on the slopes of Mauna Kea has been severely degraded by decades of browsing by goats and sheep. The dispersal behavior of „akiapōlā„au is poorly known, but habitat fragmentation may isolate the remaining populations, decrease the effective population size, and hinder recolonization of areas that were formerly inhabited (USFWS 2006b).

Predation of nests and adults by rats, cats, mongooses, and owls is suspected to have a significant impact on many native Hawaiian bird species (Atkinson 1977, Smucker et al. 2000, VanderWerf and Smith 2002). Recent surveys indicate rat densities are high at the HFU, which contains a significant portion of the largest remaining „akiapōlā„au population (USGS, unpubl.). Juvenile „akiapōlā„au may be especially vulnerable to predators during the post-fledging period because their loud, persistent begging call makes them easy to locate (USFWS 2006b).

Most Hawaiian forest birds are susceptible to introduced mosquito-borne diseases, and the „akiapōlā„au may be limited to its current high-elevation distribution by these diseases (Scott et al. 1986; van Riper et al. 1986; Atkinson et al. 1995, 2005). Despite the availability of apparently suitable habitat, „akiapōlā„au are absent from most areas below 4,500 ft, where mosquitoes are common (USFWS 2006b).

4.4.2 Hawai‘i ‘Ākepa (*Loxops coccineus coccineus*)

The Hawai„i „ākepa is a small sexually dichromatic Hawaiian honeycreeper. Males obtain their bright orange adult plumage 3 years after hatching (Lepson and Freed 1995). The subadult plumage is dull brownish-orange, although individual variation is high. Females are grayish green with a yellow breast band. The lower mandible of the „ākepa is slightly bent to one side which results in the mandible tips being offset; a characteristic shared with the „akeke„e. The bend can be to the left or right, and depending on the direction of the bend, individuals also possess an accompanying leg asymmetry; the leg opposite the curve in the mandible is slightly longer than the other leg (Mitchell et al. 2005).

Hawai„i „ākepa are endemic to the Island of Hawai„i and are currently found in five disjunct populations in „ōhi„a/koa forests in Hāmākua, Kūlani/Keauhou, Ka„ū, southern Kona, and Hualālai, totaling approximately 14,000 ± 2,500 birds (95 percent CI) in 1980 (Scott et al. 1986). The highest densities occurred in the southwestern portion of the Ka„ū Forest Reserve and in the Pua „Ākala Tract of HFU (Scott et al. 1986), and these supported the largest populations, comprising 5,300 ± 1,500 (95 percent CI) birds and 7,900 ± 1,800 (95 percent CI) birds, respectively. The populations in southern Kona and Hualālai were much smaller; approximately 660 ± 250 (95 percent CI) birds combined (Scott et al. 1986), and apparently have declined since those surveys (Mitchell et al. 2005).

More recent surveys of the North Hāmākua area (1977-2000) estimate that approximately 8,300 (± 144 SE) Hawai„i „ākepa occur in the study area (Camp et al. 2003). The HFU protects 72 percent of the Hawai„i „ākepa population in the study area (approximately 6,000 „ākepa). A positive trend in Hawai„i „ākepa density was observed for the 24-year study period (1977-2000); no changes in densities were detected for the 14-year study period (1987-2000). The densities of Hawai„i „ākepa at the HFU was 0.05 birds per acre (0.12 birds per ac, SD = 0.58) in the 1977 survey and 0.39 birds per acre (0.97 birds per ac, SD = 2.03) for the 14-year study period. However, recent analysis of surveys from 1987-2005 indicate that Hawai„i „ākepa densities are now stable or increasing at a mean rate of 2.3 percent per year (Hawai„i Forest Bird Database 2005).

In the central windward region of Hawai„i, Hawai„i„ākepa have historically demonstrated contractions in distribution. Populations in the region are presently limited to a narrow band of high elevation forest habitat in Kūlani-Keauhou and may be isolated from those in the Ka„ū and north windward regions (Gorresen et al. 2005). At Kūlani-Keauhou, although the trend was not significant, densities appear to have declined between the 1995-1998 and 2001-2003 survey periods (0.12 - 0.09 birds per acre). Hawai„i „ākepa densities averaged 0.19 birds per acre in the 1972-1975 survey and 0.15 birds per acre in 1977. The declines in Hawai„i „ākepa may be related to loss of old growth habitat at Keauhou Ranch, particularly in the early 1980s (Gorresen et al. 2005).

Hawai"i „ākepa were not recorded in the Mauna Loa Strip and are no longer found in the „Ōla„a Tract and „Ōla„a Forest Reserve. A regional population decline is also evident in the species" extirpation from adjacent areas within the Hawai„i Volcanoes National Park (Gorresen et al. 2005).

At the HFU, Hawai„i „ākepa are locally common, and found in the montane wet „ōhi„a forest, mesic koa/„ōhi„a forest, and montane dry koa/„ōhi„a māmane forest. Densities of Hawai„i „ākepa are highest in upper elevation koa/„ōhi„a and „ōhi„a forests of high stature and closed canopy (Camp et al. 2003) and occur in a gradient of population density, with a small core area of highest density in the Pua „Ākala area and rapid decreases in density away from the core (Scott et al. 1986, Hart 2001). The species was absent or occurred at low densities in heterogeneous habitats along the grass-forest interface and in mid-elevation forest (Camp et al. 2003).

Several Hawai„i „ākepa have been regularly detected during bird surveys in the KFU since 1999 (USFWS 2008).

Hawai„i „ākepa occur in „ōhi„a and koa/„ōhi„a forests above 4,300 ft (USFWS 2006b). The species feeds mainly on „ōhi„a leaf clusters, but also on koa leaves and seed pods, where it uses its bill to pry open leaf and flower buds in search of small arthropods. Birds also have been seen foraging occasionally in the leaves of naio, „a„ali„i, pūkiawe, pilo, „ōhelo, and „ākala. The Hawai„i ‚ākepa feeds primarily on small insects, spiders, and caterpillars throughout the year. It rarely feeds on nectar (Fretz 2000). Both adults and juveniles frequently join interspecific foraging flocks with other Hawaiian honeycreepers, particularly Hawai„i creepers, and also „akiapōlā„au, Hawai„i „amakihi, „i„iwi, and „apapane.

Hawai„i ‚ākepa breed from early March-May (Lepson et al. 1997). This species is an obligate cavity nester, with most nests placed in natural cavities found in old-growth „ōhi„a and koa trees. Consequently, their density depends in part on the density of large trees, because only large trees provide the cavities required for nesting (Hart 2000, 2001; Freed 2001). The average size of trees used for nesting is 3.3 ft in diameter at breast height (Freed 2001). „Ōhi„a appear to be more important to „ākepa than koa. Large ‚ōhi„a trees provide both cavities for nest-sites and the preferred foraging substrate, whereas large koa trees provide mainly cavities (Freed 2001). The greater importance of „ōhi„a is also supported by „ākepa densities because the highest density of Hawai„i „ākepa on Mauna Loa, in the Ka‟ū Forest Reserve, is in an area without koa (Scott et al. 1986). Breeding densities at HFU appear to be limited by the availability of nest sites (Hart 2000), and the population may be at or near carrying capacity with respect to food availability (Fretz 2000).

Hawai„i „ākepa are likely susceptible to the same factors that threaten other native Hawaiian forest birds, including: loss and degradation of habitat, predation by mammals, and disease (Mitchell et al. 2005, USFWS 2006b). Hawai„i „ākepa are especially sensitive to the loss of old growth forest due to their dependence on large trees with cavities for nesting (Freed 2001). The clearing of forest by logging and ranching has greatly reduced the amount of suitable habitat for Hawai„i „ākepa and other forest birds. Logging and ranching has also resulted in the fragmentation of the remaining forest habitat. It was previously thought that areas of highest „ākepa density with trees large enough to provide nest sites were falling at a rate of 13 trees per mi^2 per year at HFU and that reduction of nest sites in high-density areas was a major threat. New data by Hart et al. shows that the forest is recovering, that large tree loss may not be a limiting factor currently, and that the forest will provide nest sites in the future.

It is possible that the increased light under which „ōhi„a seedlings are germinating is producing trees with an almost exclusively sympodial (multi-trunked) growth form, which typically do not produce cavities suitable for Hawai„i „ākepa nests, although not enough data is available to say this definitively. The „ōhi„a trees used as nest sites by the birds are almost exclusively monopodial (straight and single-trunked) in form (Freed 2001).

Hawai„i „ākepa are also threatened by avian diseases. The species is not found below 4,300 ft, presumably because of the distribution of the introduced mosquito that transmits avian malaria and avian pox (van Riper et al. 1986, 2002). Furthermore, the cavity nests of the Hawai„i „ākepa may be vulnerable to rat predation. However, nest success is high at Pua „Ākala in the HFU, where rat densities are high (Mitchell et al. 2005).

Forest bird issues including potential competition between the invasive Japanese white- eye and the „ākepa, as well as „ākepa status and a debate over survey methodology and data analysis in the scientific community have been addressed in recent years through the Service‟s peer review process/the Forest Bird Workshop (USFWS 2008) and continues in published literature (Camp et. al 2010, Freed 2010, etc.). The Service expects to support appropriate studies in the future as needed to address these issues (see Appendix C).

4.4.3 Hawai‘i Creeper (*Oreomystis mana*)

The Hawai„i creeper is a small, inconspicuous Hawaiian honeycreeper. Adult males and females are predominately olive-green above, dull buff below, and have a dark gray mask extending around the eyes; males are brighter. Their similarity to Hawai„i „amakihi, Hawai„i „ākepa, and introduced Japanese white-eyes complicates field identification.

Hawai„i creeper are endemic to the Island of Hawai„i. In the 1890s, Hawai„i creepers were found in „ōhi„a and „ōhi„a/koa forests throughout the Island of Hawai„i, usually above 3,600 ft elevation. Hawai„i creepers were recorded in the Kona and Ka„ū districts as well as the forests above Hilo. They were noted to be very abundant and generally distributed but had some unexplainable gaps in their distribution, especially at lower elevations. In general, the Hawai„i creeper‟s decline was not well documented, perhaps in part due to difficulties of field identification. However, a drastic decline in numbers in Hawai„i Volcanoes National Park during the 1930s and 1940s was noted, and the species had virtually disappeared from the Park by about 1960 (USFWS 2006b).

As of 1979, the Hawai„i creeper was confined to four disjunct populations in wet and mesic forests, primarily above 5,000 ft. Two populations near Kona totaled only about 300 birds with the number of birds in central Kona estimated at 75 birds. A third subpopulation near Ka„ū consisted of about 2,100 birds. The largest subpopulation is found on the Hāmākua coast on the windward side of Mauna Kea, where 10,000 ± 1,200 (95 percent CI) birds reside (Scott et al. 1986). Recent surveys suggest that the population estimate may be higher. A population recorded on Kohala Mountain in 1972 could not be relocated during the Hawai„i Forest Bird Survey in the early 1980s (Scott et al. 1986).

It is estimated that slightly more than 17,800 (± 221 SE) Hawai„i creepers occur in the North Hāmākua study area (Camp et al. 2003). The HFU currently protects 49 percent of the Hawai„i creeper population in the study area (approximately 8,700). Positive trends in Hawai„i creeper density were observed for the 24-year (1977-2000) and 14-year (1987-2000) study periods. The mean density of creepers was 0.11 birds per acre (SD = 0.97) in 1977, and 0.51 birds per acre (SD = 2.44) from 1987-2000.

The Hawai„i creeper is found in the montane wet „ōhi„a, mesic koa/„ōhi„a forest and montane dry koa/„ōhi„a/māmane forest at the HFU. Densities of Hawai„i creeper are highest in upper elevation, high-stature „ōhi„a forest. The species is absent or occurred at low densities in grasslands, in heterogeneous habitats along the grass-forest interface, and in mid-elevation wet forest.

Surveys as recent as 2006 detected the Hawai„i creeper in the KFU (USFWS 2008). However, population or density estimates have not been documented.

Hawai„i creeper occur most commonly in mesic and wet forests dominated by „ōhi„a and koa with a subcanopy of „ōlapa, pūkiawe, „ōhelo, „ākala, kōlea, kāwa„u, and hāpu„u (USFWS 2006b). Outside the breeding season, the species frequently joins mixed-species foraging flocks (Hart and Freed

2003) and forages over home ranges that average 17.3 ac (VanderWerf 1998, Ralph and Fancy 1994). The Hawai„i creeper most frequently gleans insects, spiders, and other invertebrates from the branches, trunks, and foliage of live „ōhi„a and koa trees. Beetle larvae make up a large part of its diet, but no detailed information on prey taken is available (USFWS 2006b).

During the breeding season (typically January-early May) the species" home range averages 10-17 ac and a 33-66 ft elevation. Home range around the nest is defended territory (VanderWerf 1998, Ralph and Fancy 1994, Lepson et al. 2002). Most nests are open cup structures, but about 15 percent are placed in cavities or in bark crevices. Hawai„i creepers renest after nest failures, and pairs have been documented raising two broods in a season. Although nest success of Hawai„i creepers is very low (11-50 percent), adults have high annual survival (Woodworth et al. 2001).

Hawai„i creepers are susceptible to the same factors that threaten other native Hawaiian forest birds, including loss and degradation of habitat, predation by mammals, and disease. Hawai„i creeper population numbers are also limited by their low reproductive potential, high nesting failure, and possible competition with nonnative bird species.

Logging and grazing has reduced, degraded, and fragmented suitable forest habitats for the Hawai„i creeper. Habitat fragmentation may be a dispersal barrier preventing or restricting natural recolonization of the species" former range. The Hawai„i creeper"s absence from habitats below 4,500 ft elevation also suggests that it may be particularly susceptible to mosquito-borne avian disease (Atkinson et al. 2005).

The productivity of the Hawai„i creeper is also limited by its low reproductive potential and high rates of nesting failure. The Hawai„i creeper has small clutch sizes, relatively long developmental periods, and a limited breeding season. Productivity is further reduced by the high rate of nesting failures, possibly due to the introduction of mammalian nest predators. Hawai„i creepers place their nests near the main trunks of trees which may facilitate predation by rats (Woodworth et al. 2001). It has also been suggested that competition with Japanese white-eyes may negatively affect Hawai„i creepers (Mountainspring and Scott 1985). All these factors contribute to a slow recovery of populations.

4.4.4 ‘Ō‘ū (*Psittirostra psittacea*)

The „ō„ū is a heavy-bodied Hawaiian honeycreeper approximately 7 in in total length. The upper parts are dark olive-green, and the underparts are a lighter olive-green grading to whitish on the undertail coverts. The wings and tail are a darker brownish olive. „Ō„ū aresexually dichromatic, males having a bright yellow head that contrasts sharply with the back and breast, and females having an olive-green head similar in color to the back. Juveniles are similar to the female in color, but somewhat darker. In both sexes the bill is pale pink to straw-colored, with a hooked, parrot-like upper mandible. The males are slightly larger than females.

„Ō„ū were found historically on the islands of Hawai„i, Maui, Moloka„i, Lāna„i, O„ahu, and Kaua„i, and were common throughout their range. Currently, the „ō„ū is one of the rarest birds in Hawai„i and may possibly be extinct, although past survey efforts have been insufficient to determine its status (USFWS 2006b). The most recent observations indicate any remaining populations are extremely localized in occurrence and are restricted to only a fraction of their former range in the mid-elevation „ōhi„a forest on the islands of Kaua„i and Hawai„i only. During the Hawai„i Forest Bird Surveys from

1976-1981, „ō„ū were detected on the eastern slopes of Mauna Kea and Mauna Loa on Hawai„i Island and in the Alaka„i Wilderness Preserve on Kaua„i. Population estimates during the Hawai„i Forest Bird Survey in the late 1970s indicated 400 ± 300 (95 percent CI) birds on the Island of Hawai„i and 3 ± 6 (95 percent CI) birds on Kaua„i (Scott et al. 1986). More recent surveys have failed to detect any „ō„ū on either island, although occasional unconfirmed sightings are reported. Reexamination of past survey data indicates the level of survey effort has to date been insufficient to confirm the status of the species (USFWS 2006b).

At the HFU, a few „ō„ū were detected during the 1977 bird survey in the lower reaches of the Refuge in montane wet „ōhi„a and mesic koa/„ōhi„a forest habitat. Two unconfirmed detections have been reported since that time, along with a possible sighting in the mid-1990s at Nauhi in the lower Honohina Tract and a possible audio detection 4-5 years ago in the same area. However, a subsequent search of the area did not detect the species. „Ō„ū are not present at the KFU.

Historically, „ō„ū were known from a wide range of forests extending from sea level to alpine areas, but dense „ōhi„a forest with „ie„ie was considered to be preferred habitat (USFWS 2006b, Snetsinger et al. 1998). Although wide elevational movements from the upland māmane forests to lowland forests to feed on guava and kukui were observed seasonally in the past, recent sightings on Kaua„i and Hawai„i Island (USFWS, unpubl.) show „ō„ū to be confined to mid-elevation (3,000-5,000 ft mesic and wet „ōhi„a forests with 47-98 in annual rainfall. In this area, the canopy is dominated by „ōhi„a 33-82 ft high, with a subcanopy of „ie„ie, hāpu„u, „ōlapa, kāwa„u, kōlea, and pilo. These elevations are well within the mosquito zone where most native forest birds have been extirpated by mosquito-borne avian malaria and avian pox (Scott et al. 1986).

Collectors in the late 1800s noted that „ō„ū fed mainly on the large inflorescences of „ie„ie, were fond of the yellow fruits of arboreal *Clermontia* species, and took fruits from many other native trees including „ōlapa, māmaki, kāwa„u, alani, and probably „ohe„ohe and „ōhi„aha. „Ō„ū were also recorded to feed on young koa leaves, nectar, and on nonnative fruits such as guava, mountain apple, banana, peach, and mulberry. They have also been observed to forage extensively in kukui; however, it is unclear if they seek nectar, insects, or husks of the oily nuts (Scott et al. 1986, Snetsinger et al. 1998, USFWS 2006b). „Ō„ū were also noted to feed on caterpillars (Geometridae), and feed them to young during the summer months in the Ka„ū/Kīlauea area. Nesting of the „ō„ū has never been described and little is known of its breeding habits.

„Ō„ū are threatened by the loss and degradation of habitat, the loss of food resources, disease and predation by mammals as well as natural disasters. Modification and loss of habitat have played a significant role in the decline of the „ō„ū. Forest degradation by ungulates has reduced or eliminated forest habitat and food resources by converting vast areas of koa and „ōhi„a forest to pasturelands. Pigs have caused degradation of the understory in wet forests, destroyed food plants such as „ie„ie and *Clermontia* species, and have created mosquito breeding sites (USFWS 2006b).

Predation by rats on eggs and cats and rats on young and adults has contributed to the decline of many forest birds, probably including the „ō„ū. Herbivory by introduced black rats on the fruits and flowers of „ie„ie and other native fruiting plants also may have reduced food resources for native birds in forests throughout Hawai„i (USFWS 2006b).

In addition, recent natural disasters may have affected some of the last remaining „ō„ū populations. On the island of Hawai„i, a large portion of the Upper Waiākea Forest Reserve (a location of some of the last observations of „ō„ū and considered prime habitat for the species), was inundated by the 1984 Mauna Loa lava flow, destroying thousands of acres of forest and creating a treeless corridor over 0.62 mi wide. On Kaua„i, two strong hurricanes, Iwa in 1982 and Iniki in 1992, had devastating effects on native forest habitat and native bird species. Three native bird species, „ō„ū, „ōō, and kāma„o have not been seen since Hurricane Iniki (USFWS 2006b).

4.4.5 'Alalā (*Corvus hawaiiensis*)

The „alalā is a member of the family Corvidae, the family of birds that includes ravens, crows, jays, and magpies. Members of the crow family are recognized for having a high degree of intelligence and excellent memory. They are generally relatively raucous and gregarious birds, and are known for their complex "language-like" vocalizations. The „alalā is a typical medium-sized crow, from dark brown to black in color.

The „alalā is endemic to the Island of Hawai„i. Historically, the species was restricted to a belt of native dry woodlands, and mesic „ōhi„a and „ōhi„a/koa forests found at mid-elevation 984-8,202 ft in the western and southern portions of the island, from Pu„uanahulu in the North Kona District to the vicinity of Kīlauea Crater in the Ka„ū District. „Alalā occupied their entire documented historical range during the 1890s and were observed in large numbers in both closed and disturbed forests (USFWS 2003).

In the early 1900s, the population density of „alalā was noticeably reduced and their range was becoming fragmented. The species was extirpated from lower elevations by the 1940s, and occupied only small areas of its historical range by the 1950s. Further substantial declines occurred through the 1960s and early 1970s. In 1976, an estimated population of 76 ±18 (95 percent CI) birds was restricted to elevations of from 2,950 -6,230 ft in three areas in the Kona District (Hualālai, Hōnaunau Forest Reserve/McCandless Ranch, and Honomalino), and one area in the Ka„ū District (Scott et al. 1986). „Alalā have not been encountered in the Ka„ū District since 1977, when a single bird was observed in HAVO in the eastern most part of its known historical range (USFWS 2003).

„Alalā were extirpated from Honomalino and Hōnaunau by 1986. By 1987, the wild population had been reduced to a single 12-year-old female on Hualālai and an undetermined number on the McCandless Ranch near Hōnaunau. The Hualālai female was last observed in late 1991. A thorough survey of the McCandless Ranch in 1992 indicated a wild population of 12 birds, including a single juvenile. No additional „alalā were found during a subsequent survey of extensive forest tracts around the island. After 1993, the wild population of „alalā was observed intensively, as the number of birds gradually declined to a single pair in 2002 (USFWS 2003). This species is now believed to be extinct in the wild, as the last free-living pair has not been sighted since June 2002 (USFWS 2003).

In 1976, the State of Hawai„i formally established a captive breeding program for the restoration of the „alalā. Through the efforts of several partners, including the State, FWS, The Peregrine Fund, Zoological Society of San Diego, and private landowners, the captive population was established over successive years by obtaining birds from the wild, raising chicks from artificially incubated wild eggs, and successfully breeding captive birds. In 1993, captive-reared „alalā were reintroduced into the wild at sites along the southern boundary of the KFU at an elevation of 4,920 ft. Of the 27 fledglings released, 21 died or disappeared by 1999. Of the birds recovered, seven died from lethal interactions with „io, three died from toxoplasmosis (Work et al. 2000), two died from other infections (Work et al. 1999), and one died from mammal predation (USFWS 2003). All birds also acquired malaria soon after being released, but survived; some required active veterinary support. The remaining six surviving individuals were subsequently recaptured and reintegrated back into the captive flock (USFWS 2003).

Currently, all „alalā are under captive propagation by the San Diego Zoological Society located at the Keauhou Bird Conservation Center on the Island of Hawai„i and the Maui Bird Conservation Center on Maui. This captive propagation and research program is a 20-year agreement to help the „alalā, as well as 18 other Hawaiian forest bird species (USWFS 2008). Currently about 77 „alalā are in captivity (ZSSD, unpubl.). Areas under consideration for repatriation of this species are listed below in order of preference: (1) Southwest Ka„ū, (2) Keauhou-Kūlani, (3) Central Ka„ū, (4) Kapāpala, (5) KFU, and (6) Kona Hema (Price and Jacobi 2007).

Historically, the „alalā was common in lower and middle-elevation mesic forests between 3,610-4,920 ft on the western and southern side of the Island of Hawai„i (Giffin et al. 1987, Winter 2003). When the species was relatively abundant, flocks of „alalā were observed to make extensive seasonal movements in response to weather and the availability of the „ie„ie vine and other native fruit-bearing plants (USFWS 2003).

The habitat with the highest breeding densities of „alalā during 1970-1982 was relatively undisturbed „ōhi„a/koa forest; „alalā avoided disturbed forest where possible (Giffin et al. 1987). In addition, a significant amount of protective understory cover appeared to be important to „alalā in avoiding predation by „io (USFWS, unpubl.). The „alalā used the upper half of the canopy of mature trees for their daily activities (Sakai et al. 1986) and fed on native and introduced fruits, invertebrates gleaned from tree bark and other sites, and eggs and nestlings of other forest birds. Nestlings preyed upon included the red-billed leiothrix and Japanese white-eye as well as four native species (Hawai„i „amakihi, „i„iwi, „elepaio, and „apapane) (Sakai et al. 1986). Mice have also been noted in crow droppings (Sakai et al. 1986). Nectar, flowers, and carrion are minor diet components. A strong association was noted with „ie„ie, which formerly blanketed extensive tracts of mid-elevation mesic and wet forest; however, „alalā were not observed in wet forests where „ie„ie is abundant (USFWS 2003).

The median home range recorded for the „alalā was 1,186 ac with a range of 146 - 3,598 ac. Nest construction usually began in March and first clutches were laid in April. Recorded nests have been predominantly in „ōhi„a, although other trees and „ie„ie vines may be used. All recorded nests have been at elevations 3,280-5,905 ft. Known nest sites have been in areas with 24-98 in of annual rainfall (USFWS 2003).

Because the population is small and confined to captivity, the „alalā is highly susceptible to stochastic environmental, demographic, and genetic events. Inbreeding depression may also be reducing the reproductive success of the captive population. Before the remaining „alalā were taken into captivity, „alalā were threatened by predation from mammals, „io, avian diseases, and habitat loss and fragmentation.

Rats and mongooses are known predators on „alalā eggs and nestlings. Cats are also suspected predators on fledglings and adults (USFWS, unpubl.). Recent observations show that juvenile and adult „alalā raised in captivity can be killed and eaten by „io in the wild (USFWS 2003).

Avian pox has been implicated in the deaths of wild „alalā nestlings (Jenkins at al 1989). Avian malaria has also been detected in „alalā blood smears (Giffin et al 1987), but the lethality of avian malaria for „alalā in the wild is unknown (Jenkins et al. 1989). Juvenile captive-reared „alalā are able to survive malaria and pox infection with supportive care. Recent studies have shown that „alalā are highly susceptible to toxoplasmosis, a disease caused by a parasite that is spread by cats, which now exist throughout historical „alalā habitat (Work et al. 2000). Whether this pathogen played any role in the decline of the wild population is unknown, but it has caused mortality of young „alalā released into the wild (USFWS 2003).

Habitat changes that may have impacted „alalā populations include complete and partial deforestation, selective species loss, and invasion or replacement of habitat by nonnative plants. Because of the landscape-scale movements that allowed historical populations of „alalā to exploit patchy food resources and escape harsh weather, alteration of small but crucial parts of their range and reduction in some food plants (e.g., clearing low-elevation forest for agriculture and vegetation changes throughout the species‟ range) may have reduced the ability of the „alalā to persist over large areas. In addition, opening of the forest structure through grazing and tree cutting may have made „alalā more vulnerable to predation by „io (USFWS 2003).

Inbreeding may also be occurring among the captive population, due to the small number of individuals. Lethal abnormalities are occurring at a higher rate in the captive flock, suggesting inbreeding depression (Zoological Society of San Diego, unpubl.). The mean number of clutches produced per pair has also decreased from 2.50 ± 0.65 (SE) in 1996 to 0.87 ± 0.99 (SE) in 1999 (Harvey et al. 2002) indicating that inbreeding may also be starting to affect fertility and reproductive outcomes of the „alalā.

4.4.6 'Io (*Buteo solitarius*)

The „io has two color morphs; dark phase birds are dark brown above and below, light phase birds are dark above and pale below with dark streaking. Intermediates occur between the two extremes. Females are larger than males, and often weigh approximately 25 percent more than males. The head is dark in adults and light in immatures (Mitchell et al. 2005, HAS 2005).

The „io is endemic to the Hawaiian Islands, although historically it is known only from the Island of Hawai„i. The first quantitative survey of „io abundance was carried out from 1980-1982 and yielded a population estimate of about 2,700 birds (Griffin 1989). To update and address questions about the validity of the population estimates, the Service initiated an islandwide survey that estimated the population in 1993 at approximately 1,600 hawks (95 percent CI = 1,200 to 2,400) (Hall et al. 1997). A subsequent study in 1998 generated a population estimate of 1,457 individuals (95 percent CI = 1,149-1,847) and a growth rate of 1.03 ± 0.04 SE, indicating a stable population (Klavitter et al. 2003).

As part of a reevaluation of the species‟ endangered status, a study conducted in 2007 estimated that 3,239 hawks (95 percent CI = 2,610 - 3,868) were present in 1998 and 3,085 hawks (95 percent CI = 2,496 to 3,680) were present in 2007. Similar to the 1998 study, no significant difference in densities was found among years at either regional or islandwide scales, indicating a stable population. The twofold increase in population estimates was attributed to differences among studies in (1) the accuracy of distance estimation of „io sightings at count locations, (2) accounting for unobserved hawk movement, and (3) the extent of area used for the extrapolation of mean densities (Gorresen et al. 2008).

Gorresen et al. (2008) reports that habitat and region were significantly associated with „io density. Native-nonnative forest, mature native forest, mature native forest with grass understory, and orchards generally support greater densities of „io than shrubland, pioneer native forest, or urban habitats. However, densities in certain habitats showed considerable difference among regions. For example, native-exotic forest in Hāmākua had more than four times the „io density than similar habitats in Puna, and mature native forest in Kona also harbored markedly greater densities than those found in Puna. Data showed that Puna generally harbored lower „io numbers compared to other regions on the Island of Hawai„i (Gorresen et al. 2008).

„Io occur only on the Island of Hawai„i from sea level to 8000 ft elevation. „Io occur in lowland nonnative forests, urban areas, agricultural lands, pasturelands, and high-elevation native forests with both intact and degraded understory (Mitchell et al. 2005, Klavitter et al. 2003). During the winter, „io have been reported in subalpine māmane-naio forest, suggesting some seasonal movements (Mitchell et al. 2005).

„Io were found at the higher elevations of the HFU between 3,300-6,600 ft in montane wet „ōhi„a forest, mesic and dry koa/„ōhi„a forest, and montane wet „ōhi„a/*Dicranopteris* sp. forest and grasslands. As of 2007, densities of „io were 0.34 birds/mi^2 in mature forests with grasslands and 0.3 birds/mi^2 in mature native forest. The average density for the Island of Hawai„i is 0.21 ± 0.02 birds/mi^2 (Gorresen et al. 2008). „Io have been recorded nesting in the HFU (Klavitter et al. 2003).

At the KFU, „io densities are 0.77 birds/mi^2 in mature forests with grasslands and at densities of 0.42 birds/mi^2 in mature native forest (Gorresen, pers. comm.). „Io have been recorded nesting at all elevations of the KFU (Klavitter and Marzluff 2007).

Of 51 observed nests, 86 percent occurred in native trees, with 80 percent of nests in „ōhi„a. Nonnative trees used for nesting include eucalyptus, ironwood, mango, coconut palm, and macadamia (Klavitter 2000). Nests can be used for several years with nesting material added each breeding season (Griffin et al. 1998). Adult home ranges were estimated to be 1,000 ac and may overlap with adjacent home ranges (Gorresen, pers. comm.).

Nestlings were fed birds (45 percent) and mammals (55 percent), consisting mainly of introduced species. The most commonly caught mammals were rats and house mice, while Japanese white-eye and common myna were the most common species of bird prey. Native or migratory birds recorded as prey for nestlings were „apapane, Hawai„i „amakihi, and kōlea (or Pacific golden plover) (Griffin et al. 1998).

Nesting and foraging habitat loss is a significant threat to the species. The causes of this loss include urbanization, degradation of habitat due to grazing by ungulates, conversion of foraging habitat (e.g., conversion of pasture to forestry plantations), invasive understory plants, and increasing fire frequency (Gorresen et al. 2008).

Forest degradation by invasive plants, such as strawberry guava, can impact large areas of „io nesting and foraging habitat (Gorresen et al. 2008). In addition to concealing prey and making the understory unavailable to foraging hawks, dense stands of introduced plants can suppress the establishment and growth of native species such as „ōhi„a, a preferred nesting tree (Griffin et al. 1998). Moreover, pigs can facilitate the dispersal of nonnative plants and can significantly damage „ōhi„a seedlings by their foraging activity. Strawberry guava in particular has the potential to invade and degrade up to 36 percent of the „io breeding range (Gorresen et al. 2008).

Introduced grasses have also altered natural fire regimes and ecosystem properties throughout much of Hawai„i. Invasive fire-adapted species have increased the frequency, intensity, and extent of wildfire, and contributed to declines in native tree cover and the expansion of grasslands in many areas (Gorresen et al. 2008). Other possible limiting factors for the „io population include harassment of nesting birds and shooting of adults. However, the level of harassment and shooting is difficult to assess (USFWS 1984).

Little supporting evidence that environmental contaminants, avian pox, avian malaria, or *Toxoplasma gondii* are limiting factors for the „io population currently exists (Griffin et al. 1998, Klavitter et al. 2003). There is also little evidence that „io fledglings are preyed upon by introduced mammals such as rats, cats, and Indian mongooses (Griffin et al. 1998).

The „io was listed as endangered on March 11, 1967, and a final recovery plan was released in 1984 (Federal Register 2008a). The plan did not include specific delisting criteria; however, the primary objective in the plan was to „„„ensure a self-sustaining „io population in the range of 1,500-2,500 adult birds in the wild, as distributed in 1983, and maintained in stable, secure habitat” (Federal Register 2008a). Because these targets were met, the Service proposed reclassification of the „io from endangered to threatened status in August 1993, but this rule was not finalized. In August 2008, the Service proposed to remove the „io from the Federal list of endangered and threatened wildlife. This proposal is based on evidence that the species is broadly distributed throughout the Island of Hawai„i, has been stable for at least 20 years, has large areas of habitat in protected status, and is able to nest and forage in altered habitats (Federal Register 2008a). A post-delisting monitoring plan has been drafted and public comments have been received. Delisting is currently under review.

4.5 Other Native Hawaiian Forest Birds

Native Hawaiian forest birds (nonlisted) found within the Hakalau Forest NWR are comprised of four families: Fringillidae (honeycreepers), Monarchidae (monarch flycatchers), Turdidae (thrushes), and Strigidae (true owls). The honeycreepers include the „i„iwi, common „amakihi, and „apapane. The monarch flycatcher family is represented by the Hawai„i „elepaio, the thrush by the „ōma„o, and the true owl by the pueo. Most of these bird species are most abundant in native montane forests; however, the common „amakihi, Hawai„i „elepaio, and pueo are also found in nonnative forests and can be common at lower elevations (Camp et al. 2003, Spiegel et al. 2006, Woodworth et al. 2005, Mitchell et al. 2005).

Native bird populations have been closely monitored and information on changes in native forest bird densities are available, particularly for North Hāmākua and the central windward region of Hawai„i.

4.5.1 ‘I‘iwi (*Vestiaria coccinea*)

Male and female „i„iwi are primarily vermillion red, with a black tail and wings, and a long, decurved pink bill. The juvenile is green with black spots and a shorter dusky bill, which becomes yellow then pink with age.

The following island population estimates are based on Hawaiian Forest Bird Surveys (1976-1981): 340,000 ± 12,000 (95 percent CI) individuals on the Island of Hawai„i (88 percent in Hāmākua), 19,000 ± 2,000 (95 percent CI) individuals on east Maui, 180 ± 150 (95 percent CI) on west Maui, 80 ± 65 (95 percent CI) individuals on Moloka„i, and 5,400 ± 500 (95 percent CI) in the Alaka„i Swamp on Kaua„i. Recent surveys (1996) suggest that O„ahu supports less than 50 birds. In 1988, two birds were detected on Moloka„i. On Kaua„i, populations declined after the 1992 hurricane, but changed little from 1994-2000. The overall population may be declining, but the species‟ wide-ranging foraging complicates population estimates and the determination of long-term trends (Mitchell et al. 2005).

From 1987-2000, a population of 285,422 ± 1,267 (SE) „i„iwi was estimated to occur in the North Hāmākua study area. Of this total, 100,347 birds (35 percent) were predicted to occur within the HFU. „I„iwi mean density for the 14-year study period of surveys (1987-2000) within the HFU was 8.5 birds per acre (SD = 9.27). „I„iwi populations did not show a positive or negative trend in density over the 14-year study period. However, a moderate increase in density did occur over the 24-year study period (1977-2000) (Camp et al. 2003).

In the central windward region of Hawai„i, i„iwi were extirpated from the mid-elevation study areas and are possibly in decline in Kūlani-Keauhou. Declines of „i„iwi havebeen observed elsewhere within mid-elevation habitat suggesting that their ranges are contracting westward and upslope in the central windward region (Gorresen et al. 2005).

„I„iwi density decreased at the high elevation site Kūlani-Keauhou between 1995-2003 (4.0-3.4 birds per acre). However, inter-annual densities were fairly variable and differences may reflect local movement in response to nectar availability instead (Ralph and Fancy 1995). At the Mauna Loa Strip, „i„iwi were present at 0.04 birds per acre and did not exhibit increasing or decreasing trends. At lower elevations, „i„iwi densities declined more than tenfold from 1977-1994 from 1.2-0.09 birds per acre in the „Ōla„astudy area and were not present at the East Rift (Gorresen et al. 2005).

At the HFU, densities of „i„iwi were highest in upper elevation (greater than 4,900 ft) in mesic and wet koa/„ōhi„a and „ōhi„a forests of high stature and closed canopy. „I„iwi abundances were positively associated with koa, presence of banana poka and elevation, and negatively associated with grass, nonnative vegetation, and presence of tree fern. The positive association with *P. mollissima* may be due to the use of its copious nectar by „i„iwi (Fancy and Ralph 1998). „I„iwi occurred at low densities in heterogeneous habitats along the grass-forest interface and in mid-elevation forest.

At the KFU, „i„iwi are found above 4,900 ft (Atkinson et al. 2005). Density estimates and habitat preferences in this area have not been studied.

The „i„iwi is a common forest bird in mesic and wet koa-„ōhi„aand „ōhi„aforest above 4,900 ft. The habitat on the windward slopes of Hawai„i receive 27.6-39.4 in of rainfall annually. „I„iwi are highly dependent on „ōhi„a forfood and nesting. „I„iwispend up to 80-90 percent of their time foraging on „ōhi„a for nectar and insects. As they are primarily nectarivorous; the nectar of „ōhi„aand māmane make up a major portion of their diet. The species also feeds on foliage insects and spiders (Ralph and Fancy 1995). Other plant species used for foraging on nectar and insects include koa, naio, kōlea, „ākala, alani, kanawao, koki„o ke„oke„o, and native lobelioids. Banana poka nectar is a major food source in some areas (Fancy and Ralph 1998).

Breeding season on Hawai„i Island begins October-November, with peak breeding between February-June. Breeding coincides with seasonal availability of „ōhi„a nectar. Both sexes defend small nesting territories and may sometimes defend individual „ōhi„a trees as nectar resources. While „i„iwi are dependent on „ōhi„a for feeding and nesting, „i„iwi also serve as important pollinators of „ōhi„a and native lobeliods.

„Ī„iwi distribution range is restricted mostly to elevations greater than 4,100 ft because of loss and destruction of native forests and presence of cold-intolerant *Culex* mosquitoes that transmit avian diseases at lower elevations (Scott et al. 1986, van Riper et al. 1986, Atkinson et al. 1995). However, „i„iwi are known to migrate to lower elevations during the summer. „I„iwi arevery susceptible to avian malaria and avian pox. Mortality of experimentally infected „i„iwi is high, with estimates at 90 percent (Atkinson et al. 1995). Individuals infected with pox also are more likely to be infected with malaria. The KFU has a high prevalence of malaria and avian pox, and data shows that few „i„iwi survive the exposure (Atkinson et al. 2005). The presence of pigs in the KFU and limited areas of the HFU may also spread malaria as the compaction of soils and felling and hollowing of tree ferns by pigs create favored breeding sites for *Culex* mosquitoes.„I„iwi fledglings may also be susceptible to predation by rats and cats found in the units (Mitchell et al. 2005).

4.5.2 Common ‘Amakihi (*Hemignathus virens*)

Male common „amakihi are bright yellow-green with black lores. Females are generally similar, but duller. All „amakihi have decurved bills. The immatures are drab gray and may lack dark lores and some have faint wingbars.

The Hawaiian Forest Bird Survey (1976-1983) estimated the Hawai„i „amakihi population at 870,000 ± 5,612 (95 percent CI) individuals on the Island of Hawai„i, 44,000 ± 1,786 (95 percent CI) birds on east Maui, 3,000 ± 408 (95 percent CI) on west Maui, and 1,800 ± 357 (95 percent CI) individuals on Moloka„i. Populations on the islands of Hawai„i and Maui are probably stable; the Moloka„i population is probably declining (Mitchell et al. 2005).

A population of 200,760 ± 990 (SE) common „amakihi was estimated to occur within the north Hāmākua study area, of which 51,600 birds (26 percent) were predicted to occur within the HFU (Camp et al. 2003). The mean density of common „amakihi for the 14-year study period of surveys within the HFU (1987-2000) was 5.2 birds per acre (SD = 7.63). Common „amakihi populations within and near the HFU did not show a significantly positive or negative trend in density from 1987-2000. However, „amakihi density increased over the 24-year study period (1977-2000). From 1999-2007, the population of common „amakihi at the HFU was also stable or increasing. The population was estimated to potentially have increased at a mean rate of 2.5 percent per year (95 percent CI -7.9-12.9 percent) (Hawai„i Forest Database 2005). Common „amakihi demonstrated low within-year but moderately high between-year variability in density.

In the central windward region of Hawai„i, common „amakihi trends are stable or increasing at the upper elevation study areas such as Kūlani-Keauhou and the Mauna Loa Strip; however, they are trending downward at lower elevation sites such as „Ōla„a and East Rift. Between 1995-2003, common „amakihi density increased at Kūlani-Keauhou from 1.3-1.6 birds per acre. From 1977-1994, common „amakihi showed a stable trend at the Mauna Loa Strip (1.8 birds per acre). Common „amakihi were absent at „Ōla„a throughout the survey period (1977-1994) and nearly absent at East Rift (0.008 birds per acre from 1979-1994) (Gorresen et al. 2005).

Elevational changes in distribution in the common „amakihi have also been documented. While „amakihi are uncommon lower than 1,640 ft (Scott et al. 1986), range expansion of the „amakihi to lower elevations has been documented in the Puna district located on the southeastern corner of Hawai„i Island. Common „amakihi are the most common native birds in these areas of active malaria transmission (Spiegel et al. 2006, Woodworth et al. 2005).

At the HFU, common „amakihi attained highest densities in the higher elevation portion of the unit above 4,900 ft. These densities occurred in a range of habitats including grassland, closed canopy forest with a koa component, banana poka-infested stands, and heterogeneous habitats along the forest margins. The species were absent or occurred at low densities in the wet forest with tree fern and matted fern. Common „amakihi densities were positively associated with koa and species richness, and negatively associated with nonnative vegetation and rainfall (Camp et al. 2003). Common „amakihi are found at the KFU and are present at all elevations (Atkinson et al. 2005).

The common „amakihi is a year-round inhabitant of a wide range of native dry shrublands and dry, mesic, and wet forests in montane and subalpine communities (Scott et al. 1986). The species is also a characteristic bird of „ōhi„a forests (Lindsey et al. 1998).

Common „amakihi are generalized foragers that most often glean arthropods from the leaves, blossoms, twigs, branches, and less frequently from tree trunks of a variety of trees, ferns, and shrubs. They feed on nectar predominately from the flowers of „ōhi„a, māmane, and native lobelias (Campanulaceae), but also forage on flowers of a number of other native and nonnative plants. Common „amakihi also eat fruit from native and nonnative plants, but predominately from pilo (Mitchell et al. 2005).

Common „amakihi breed from December-July on the Island of Hawai„i (Lindsey et al.1998, van Riper 1987). In dryland māmane-naio forest, māmane trees are the preferred nesting substrate; of 174 nests, 88 percent were found in māmane trees and 12 percent were detected in naio (van Riper 1987). In mesic and wet forests, „amakihi use „ōhi„a trees almost exclusively for nesting (Kern and van Riper 1984).

Common „amakihi are range limited because of loss and destruction of native forests, the presence of malaria at lower elevations, and predation by mammals. Mortality of „amakihi experimentally infected with the malaria parasite was 65 percent. While „amakihi are uncommon under 1,640 ft, range expansion of the species to lower elevations has been documented at Puna, where they are the most common native birds in these areas of active malaria transmission (Spiegel et al. 2006, Woodworth et al. 2005). Common „amakihi are also found at lower elevations in the KFU (Atkinson et al. 2005). Common „amakihi in these low-elevation areas show malaria prevalence levels of up to 80 percent and were also more likely to be infected with pox (Atkinson et al. 2005, Woodworth et al.

2005). However, individuals that have chronic malaria infections have had similar or higher reproductive success than noninfected individuals (Kilpatrick et al. 2006).

Common „amakihi adults and nestlings are also susceptible to predation by mammal predators (Lindsey et al. 1998). It has been suggested that predator control in mid-elevations may increase the survivorship of malaria-resistant individuals, resulting in the persistence of native bird populations in areas of active malaria transmission (Kilpatrick 2006, VanderWerf and Smith 2002).

4.5.3 'Apapane (*Himatione sanguinea*)

The „apapane is a small, crimson bird with black wings and tail. The immatures are like the adults, except the crimson is replaced by a dull dark brown. The black bill of the „apapane is slightly curved.

„Apapane were formerly found on all forested islands in the Hawaiian Archipelago to sea level, but are now restricted to higher elevations. Island population estimates based on Hawaiian Forest Bird Surveys (1976-1981) are 1,080,000 ± 25,000 (95 percent CI) individuals on the Island of Hawai„i, 110,000 ± 9,000 individuals on Maui on Haleakalā (86 percent), 39,000 ± 5,000 individuals on Moloka„i, 540 ± 213 individuals on Lāna„i, and 30,000 ± 1,500 individuals on Kaua„i. On Kaua„i, populations declined after the 1992 hurricane, but have significantly increased since. The 2000 Kaua„i Forest Bird Survey estimated the population at 64,972 ± 2,014 (SE) individuals. „Apapane are now rare or absent on Moloka„i and Lāna„i (Fancy and Ralph 1997, Mitchell et al. 2005).

Recent surveys estimate that approximately 255,900 (± 1,037 SE) „apapane occur in the north Hāmākua study area. The HFU currently protects 29 percent of the „apapane population in the study area (approximately 75,200 „apapane). An increase in „apapane density was observed for the 24-year study period (1977-2000); no trends in „apapane densities were detected for the 14-year study period (1987-2000). Mean density of „apapane in 1977 was 1.6 birds per acre and increased to 4.0 birds per acre (SD = 5.61) for the 14-year study period within the HFU (Camp et al. 2003).

In the central windward region of Hawai„i, „apapane were ubiquitous and showed increasing or stable trends at the higher elevations. At the Kūlani-Keauhou study area, „apapane were observed at an average density of 6.7 birds per acre in 1972-1975, and 7.8 birds per acre in 1977. Densities significantly increased from the 1990s to 2000s (9.9-11.5 birds per acre). At the Mauna Loa Strip, „apapane occurred at stable densities of 0.1 birds per acre throughout the study period (Gorresen et al. 2005).

At the lower elevation sites, „apapane numbers have declined. In the „Ōla„a study area, „apapane densities declined from 7.8 birds per acre in 1977 and 2.8 birds per acre in 1994. The East Rift area also exhibited significant declines from 4.1 to 2.6 birds per acre between the 1979-1993/1994 survey periods (Gorresen et al. 2005).

„Apapane are found throughout HFU. Densities of „apapane are highest in upper-elevation koa-„ōhi„a and „ōhi„a forests of high stature and closed canopy, and occur at low densities in grassland, heterogeneous habitats along the grass-forest interface, and in mid- to low-elevation forest (Camp et al. 2003). „Apapane are found at all elevations in the KFU (Atkinson et al. 2005), although densities have not been estimated.

Occurring primarily at elevations greater than 4,100 ft, „apapane occur in mesic and wet forests dominated by „ōhi„a and koa. However, they are also known to migrate to lower elevations during the summer. Occupied habitats also support kōlea, naio, and hāpu„u. Māmane is common in high-elevation foraging habitat (Mitchell et al. 2005).

„Apapane are primarily nectarivorous and the species is an important „ōhi„a pollinator. Their widespread seasonal movements, particularly from June-August, occur in response to „ōhi„a flower availability (Macmillen and Carpenter 1980, Ralph and Fancy 1995). „Apapane also eat insects, which they glean from outer foliage and twigs in the upper- and mid-canopy. Juvenile „apapane favor arthropod prey more than adults possibly due to their higher protein/calorie requirements (Carothers 2001). „Apapane often forage in conspecific flocks, which can overwhelm „i„iwi and „ākohekohe, which often defend flower-rich trees (Mitchell et al. 2005).

Birds in breeding condition may be found in any month of the year, but peak breeding occurs February - June. The nest is usually a cup on a high terminal branch of „ōhi„a, but nests have also been found in tree cavities and lava tubes, and on upper branches of koa, ilex, and *Cibotium* tree ferns (Fancy and Ralph 1997).

„Apapane are susceptible to the same factors that threaten other native Hawaiian forest birds including loss and degradation of habitat, disease, and predation by mammals. Disease is of particular concern as „apapane have the highest prevalence of avian malaria of all native forest birds (Samuel et al 2007, Atkinson et al. 2005, USFWS 2005). Because „apapane typically undergo altitudinal migrations to follow „ōhi„abloom, the species might be expected to receive higher exposure to this disease than other more resident species such as „amakihi and Hawai„i „elepaio. Five of eight (63 percent) juvenile „apapane experimentally infected with malaria suffered mortality (Yorinks and Atkinson 2000). Individuals infected with avian pox also are more likely to be infected with malaria. At low elevations of the KFU, malaria infection prevalence was recorded as high as 100 percent for „apapane. However, „apapane do breed in mid-elevation forests and have nesting success similar to nests at higher elevation, suggesting that some individuals may be developing disease resistance (Atkinson et al. 2005, Mitchell et al. 2005). The high mobility of „apapane coupled with their high susceptibility to the parasite also make them exceptional reservoir hosts for the parasite.

4.5.4 Hawai‘i ‘Elepaio (*Chasiempis sandwichensis*)

The Hawai„i „elepaio is a monarch flycatcher endemic to the Island of Hawai„i. The species has highly variable plumage. The Hawai„i Island subspecies is morphologically variable and shows the most dramatic differences between sexes compared to other subspecies. In general, adults are primarily brown, with white and chestnut streaks below. Immature Hawai„i „elepaio are dull gray brown, with gray below, and have buffy wingbars. Male and female „elepaio have a 2 year delay in plumage maturation, meaning they do not acquire their adults plumage until they are 3 years old. As the age of the bird increases, the amount of white increases at the throat, wing covert, rump, and tail. Due to variations in plumage color, authorities have described additional subspecies on Hawai„i Island (*C. s. ridgwayi* and *C. s. bryani*), but these are not widely accepted (VanderWerf 1999).

Currently, two additional subspecies (*C. s. sclateri* and *C. s. ibidis*) are recognized on the islands of Kaua„i and O„ahu, respectively. *Chasiempis sandwichensis* originally colonized the State between 1.5-1.9 million years ago. Interisland song playbacks by VanderWerf (2007) suggest that the passerine first arrived to Kaua„i and was subsequently blown to Hawai„i Island and then O„ahu after different storms. The entire species is absent from other islands in the State. It is likely that these subspecies may eventually be separated into three species due to genetic evidence and plumage differences (VanderWerf 2007).

The „elepaio is a nonmigratory, highly curious bird. Pairs are monogamous and territorial throughout the year. The young remain with their parents for 9 months, during which time they are taught foraging behaviors. After leaving the nest, the young remain within 0.6 mi of their parents.

The „elepaio was given its name due to the sound of its song. Males sing to defend their territory and attract mates. This song is generally answered by the female‟s two-note call. Although „elepaio are territorial during the entire year, this behavior is more prevalent immediately before and during nest construction. As a result, they do not generally call during the nonbreeding season. Compared to subspecies on the other islands, the Hawai„i „elepaio has the most phases and frequencies in their calls (VanderWerf 2007).

Currently, Hawai„i „elepaio can be found in forested areas above 2,000 ft. Known populations occur in Kohala and on the western slope of Mauna Kea. The estimated islandwide population is about 150,000 individuals (Mitchell et al. 2005).

Approximately 138,900 (± 605 SE) Hawai„i „elepaio occur in the North Hāmākua study area. Of this total, roughly 27 percent of the population (or 38,000 birds) occur in the HFU. The primary concentration within the study area occurs in the southerly portion of the upper elevation forest, just south of the Refuge. Surveys conducted during a 24-year study period (1977- 2000) between the months of February-July resulted in 5,537 „elepaio observations. During a 14-year study period (1987-2000), the mean density of „elepaio specifically within the HFU was 2.57 birds per 2.47 acre. No trends in density were observed during either of these study periods (Camp et al. 2003).

Higher densities of „elepaio occur in upper-elevation, closed-canopy, high-stature forests compared to the lower degraded, open forests. More specifically, „elepaio densities were positively influenced by „ōhi„a, high-stature forests, and elevation. In contrast, variables negatively associated with density include grass, open or sparse canopy, midstature forest, presence of matted ferns, banana poka, *Psidium*, slope, temperature, and rainfall (Camp et al. 2003).

Except for the O„ahu „elepaio, this species appears to be less affected by human disturbance than most native Hawaiian birds due to their high adaptability. „Elepaio are able to utilize a variety of habitats, employ various behaviors to search for and capture prey, and consume a wide range of invertebrates. Foraging techniques range from gleaning to hanging and aerial hawking. „Elepaio are also able to survive in both native and nonnative forests from dense rainforests to dry, open woodlands in a wide range of elevations (VanderWerf 1998, 2007). Though avian disease is a concern for Hawai„i „elepaio as well, they have also shown to have a greater immunity to avian diseases compared to other native Hawaiian forest birds. Hawai„i „elepaio showed recovery 4-years after an outbreak of the pox virus at the HFU in 1992 (VanderWerf 1998). However, recent evidence indicates that the species‟ low -elevation range may be decreasing on Hawai„i Island (Camp et al. 2003).

Loss and degradation of habitat is an important factor in the population status of the „elepaio (VanderWerf 1993). In addition, disease and predation by mammals (especially rats) also threaten populations. The results of ungulate and small mammal control, habitat restoration, habitat monitoring, and disease studies could help to sustain existing populations (Mitchell et al. 2005).

4.5.5 'Ōma'o (*Myadestes obscurus*)

The „ōma„o is one of five species of Hawaiian thrushes (Turdidae). Like all adult Hawaiian thrushes, „ōma„o have drab olive-brown and gray plumage. Immature birds are heavily scalloped with buff on the wings and breast. „Ōma„o often perch silently for long periods and are more often detected by their song. Males perform a flight-song display known as "skylarking".

The „ōma„o is endemic to the Island of Hawai„i. „Ōma„o primarily occur in two populations on the eastern and southern slopes of the Island of Hawai„i at elevations greater than 3,300 ft. A third, smaller population occurs in alpine scrub habitat between 6,500-9,750 ft elevation. Currently, „ōma„o occupy an estimated 30 percent of their former range, which historically included habitats from 1,000-9,750 ft elevation. Bird surveys from 1976-1983 estimated the population at 170,000 individuals. Based on more recent surveys, the populations appear stable and may be increasing in habitats below 3,450 ft (Mitchell et al. 2005).

Approximately 57,500 (± 191 SE) „ōma„o occur in the North Hāmākua study area. The HFU currently protects 29 percent of the „ōma„o population in the study area (approximately 16,900 „ōma„o) and no trends in „ōma„o densities were detected for either the 24-year (1977-2000) or 14-year (1987-2000) study periods. „Ōma„o occurred at a density of 0.7 birds per acre (SD = 1.22) at the HFU over the 14-year study period (Camp et al. 2003).

„Ōma„o may be declining throughout the central windward region of Hawai„i. „Ōma„o at the Kūlani-Keauhou study area significantly declined from the 1990s-2000s (1.1-0.8 birds per acre). Moreover, higher densities of 1.1-1.4 birds per acre were previously observed during the 1972-1975 and 1977 surveys, respectively (Gorresen et al. 2005).

„Ōma„o appear to have recolonized the Mauna Loa Strip study area in the late 1970s as the species was recorded as absent or rare in prior surveys conducted in the 1940s and early 1970s. However, the density of „ōma„o appears to have significantly decreased shortly after 1977, after which it maintained fairly stable, if low, densities (0.07-0.004 birds per acre).

In the East Rift study area, „ōma„o densities decreased from 0.6 birds per acre in 1979 to 0.4 birds per acre during the 1993/1994 survey periods. At the „Ōla„a study area, „ōma„o densities during the 1977 and 1994 surveys were not significantly different (1.64 birds/2.47 ac in 1977, 0.77 birds/2.47 ac from 1992-1994). However, the highly variable densities of „ōma„o observed over the 4 years of survey in the „Ōla„a study area may act to conceal trends.

„Ōma„o are found at their highest densities in the wet forests at high elevations within the HFU. However, „ōma„o also occur at lower densities at mid-elevations and in open and drier habitats of the Refuge (Camp et at. 2003). „Ōma„o disappeared from the Kona district during the early part of the 20th century (Ralph and Fancy 1994b) and are not present at the KFU. „Ōma„o occur in mesic and wet montane „ōhi„a or mixed „ōhi„a and koa forests in the Hāmākua, Ka„ū, and Kīlauea districts (Mitchell et al. 20005).

„Ōma„o have a diet of primarily native and introduced fruits, supplemented by invertebrates. Food plants include „ōlapa, kōlea, kāwa„u, naio, pilo, pūkiawe, „ōhelo, and „ākala. In the small alpine scrub population on Mauna Loa, pūkiawe, „ōhelo, kūkaenēnē, and „a„ali„i are consumed (USFWS 2005). The birds also forage opportunistically for seasonally available food items. Invertebrate prey items include caterpillars (Lepidoptera), spiders (Araneida), beetles (Coleoptera), and land snails (Gastropoda) (Wakelee et al. 1999).

Breeding activity of the „ōma„o extends from January-November, with nesting peaking from April-July. Nest sites are highly variable and include tree ferns; natural true cavities, cavity-like spaces (open cavities), ledges, niches, and natural scars in „ōhi„a and koa trees; and trunk and trunk or branch forks in „ōhi„a, koa, and naio trees. Live, dead, and partially dead trees are all used as nest sites. Birds in the high-elevation Mauna Loa population apparently nest on the ground in lava formations or in lava tubes (Wakelee et al. 1999). Both sexes defend small nesting territories and have a mean home range size of 0.9 ± 0.1 ac (Ralph and Fancy 1994b). Fledglings remain in their natal territories for 4-6 months after fledging. A male-biased sex-ratio exists, but its significance to populations is unknown (Fancy et al. 2001).

„Ōma„o are susceptible to the same factors that threaten other native Hawaiian forest birds, including loss and degradation of habitat, predation by mammals, and disease. „Ōma„o occur at lower densities in degraded habitat likely because pigs and other ungulates destroy important food plants and degrade habitat. „Ōma„o nests are very accessible and are therefore vulnerable to predation by rats and native raptors. The prevalence of disease (malaria and avian pox) in tested areas is low, and „ōma„o from low elevations exposed to malaria recovered quickly (Atkinson et al. 2001), suggesting a greater resistance to disease compared to other native forest birds. However, the disappearance of populations from lower elevations has been the pattern of decline noted in other Hawaiian birds susceptible to mosquito-borne diseases (Mitchell et al. 2005).

4.5.6 Pueo (*Asio flammeus sandwichensis*)

The pueo is an endemic subspecies of the nearly pandemic short-eared owl. The adult is brown and buffy white and ventrally streaked with darker brown. The eyes are yellow and the bill is black. Unlike most owls, pueo are diurnal, though nocturnal or crepuscular activity has also been documented. Pueo are commonly seen hovering or soaring over open areas.

The pueo is found on all the main Hawaiian Islands from sea level-8,000 ft. There have been no surveys to estimate the population of the Hawaiian short-eared owl. The species was widespread at the end of the 19th century but is thought to be declining (Mostello 1996, Mitchell et al. 2005).

Pueo occupy a variety of habitats, including wet and dry forests, but are most common in open habitats such as grasslands, shrublands, and montane parklands, including urban areas and those actively managed for conservation (Mitchell et al. 2005). Their relatively recent establishment on Hawai„i may have been tied to the rats that Polynesians brought to the islands. In Hawai„i, pellet analyses indicate that rodents, birds, and insects respectively are their most common prey. Birds depredated by pueo have included passerines, seabirds, and shorebirds.

Little information is available on the impact of pueo predation on populations of native birds. The pueo has been implicated as a predator of nestlings of various endangered bird species in Hawai„i such as the „ākohekohe (VanGelder et al. 2001) and Maui parrotbill on Maui (Mounce 2008), palila on Hawai„i (Pratt et al. 1998), and puaiohi on Kaua„i (Snetsinger 2005). Pueo are also known to prey upon „apapane, common „amakihi, „i„iwi, and kōlea (Snetsinger et al. 1994).

Little is known about the breeding biology of the ground nesting pueo, but nests have been found throughout the year. Nests are constructed by females and are comprised of simple scrapes in the ground lined with grasses and feather down. Females also perform all incubating and brooding, while males feed females and defend nests. The young may fledge from nest on foot before they are able to fly and depend on their parents for approximately 2 months (Mitchell et al. 2005).

At the HFU, pueo are found only in the open areas and pastures of the reserve (Jeffrey, pers. comm.). The pueo is rare in the KFU of the Hakalau Forest NWR (Ball, pers. comm.).

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

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

4.6 Endangered Hawaiian Waterbirds

The Hawaiian Island archipelago supports six species of endangered waterbirds: the koloa maoli, „alae ke„oke„o, „alae „ula, ae„o, nēnē, and Laysan duck. All of these species, except for the nēnē, require wetlands for their survival. As a result, the loss and degradation of Hawai„i‟s coastal wetlands have been a significant factor in the decline of four endemic waterbirds in the main Hawaiian Islands. From 1780-1980, the area of coastal wetland habitat in the main Hawaiian Islands declined by 31 percent. Coastal wetlands were filled for commercial, residential, and resort developments and drained for agriculture. These developments have also degraded the water quality of the wetlands (Evans et al. 1994, USFWS 2005a). Predation by introduced animals, disease, and environmental contaminants have also contributed to the population decline of Hawai„i‟s endangered waterbirds. Furthermore, nonnative plants, such as mangroves and grasses, have encroached on wetlands and altered natural processes. Key threats to the nēnē (including habitat loss, behavioral problems, and inbreeding depression) are discussed in detail below (USFWS 2004).

No critical habitat has been designated for any of Hawai„i's endangered waterbirds (USFWS 2005a). The general recovery objectives for the endangered waterbirds (except the Laysan duck), as described in the Second Draft Recovery Plan for Hawaiian Waterbirds (2005a), are the following: stabilize or increase species populations to greater than 2,000 individuals; establish multiple self-sustaining breeding populations throughout their historical ranges; protect and manage core and supporting wetlands Statewide; eliminate or control the threat of introduced predators, diseases, and contaminants; and remove the islandwide threat of the koloa maoli hybridizing with mallards. Specific recovery objectives for the nēnē are outlined in the Draft Revised Recovery Plan for the Nēnē (2004) and are discussed below.

4.6.1 Nēnē (*Branta sandvicensis*)

The nēnē is a medium-sized goose endemic to the Hawaiian Islands. Adult males and females 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; these differences likely facilitate nēnē walking on lava flows. The nēnē was listed as endangered in March 1967 and is the State bird of Hawai„i.

In 1951, the wild nēnē population was estimated at 30 individuals. All populations since then have been or are currently being supplemented by captive-bred birds. As of 2009, the population was estimated at between 1,877-1,927 individuals, with 446 birds on the Island of Hawai„i, 416 birds on Maui, 850-900 birds on Kaua„i, and 165 birds on Moloka„i (USFWS unpubl).

At the HFU, a total of 10 adults and 25 goslings were introduced in 1996, 1997, 2002, and 2003. The population of nēnē has increased from 10 in 1996-1997 to approximately 200 in 2007. The number of known nests has increased from 1 to 38, and 40 mated pairs of nēnē were observed in 2007. Nēnē are found at the higher elevations of the HFU around the cattle ponds and are frequently seen at the administrative site (Jeffrey, pers. comm.). Adult nēnē disperse from the HFU typically by the end of May and have been regularly sighted at Kahuku (HAVO), Kūlani, Pōhakuloa Training Area (PTA), and Pu„u Anahulu. Several Hakalau individuals are also known to seasonally use Kapāpala Ranch and the Kīlauea region of HAVO. Nēnē can commonly be found in the pastures at the junction of Keanakolu Road, the Mauna Kea Summit Road, and Saddle Road (USFWS, unpubl.). Nēnē do not occur on the KFU (Jeffrey, pers. comm.).

Nēnē historically occurred in lowland dry forests, shrublands, grasslands, and montane dry forests and shrublands. Habitat preferences of contemporary populations are likely biased as preferences may be influenced by the location of release sites of captive-bred birds. Birds 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. Nēnē can be found from sea level to 7,900 ft (Mitchell et al. 2005, USFWS 2004). Seasonally, nēnē have been known to use areas up to 8,900 ft at HAVO/Kapāpala.

Nēnē graze and browse on the leaves, seeds, flowers, and fruits of at least 90 native and nonnative grasses, sedges, composites, and shrubs. Composition of diet varies with location and habitat, and the species may require a diverse suite of food plants. Nēnē disperse seeds and therefore play an important ecological role, especially in influencing the species composition of early successional plant communities. Historically, flocks moved between high-elevation feeding habitats to lowland nesting areas (Mitchell et al. 2005, USFWS 2004).

Pairs mate for life, and nēnē have an extended breeding season. Eggs can be found in all months except May-July, although the majority of birds nest between October-March. Nēnē nests consist of a shallow scrape, moderately lined with plant materials and down. Pairs typically return to previous years‟ nests sites, which are usually in dense vegetation (though this is highly variable); when available, kīpuka (islands surrounded by lava flows) may be preferred. Breeding areas encompass a variety of habitats including beach strand, shrubland, grassland, and lava rock, and occur at a range of elevations. On the islands of Hawai„i and Maui, most nests are built under native vegetation such as pūkiawe, „a„ali„i, and „ōhi„a. On Kaua„i, however, most nesting areas are dominated by nonnative species, and nēnē often nest under Christmas berry, shrub verbena, and ironwood. The young remain with their parents for up to 1 year (Mitchell et al. 2005, USFWS 2004).

Current threats to the nēnē include predation by mammals, exposure in high-elevation habitats, insufficient nutritional resources for both breeding females and goslings, a lack of lowland habitat, human-caused disturbance and mortality (e.g., road mortality, disturbance by human foot traffic), behavioral problems related to captive propagation as well as habituation to humans in general, and inbreeding depression (USFWS, unpubl., USFWS 2004). Predators of nēnē eggs and goslings include dogs, cats, rats, pigs, and mongooses. Dogs, cats, and mongooses are responsible for most of the known cases of adult predation (USFWS 2004). Nēnē have also been negatively impacted by human disturbance by hikers, hunters, and outdoor recreationists. In recent years, nēnē have been struck and killed by golf balls and vehicles (USFWS 2004).

Starvation and dehydration can also be major factors in gosling mortality. Approximately 81.5 percent of gosling mortality in Haleakalā National Park during the 1994-1995 breeding season was due to starvation and dehydration (USFWS 2004). In 2005-2007, between 30-50 percent of the goslings died due to dehydration and exposure at the HFU (USFWS, unpubl.). A lack of adequate food and water also seems to be a limiting factor in Hawai„i Volcanoes National Park (USFWS 2004). A similar study (gosling telemetry) at HAVO in 1995 and 1996 identified dehydration and starvation as the cause of death in the majority of gosling carcasses removed.

4.6.2 Koloa Maoli (*Anas wyvilliana*)

The koloa maoli is an endangered waterfowl endemic to the Hawaiian Islands. Federally listed as endangered in 1967, the koloa maoli is a small, mottled brown duck with emerald green to blue patches on their wings (speculums). Males are typically larger, have distinctive dark brown chevrons on the breast and feathers, olive-colored bill, and brighter orange feet. Females are slightly smaller and lighter in color. Compared to mallard ducks, koloa maoli are more secretive and about 20-30 percent smaller.

The former range of the koloa maoli includes all the main Hawaiian Islands, except for the islands of Lāna„i and Kaho„olawe. They are capable of spreading between islands and may be found up to 10,000 ft in elevation (Uyehara et al. 2007). Currently, the only naturally occurring population of koloa maoli exists on Kaua„i, with repatriated populations on O„ahu, Hawai„i, and Maui (Pratt et al. 1987, Engilis et al. 2002, Hawaii Audubon Society 2005). The current Statewide population of pure koloa maoli is estimated at 2,200 birds; approximately 200 individuals occur on the island of Hawai„i and the remainder reside on Kaua„i. The populations on O„ahu and Maui are suspected to largely consist of hybrids – a crossbreed between the koloa maoli and mallard ducks. Estimated koloa maoli counts on these islands are 300 and 50 birds, respectively (Engilis et al. 2002, USFWS 2005a). Genetic studies of the species have suggested that a pure, intact population of koloa maoli may not exist on O„ahu (Browne et al. 1993). Although hybridization has been documented to occur on Hawai„i"s lowland wetlands and remains a threat on Kaua„i, the koloa maoli population on these two islands appear to be stable (Engilis et al. 2002).

The Hawai„i Island population was reestablished between 1976-1982, when captive-bred birds were released in the Kohala Mountain (Engilis et al. 2002). Populations currently occur in the stock ponds in the Kohala Mountains; stream habitats of Pololū, Waimanu, and Waipio Valleys; and in the stock ponds and larger montane streams on Mauna Kea. On the HFU, this species inhabits and breeds in streams and ponds (USFWS 2002a, USFWS 2005a, Jeffrey, pers. comm.). Due to the lack of surface water at the KFU, this species is not expected to occur within the unit boundaries.

The koloa maoli uses a wide array of habitat types such as natural and manmade lowland wetlands, flooded grasslands, river valleys, mountain streams, montane pools, forest swamplands, aquaculture ponds, and agricultural areas. The diet of koloa maoli consists of aquatic invertebrates, aquatic plants, seeds, grains, green algae, aquatic mollusks, crustaceans, and tadpoles (Engilis et al. 2002, Hawaii Audubon Society 2005, USFWS 2005a). The majority of nesting occurs from March-June with broods observed year-round. Nests are placed in dense shoreline vegetation of small ponds, streams, ditches, and reservoirs. Bunch-type grasses, rhizominous ferns, and shrubs are typically used at nesting sites (Engilis et al. 2002). On the island of Hawai„i, successful breeding in the wild has been documented in the Kohala Mountains and at HFU (USFWS 2005a).

Although the USFWS Recovery Plan for Hawaiian Waterbirds lists the koloa maoli as having a high potential for recovery, the species has a high degree of threat due to hybridization with mallard ducks (USFWS 2005a). Hybridization with mallards is currently the greatest threat to this species" continued existence (Engilis et al. 2002, Uyehara et al. 2007). In addition to hybridization concerns, other hazards exist for koloa maoli. Known predators of eggs and chicks include mongooses, cats, dogs, and possibly rats. „Auku„u, largemouth bass, and American bullfrogs have been observed to take ducklings. Avian diseases are another threat to koloa maoli with outbreaks of avian botulism occurring annually throughout the State (Engilis et al. 2002).

4.6.3 ‘Alae ke‘oke‘o (*Fulica alai*)

The „alae ke„oke„o, or Hawaiian coot, is a small waterbird endemic to Hawai„i that is federally listed as endangered. Adult males and females have a black head, a slate gray body with white undertail feathers, and a prominent white frontal shield and bill; feet are lobed rather than webbed and are greenish-gray. Life-history and breeding biology are poorly known. „Alae ke„oke„o usefreshwater and brackish wetlands, which can include agricultural wetlands and aquaculture ponds. They are generalists and feed on land, from the surface of the water, or will dive. They will also graze on grass adjacent to wetlands. They will travel long distances if local food sources (e.g., seeds, leaves, snails, crustaceans, insects, small fish, etc.) are not available. Appropriate water levels are critical to nesting success. They create either open water nests or nests in emergent vegetation. Nesting occurs year-round, but most activity occurs March-September. Eighty percent of the population occurs on Kaua„i, but they are found on all the main Hawaiian Islands (with the exception of Kaho„olawe). The population is stable and estimated to be 2,000-4,000. Similar to the rest of the Hawaiian waterbirds, threats to „alae ke„oke„o are habitat loss, nonnative mammalian predators such as mongooses, rats, cats, barn owls, etc., altered hydrology (modified wetlands), nonnative invasive plants, and avian diseases (e.g., botulism). Though rare, „alae ke„oke„o are known to be present at the ponds at HFU (Mitchell et. al, 2005).

4.7 Endangered Mammal

4.7.1 ‘Ōpe‘ape‘a (*Lasiurus cinereus semotus*)

The endangered „ōpe„ape„a is the only extant native land mammal in the archipelago. Both males and females have a wingspan of approximately 1 ft, and females are typically larger bodied than males. Both sexes have a coat of brown and gray fur. Individual hairs are tipped or frosted with white.

Population estimates for all islands have ranged from hundreds to a few thousand. Since no accurate population estimates exist for this subspecies and because historical information regarding its past distribution is scant, the decline of the bat has been largely inferred. „Ōpe„ape„a have been regularly sighted in Kaua„i, Hawai„i, and Maui (Menard 2001).

Changes in seasonal abundance of „ōpe„ape„a at locations of different elevations indicate that altitudinal migrations occur on the Island of Hawai„i. During the breeding period (which begins as early as April), „ōpe„ape„a occurrences increase in the lowlands and decrease at high elevation habitats, such as the HFU. „Ōpe„ape„a occurrences are especially low from June-August in high elevation areas. In October, during the post-lactation period, bat occurrences increase at the HFU and in the central highlands. In January, bat occurrences at HFU also increase, possibly receiving „ōpe„ape„a from both the lowlands and central highlands (Menard 2001).

Echolocation studies in the Pua „Ākala tract at the HFU confirm these observations. The area has moderate use (less than 40 bat call pulses per week sampled) by „ōpe„ape„a between May-June. However, bat activity at Pua „Ākala dramatically increases during fall and winter (August-March) such that this area may be considered an important „ōpe„ape„a wintering ground for „ōpe„ape„a from many parts of the island (Bonaccorso 2008).

„Ōpe„ape„a roost in native and nonnative vegetation from 3-29 ft above ground level. They occur in both wet and dry areas of the island but are believed to be more abundant on the drier leeward side (Jacobs 1994). „Ōpe„ape„a have been found roosting in „ōhi„a, hala, coconut palms, kukui, kiawe, avocado, shower trees, pūkiawe, and fern clumps; they are suspected to roost in eucalyptus and Sugi pine stands. The species is rarely observed using lava tubes, cracks in rocks, or manmade structures for roosting. While roosting during the day, „ōpe„ape„a are solitary, although mothers and pups roost together (USFWS 1998c, Mitchell et al. 2005).

„Ōpe„ape„a feed on a variety of native and nonnative night-flying insects, including moths, beetles, crickets, mosquitoes, and termites (Whitaker and Tomich 1983) but may have a preference for moths of size range 0.6-0.89 in (Belwood and Fullard 1984, Fullard 2001). Prey is located using echolocation. Water courses and edges (e.g., coastlines and forest/pasture boundaries) appear to be important foraging areas. In addition, the species is attracted to insects that congregate near lights. They begin foraging either just before or after sunset depending on the time of year; altitude also may affect these patterns (USFWS 1998c, Mitchell et al. 2005).

It is suspected that breeding primarily occurs between September-December. Typically, two young are birthed in May or June. Breeding has only been documented on the islands of Hawai„i and Kaua„i (Baldwin 1950, Kepler and Scott 1990, Menard 2001).

Within the HFU, „ōpe„ape„a are found at Pua „Ākala, Maulua, and Upper Maulua Pond. Bats have been observed and/or heard year-round along roads, forest clearings, and within koa/„ōhi„a mixed montane mesic forests. Detections have occurred at elevations between 5,250-6,230 ft. Echolocation data show that the HFU is an important foraging site for the „ōpe„ape„a (Menard 2001, Bonaccorso 2008). „Ōpe„ape„a have been seen within the KFU, though little is known about their foraging or roosting habits there (USFWS 2008).

The availability of roosting sites is believed to be a major limitation in many bat species, but other possible threats to the „ōpe„ape„a include pesticides (either directly or by impacting prey species), predation, alteration of prey availability due to the introduction of nonnative insects, and roost disturbance. Management of the „ōpe„ape„a is also limited by a lack of information on key roosting and foraging areas, food habits, seasonal movements and reliable population estimates (USFWS 1998bc).

4.8 Native Hawaiian Invertebrates

Invertebrates are composed of a variety of groups including snails (Gastropoda) and various insects such as beetles (Coleoptera), true bugs (Heteroptera), and moths/butterflies (Lepidoptera). Over 5,000 endemic insect species occur in Hawai„i (Howarth et al. 2003), of which beetles and flies are the most specious (Goldsmith 2007).

Hawaiian invertebrates play an important role in native ecosystems. Invertebrate populations serve as critical food resources for „ōpe„ape„a and native Hawaiian birds and therefore limit the populations and distributions of these species (Howarth et al. 2003). Invertebrates are also essential pollinators and detritivores (Gambino and Loope 1992).

Native Hawaiian invertebrates found during surveys of the Refuge units are listed in Tables 4-2, 3, and 4. Due to the diversity of invertebrate species, expansive area of the Refuge units, and limitations of baiting techniques, numerous additional invertebrates species may be present on the units.

Several federally listed endangered invertebrate species, including three endangered picture-wing flies, occur on the Island of Hawai„i and within the Refuge units (Howarth et al. 2003, Haines and Foote 2005). The Blackburn‟s sphinx moth (*Manduca blackburni*), an endangered arthropod that occurs on Hawai„i Island, is not expected to occur at the HFU (Howarth et al. 2003) and has not been observed on the KFU.

In addition, Hawai„i Island is home to candidate endangered species, as well as species of concern (SOC). Species of concern do not receive legal protection, but might be in need of concentrated conservation actions. Eight candidate endangered arthropod species occur, and more than 100 species of concern are listed (Howarth et al. 2003). Some of these are expected to occur in the Hakalau Forest NWR. The HFU shelters a number of candidate endangered damselfly species in the endemic genus *Megalagrion* (Howarth et al. 2003).

Table 4-2. Endangered and Rare Native Invertebrate Species Occurring or Potentially Occurring on the Hakalau Forest NWR.

Family	Genus	Hawai‘i Island	Listed Species	Candidate Species	SOC
COLEOPTERA (Beetles)					
Aglycyderidae	*Proterhinus*	23	0	0	0
Cerambycidae	*Plagithmysus*	39	0	0	12
Curculionidae	*Rhyncogonus*	2	0	0	1
Elateridae	*Eopenthes*	3	0	0	2
DIPTERA (True Flies)					
Drosophilidae	*Drosophila*	141	3	1	0
HYMENOPTERA (Wasps, Bees & Ants)					
Colletidae	*Hylaeus*	28	0	0	17
LEPIDOPTERA (Moths & Butterflies)					
Crambidae	*Omiodes*	19	0	0	10
Geometridae	*Scotorythra*	20	0	0	0
ODONATA (Dragonflies & Damselflies)					
Coenagrionidae	*Megalagrion*	9	0	2	2

Source: Howarth et al. (2003), Haines and Foote (2005).

4.8.1 Picture-wing Flies (*Drosophila*)

In Hawai„i, the genus *Drosophila* contains over 600 endemic species of picture-wing flies. The Hawaiian drosophilids have been thoroughly studied throughout the State, beginning with genetic and evolution studies in the 1963 Hawaiian Drosophila Project (Howarth and Mull 1992). Within this genus, 11 species are listed as federally and State endangered species, a single species is listed as threatened, and 2 species are listed as candidate endangered species. Of the endangered species, two can be found on the Island of Hawai„i: *Drosophila heteroneura* and *Drosophila ochrobasis* (Federal Register 2008b). A third species found on the island, *Drosophila mulli*, is listed as threatened and a candidate endangered species, *Drosophila digressa*, is restricted to Hawai„i Island.

Drosophila surveys at the KFU were conducted in November 1999 and February 2000 using sponges baited with fermented mushrooms and bananas. Six species of endemic picture-wing flies were observed on the KFU including *D. basisetae*, *D. conspicua*, *D. heteroneura*, *D. silvestris*, *D. sproati*, and *D. tanythrix*. Nearly all of the drosophilids were found on the 4,500 ft transect (Foote 1999). Only one species found on the KFU is listed as endangered: *Drosophila heteroneura*. Of the 314 picture-wing flies collected on the Refuge, 37 percent were identified as *D. heteroneura*, making it the most abundant picture-wing fly on the Refuge unit. In addition, *D. heteroneura* observed during the KFU survey were the first observations of this species in the wild in approximately

10 years; the last specimen was seen in 1993 at Hualālai (Foote 1999). Thus, the population of *D. heteroneura* at the KFU is the only known extant population of this species (Haines and Foote 2005).

Drosophila heteroneura is endemic to the island of Hawai„i and restricted to montane wet „ōhi„a and mesic koa „ōhi„a forests on the west side of the island. Historically, *D. heteroneura* was relatively widely distributed between 3,400-6,000 ft above sea level. The picture-wing fly has historically been observed at Hualālai, Mauna Kea, Mauna Loa, and Kīlauea in five different montane environments (Federal Register 2006a).

The life-history of *D. heteroneura* requires breeding on the bark and stems of *Clermontia* (especially *C. clermontioides*) and *Delissea* spp. The larvae primarily inhabit the decomposing bark and stems of these two plants, but it is also known to feed within decomposing portions of *Cheirodendron* sp. in open mesic and wet forest habitat (Foote 1999, Federal Register 2008b).

According to the Designation of Critical Habitat for 12 species of picture-wing flies from the Hawaiian Islands (Federal Register 2008b), *D. heteroneura* has two Primary Constituent Elements or habitat features that are essential to the conservation of the species. These features include: (1) mesic to wet, montane, „ōhi„a and koa forest; and (2) the larval host plants *Cheirodendron trigynum* subsp. *trigynum*, *C. clermontioides*, *C. hawaiiensis*, *C. kohalae*, *C. lindseyana*, *C. montis- loa*, *C. paviflora*, *C. peleana*, *C. pyrularia,* and *Delissea parviflora*.

Five critical habitat units are designated for *D. heteroneura* within the Designation of Critical Habitat (Federal Register 2008b). Three of the units: Ka„ū Forest Reserve, Pit Crater, and Waihaka Gulch – occur on State or private land, and total 291 ac. An additional 687 ac in Lower Kahuku owned and managed by Hawai„i Volcanoes National Park comprise another critical habitat unit. Finally, 3,604 ac within the KFU are occupied habitat and have the necessary features that are essential for the conservation of *D. heteroneura*; thus they are designated as the fifth critical habitat unit (Federal Register 2008b).

Threats to the picture-wing flies include habitat degradation by ungulates, loss of host plants, and impacts of nonnative insect predators and parasites such as ants and wasps. The species is also eaten by native species such as the caterpillar *Eupithecia staurophragma* (Howarth and Mull 1992). The construction of an ungulate exclosure and rat control will remove the primary threats to *D. heteroneura* within the KFU (USFWS 2008).

4.8.2 Koa Bug (*Coleotichus blackburniae*)

The koa bug (Heteroptera: Scutellaridae) is a rare iridescent, blue, green, maroon, and yellow stink bug. Measuring almost an inch in length, *Coleotichus blackburniae* is the largest native true bug (Howarth et al. 2003). Historically, this species was common on koa and a„ali„i (*Dodonaea viscosa*) on the islands of Hawai„i, Maui, O„ahu, Kaua„i, and Moloka„i. Currently, the koa bug is rarely found in the State. The koa bug does occur at the HFU (Jeffrey, pers. comm.).

Information on the koa bug is scarce. Adults and nymphs feed on the fruits of native koa and a„ali„i, as well as the nonnative formosa koa. Adult females lay their eggs (about 32 per egg mass) on the leaves and fruits of these species, where the larvae develop (Johnson et al. 2005). The red and black larvae develop in five stages for an estimated 38 days. Female koa bugs are estimated to live for

80 days and begin mating 30 days after hatching. Both larvae and adult koa bugs emit odorous defense compounds when disturbed (Johnson et al. 2005).

The koa bug has no known natural predators; however, nonnative spiders and ants are known to parasitize *C. blackburniae* eggs, nymphs, and adults. The big-headed ant chews koa bug eggs and Western yellowjacket wasps are predators of young (Johnson et al. 2005). Other species known to kill koa bugs include *Anastatus* sp., *Acroclisoides* sp., and birds. In addition, two biocontrol agents (*Trissolcus basalis* and *Trichopoda pilipes*) that were introduced to control the southern green stink bug are able to locate and develop on *C. blackburniae*. Although these species have a relatively minor impact on *C. blackburniae* overall, substantial impacts may occur at individual sites (Johnson et al. 2005).

The koa bug has also been impacted by the reduced abundance and distribution of its host species as a result of agricultural activities and urban development. Because these plants typically fruit at the same time, locating host plants suitable to lay eggs may require *C. blackburniae* to disperse over long distances. Studies have shown that koa bug mortality due to dispersal accounted for about 50 percent mortality in all individuals studied (Johnson et al. 2005).

4.8.3 Cave Invertebrates

Until the 1970s, it was assumed that the young and geologically unique Hawaiian Islands did not support an abundance of cave-adapted fauna. However, Hawaiian caves have been found to support a diverse array of rare and highly specialized invertebrates (Howarth 1972, 1983, 1991). These cavernicoles can be classified into three categories: (1) troglobites, which are obligate cave species; (2) troglophyles, which can live in caves or other cave-like (moist cool dark) habitats; and (3) trogloxenes, which can be found in caves, but do not live their entire life in caves (Howarth 1973, 1983).

The Service recognizes one species of cave invertebrate on the Island of Hawai„i, the troglobitic cixid leafhopper *Oliarus polyphemus*, as a species of concern. Troglobites are only able to survive in cave ecosystems. These species are characterized by a number of anatomical and physiological adaptations to cave life (Barr 1968, Christiansen 1982, Holsinger 1994, Culver et al. 1995). Troglobites tend to lose their pigmentation, eyes, and hard exoskeletons. Additionally, troglobites have elongated appendages and sensory structures with long hairs, lengthened life span, and modified life-history patterns. As a result of their nutrient-poor environments, the life cycle of many troglobites is characterized by delayed reproduction, increased longevity, lower total egg production, and production of larger eggs (Culver 1982).

Obligate cave species have narrow and specific ecological requirements. Such requirements include high relative humidity, stable temperatures, and a preference for high CO_2 levels (Howarth and Stone 1990). They do not acclimate well to rapid changes in their physical, biological, or chemical environment (Barr 1968, Culver 1982). Troglobites also rely on energy and nutrient input from the surface. These invertebrates primarily feed on „ōhi„a roots or other plant roots that penetrate the lava tube roof (Howarth 1973; 1983, Howarth et al. 2007). Additional nutrient sources into caves include plant detritus washed in by surface waters, organisms that enter caves under their own power, and guano from bats, rats, and mice. Thus, cave systems can be strongly influenced by the surface ecosystem (Barr 1968, Culver 1982).

Obligate species known to occur on the Island of Hawai„i include endemic moths and spiders (*Sinella yoshiia*, *Schrankia* sp., *Littorophiloscia* sp.). None of the obligate cave fauna known from Hawai„i Island are currently listed as candidate, threatened, or endangered species, although two endangered species occur on Kaua„i.

Cave invertebrate studies were conducted at KFU by Dr. Howarth and Stone of the B. P. Bishop Museum (1998). Endemic arthropods found during this survey are listed in Table 4-3. These species included the cave carabid ground beetle, root moths, and a fruit moth. Linyphiid spider webs were also seen, which are likely a native species, and trails of the native *Limonia* crane flies (Tipulidae) were common in cave slime. In addition, several dead moths, probably native agrotine noctuids, were found. These moths are known to roost in caves (Howarth and Stone 1998).

4.8.4 Arthropods

Arthropods include insects, spiders, and crustaceans. There are 5,732 endemic and 101 indigenous terrestrial arthropod species identified in the Hawaiian Islands. The majority of the native arthropod fauna are insects (Howarth et al. 2003). Population declines of native arthropods throughout the State have been attributed to habitat destruction and loss of host species (Howarth et al. 2003). Nonnative ungulates, plants, and other arthropods also compete with native species and disturb their habitat (Haines and Foote 2005).

An arthropod survey was conducted at the HFU by Howarth et al. (2003). Sampling was conducted along a transect in the Pua „Ākala Tract, a transect in the Maulua Tract, and in the vicinity of the University of Hawai„i Biological Field Station in the Hakalau Tract. Of the 2,500 specimens

Table 4-3. Endemic Arthropods in Three Cave Systems at the KFU.

Taxon	Caves Surveyed		
	Cave 1	Cave 3	Cave 4
ARACHNID: Subclass: Acari (Mites)			
Unidentified			Live
ARANEAE (Spiders)			
Linyphiidae			
Unidentified		Webs only	
COLEOPTERA (Beetles)			
Carabidae			
Mecyclothorax sp.	Dead		
LEPIDOPTERA (Moths & Butterflies)			
Carposinidae			
Carposina cf. gracillima (Walsingham)			Live
Noctuidae			
Unidentified	Dead		
Schrankia sp. A (Twilight morph)		Live	Live
Schrankia sp. B (Cave morph)			Live
DIPTERA (Flies)			
Tipulidae			
Limonia sp.	Larval trails	Larval trails	

Source: Howarth and Stone (1998).

collected during the survey, only about 50 species have been identified. Although generalizations are difficult based on the low number of species identified, arthropod diversity was lower than expected.

Arthropod surveys in other areas of the island found that the optimal range of native arthropods is between 3,500-4,000 ft; thus, the majority of the Hakalau Unit is above the upper limit. During the survey, increased diversity was observed at lower elevation sites (Howarth et al. 2003). Ongoing arthropods surveys are being conducted by Goldsmith (2007), and by USGS-BRD (Banko and Peck) at the HFU.

Arthropod surveys were conducted by Haines and Foote (2005) throughout the KFU. This study occurred along four transects at elevations of roughly 2,500, 3,500, 4,500, and 5,500 ft. Several trends were observed during the study. First of all, diversity among native target genera was highest in the middle elevations of the KFU. In addition, native insect diversity generally decreases as disturbance increased (occupied by ungulates) and as invasive insect populations increased (Haines and Foote 2005).

Megalagrion (Odonata: Coenagrionidae)

Approximately nine species of native Hawaiian damselflies of the *Megalagrion* genus (Odonata: Coenagrionidae) occur on the Island of Hawai„i. *Megalagrion* damselflies inhabit a wide range of habitats including perennial stream, intermittent stream, rheocrenes (flowing seeps and springs), and standing water ecosystems (Polhemus 1993, Polhemus and Asquith 1996). Immature damselflies (or larvae) are typically aquatic, while some live in and under native plants. The adults feed on various small insects captured using their spiny legs. Immature damselflies prey on small animals using their extendable lower mouthpart (Polhemus and Asquith 1996).

Competition and predation from nonnative fish, frogs, and invertebrates is a primary threat to this genus (Polhemus 1993). Fish predators include Poeciliids (*Gambusia affinis, Poecilia reticulata, P. latipinna, Xiphophorus helleri,* and *X. maculatus*), as well as catfish, cichllids, and gobies. Alteration and degradation of freshwater habitat has also contributed to species declines. Human modifications that occurred during ancient Hawaiian times (taro lo„i and fishponds) and in the more modern times (diversion systems, urban development, ground water pumping) have impacted *Megalagrion* habitat (Polhemus and Asquith 1996).

Four damselflies species have been reported at the HFU and several additional species may also occur. One of these, *M. amaurodytum peles,* is a species of concern that was found throughout the Refuge in damp litter in axils of pa„iniu lilies (*Astelia menziesiana)* and „ie„ie (*Freycinetia arborea*) (Howarth et al. 2003). The Pacific Hawaiian damselfly (*M. pacificum*), an endangered species, may occur at the lowest elevations in the HFU. This damselfly species breeds in pools and streams. An additional species of concern that breeds in streams, *M. nigrohamatum*, may also occur in the lower elevations of the Refuge unit (Howarth et al. 2003).

Only a single *Megalagrion* species, the Beautiful Hawaiian damselfly (*M. calliphya*), is known at the KFU. Two males were seen in a pool at the unit (Haines and Foote 2005). On Hawai„i Island, this species is usually limited to areas above 985 ft. Male *M. calliphya* are mostly red with black strips, while females have a green thorax (Polhemus and Asquith 1996). Adults can breed in standing water, but prefer slow moving streams (Haines and Foote 2005).

Proterhinus (Coleoptera: Aglycyderidae)

A large diversity of beetles are found at the HFU of the Hakalau Forest NWR. Twenty-three species of weevils in the genus *Proterhinus* (Coleoptera: Aglycyderidae) are endemic to Hawai„i Island. These tiny, slow-moving beetles bore into leafs, twigs, stems, and wood and are known to have a very narrow host range (Haines and Foote 2005). This species exhibits a wide array of morphological diversity, making species level identification difficult. *Proterhinus* spp. were determined to be scarce throughout the HFU (Howarth et al. 2003).

A total of 71 *Proterhinus* specimens within five species (*P. affinis*, *P. ferrugineus*, *P. hawaiiensis*, *P. similis*, and *P. subangularis*) were collected from the KFU. Of the five species encountered, *P. similes* was the most abundant and was collected from eight different plant species (Haines and Foote 2005).

Plagithmysus (Coleoptera: Cerambycidae)

There are about 140 species of endemic longhorned beetles in the genus *Plagithmysus* (Coleoptera: Cerambycidae) in the State and 12 are considered species of concern on the island (Howarth et al. 2003). These wood-boring beetles are more showy and active than *Proterhinus* beetles (Haines and Foote 2005). Larvae pupate in the wood and adults emerge by chewing out, leaving visible exit holes. Typically adults lay eggs on recently fallen tree branches, but live trees are also used. *Plagithmysus* help with forest decomposition and serve as food for birds and other species.

Three species of longhorned beetles have been recorded as widespread throughout the HFU – *P. varians*, *P. clavigeris,* and *P. vicinus* (Howarth et al. 2003, Goldsmith 2007). Both *P. varians* and *P. clavigeris* are host-specific to dead koa (Howarth et al. 2003). At HFU, the density of longhorned beetles at low-elevation sites was double the density found at high-elevation sites. There are also seasonal differences in population size and characteristics. Because of their importance in forest ecology, longhorned beetles have been used as indicator species to assess recent reforestation efforts at the HFU (Goldsmith 2007).

At the KFU, three different species of longhorn beetles were collected: *P. bilineatus*, *P.debilis*, and *P. nodifer*. The host plant for *P. bilineatus* is „ōhi„ą while *P.debilis* and *P. nodifer* were both reared from koa. A new *Plagithmysus* species was also found on the unit. This new species was found on dead or dying branches of „a„ąwa (*Pittosporum hosmeri*) (Haines and Foote 2005).

Omiodes (Lepidoptera: Crambidae)

Several moths and butterflies (Lepidoptera) have been recorded on the HFU. Ten species of endemic leaf roller moths in the genus *Omiodes* (Lepidoptera: Crambidae) are listed as species of concern. This group gets its name because the larvae roll or fold leaves, or bind them together with silk, to create a retreat (Haines and Foote 2005). Most species utilize monocots as host plants.

Omiodes pritchardii, which is restricted to *Pritchardia* palms, was found at the lower elevation site in Pua „Ākala at the HFU (Howarth et al. 2003). *Omiodes accepta*, *O. asaphombra, O. localis* and *O. scotaea* have been collected from the KFU. *Omiodes accepta*, the sugarcane leafroller, was found to be the most abundant (27 of 49 total specimens) and is common on grasses and sedges. *Omiodes asaphombra* only breeds on rare „ohe (*Joinvillea ascendens*), which is not known to occur on the west side of Hawai„i Island. In addition, the species was previously determined to be extinct (Haines and Foote 2005).

Scotorythra (Lepidoptera: Geometridae)

The endemic inchworm genus *Scotorythra* (Lepidoptera: Geometridae) contains 20 species on Hawai„i Island. Members of this genus use a wide variety of host plants from koa to *Hedyotis* spp. The larvae are nocturnal foliage feeders that serve as important food items of nestling and fledgling native forest birds. During the daytime, the larvae hide in moss or under bark (Haines and Foote 2005).

Eight *Scotorythra* species were collected on the HFU during a survey by Howarth et al. (2003). Two of these were considered new species. During a study by Goldsmith (2007), five species of endemic *Scotorythra* were collected at the HFU. These specimens made up 83 percent of the Lepidoptera in winter and 87 percent in summer. The KFU provides habitat for eight species of *Scotorythra* moths. *Scotorythra arboricolans* and *S. artemidora* were the most abundant species, with 33 and 32 individuals collected from light field traps, respectively. *Scotorythr arboricolans* is found on all the main Hawaiian Islands, while *S. artemidora* is restricted to Hawai„i Island (Haines and Foote 2005).

Eopenthes (Coleoptera: Elateridae)

Three endemic *Eopenthes* click beetles (Coleoptera: Elateridae) are recorded on Hawai„i Island. This genus is active almost exclusively during the summer months and is only found within mountainous regions. *Eopenthes* larvae, which are typically found in decaying wood, presumably feed on other invertebrates. Adults, on the other hand, feed solely on nectar.

Although this genus was not reported during surveys at the HFU, it is expected to occur within the unit (Howarth et al. 2003). One specimen of *Eopenthes* was collected from blossoms of Hawaiian holly (*Ilex anomala*) along the southern boundary of the KFU. This individual is most likely *E. cognatus*, which is a SOC and former "Category 2" species. Additional *Eopenthes* individuals were seen around Hawaiian holly blossoms (Haines and Foote 2005).

Dyscritomyia (Diptera: Calliphoridae)

In addition to the *Drosophila* genus, other Diptera species occur throughout the island. Twelve species of *Dyscritomyia* flies (Diptera: Calliphoridae) occur on Hawai„i Island, generally confined to high-elevation wet habitats. The immature *Dyscritomyia* feeds on carrion (land snails), while the adults feed on snail slime trails and other liquid proteins. Only one *Dyscritomyia* species was found during the survey at Hakalau. Four orders of flies were found in the HFU (Howarth et al. 2003).

Hylaeus (Hymenoptera: Colletidae)

Of the 28 species of yellow-faced *Hylaeus* bees (Hymenoptera: Colletidae) on Hawai„i Island, currently 17 are considered species of concern. Male *Hylaeus* bees tend to have distinct yellow markings on the fronts of their heads. The adults eat the nectar of native plant species and subsequently assist with pollination.

No yellow-faced bees were reported during the HFU survey by Howarth et al. (2003), although this taxa should occur onsite. Ten yellow-faced bee species were collected on the KFU. Three of these, *H. crabronoides*, *H. filicum*, and *H. specularis* are extremely rare and local (Haines and Foote 2005). Certain ant species compete with this genus for nesting sites (Mitchell et al. 2005).

Table 4-4. Arthropods Occurring at the HFU and KFU.

SPECIES	Hakalau Unit-Abundance	Kona Unit-Number Observed
ARANEAE (Spiders)		
Tetragnathidae		
Tetragnatha quasimodo	C	
Tetragnatha sp. 1	S	
Tetragnatha sp. 2	R	
Theridiidae		
Theridion grallator		2
ODONATA (Dragonflies & Damselflies)		
Aeshnidae		
Anax strenuous	S	
Coenagrionidae		
Megalagrion calliphya calliphya	R	2
Megalagrion hawaiiense	R	
Megalagrion amaurodytum peles	S	
Megalagrion blackburni	R	
ORTHOPTERA (Grasshoppers & Crickets)		
Gryllidae		
Laupala sp. 1	C	
Leptogryllus sp. 1	S	
Trigonidium spp.	C	
DIPTERA (True Flies)		
Calliphoridae		
Dyscritomyia sp. 1	R	
Drosophilidae		
Drosophila basisetae		8
Drosophila conspicua		4
Drosophila heteroneura (CE)		116
Drosophila silvestris		13
Drosophila sproati		80
Drosophila tanythrix		93
Muscidae		
Lispocephala sp. 1	R	
Pipunculidae		
Cephalops sp.	R	
Tipulidae		
Gonomyia hawaiiensis	R	

SPECIES	Hakalau Unit-Abundance	Kona Unit-Number Observed
HETEROPTERA (True bugs)		
Colletidae		
*Hylaeus coniceps**		*27*
*Hylaeus connectens**		*2*
*Hylaeus crabronoides**		*10*
*Hylaeus difficilis**		*69*
Hylaeus dumetorum		12
*Hylaeus filicum**		1
*Hylaeus pubescens**		1
Hylaeus specularis		22
*Hylaeus sphecodoides**		11
Hylaeus volcanicus		2
Miridae (Leaf bugs)		
Kamehameha lunalilo	R	
Koanoa hawaiiensis		
Orthotylus sp. 1	S	
Nabidae (damselbugs)		
Nabis lusciosus	C	
Nabis oscillans	S	
Reduviidae (Assassin bugs)		
Nesidiolestes selium	R	
Saicella mulli	R	
LEPIDOPTERA (Moths & Butterflies)		
Crambidae		
Omiodes accepta		27
Omiodes asaphombra		4
Omiodes localis		11
Omiodes (=Hedylepta) prichardii	R	
Omiodes scotaea		8
Geometridae		
Eupithecia craterias		5
Eupithecia monticolans		3
Eupithecia staurophragma		2
Prognostola cremnopsis	S	
Scotorythra apicalis		1
Scotorythra arboricolens	C	33
Scotorythra artemidora	C	32
Scotorythra epixantha	R	
Scotorythra euryphaea		40
Scotorythra goniastis	R	
Scotorythra paludicola	R	6
Scotorythra rara	C	53
Scotorythra new sp. 5		6
Scotorythra new sp. 7	R	
Scotorythra new sp. 13	R	4

SPECIES	Hakalau Unit-Abundance	Kona Unit-Number Observed
Noctuidae		
Agrotis epicremna	R	
Haliophyle euclidias	C	
Haliophyle flavistigma	R	
Haliophyle ignita	R	
Pseudaletia macrosaris	R	
Pseudaletia sp. A	R	
Oecophoridae		
Thyrocopa sp.	C	
Sphingidae		
Hyles wilsoni		11
COLEOPTERA (Beetles)		
Aglycyderidae		
Proterhinus spp.	S	
Proterhinus affinis		11
Proterhinus ferrugineus		6
Proterhinus hawaiiensis		5
Proterhinus similes		43
Proterhinus subangularis		6
Anobiidae		
Xyletobius sp. 1	S	
Carabidae		
Bembidion spp.	S	
Blackburnia sp. 1	S	
Blackburnia sp. 2	S	
Blackburnia sp. 3	S	
Mecyclothorax sp. 1	R	
Cerambycidae		
Plagithmysus bilineatus		3
Plagithmysus clavigeris		X
Plagithmysus debilis		X
Plagithmysus nodifer		X
Plagithmysus vicinus vicinus	C	
Plagithmysus varians		
Plagithmysus sp.		4
Curculionidae		
Achalles sp. 1	S	
Oodemas sp. 1		
Elateridae		
Anchastus swezeyi		62
Eopenthes cognatus?		1
HYMENOPTERA (Wasps, Bees & Ants)		
Ichneumonidae		
Enicospilus sp. A	S	
Enicospilus sp. B	S	

SPECIES	Hakalau Unit-Abundance	Kona Unit-Number Observed
Enicospilus sp. C	S	
Sphecidae		
Ectemnius atripennis		6
Ectemnius sp. A	R	1
NEUROPTERA (Lacewings)		
Chrysopidae		
Anomalochrysa sp. A	R	
Hemerobiidae		
Micromus spp.	S	
SPIROSTREPIDA (Millipedes)		
Cambalidae		
Nannolene sp. 1	S	

R = Rare, S = Scarce, C = Common; * = Species of concern, CE = Candidate endangered. Source: Howarth et al. (2003), Haines and Foote (2005).

4.8.5 Mollusks

Native land snails in Hawai„i are comprised of 767 currently identified endemic species within 51 genera (Mitchell et al. 2005). Most of these are endangered due to habitat destruction, shell collecting, and predation by nonnative species (Howarth et al. 2003). Of the extant groups, *Tornatellides* (Achatinellidae) and *Succinea* (Succineidae) are the most abundant (Mitchell et al. 2005). No endangered land snails occur on the Island of Hawai„i.

Mollusk surveys were conducted by Howarth et al. (2003) along two elevational transects in the HFU: Pua „Ākala in the south and the Maulua tract in the north. Additional sampling was conducted in the Hakalau tract, along the dry gulch, and in the vicinity of the University of Hawai„i Biological Field Station. A total of 231 live specimens and 111 empty shells were collected during this survey; however, additional species are believed to occur in areas that were not sampled (Howarth et al. 2003).

Succinea cf. cepulla (Succineidae) and *Tornatellides* sp. (Achatinellidae) were the only two native mollusk species found. In the Pua „Ākala Tract, two specimens of *Succinea* cf. *cepulla* were found around 4,200 ft elevation. The two specimens of *Tornatellides* sp. found at the Refuge were collected in „ōhi„a leaf litter at the Maulua Tract and the Pua „Ākala Tract. This species has a translucent, conical shell measuring 0.12 inches long (Howarth et al. 2003).

Aquatic mollusks in Hawai„i favor brackish habitats and therefore are usually restricted to lower elevation areas near the ocean. The endemic freshwater snail, hīhīwai, can live in higher elevation freshwater areas; however, it would most likely not be able to reach the lower elevations of the HFU (Kinzie, pers. comm.).

4.9 Endangered and Threatened Plants

Forty-four percent of all the endangered plants in the United States occur in the Hawaiian Islands (Messing et al. 2007). Currently, 343 plants are listed as Federal and State endangered species in the State of Hawai„i and 11 additional species are listed as threatened. Of these totals, 68 endangered species and 1 threatened species occur on Hawai„i Island. Additional species are deemed candidates for listing throughout the State.

Both units of the Hakalau Forest NWR contain endangered and threatened plants and/or contain habitat that could support endangered and threatened individuals. Endangered and threatened species that occur (or potentially occur) at the Hakalau Forest NWR are listed in Table 4-2.

It is estimated that roughly 97 plant species that previously existed throughout the Hawaiian Islands are now extinct (USFWS 2008). In an effort to avoid further extinctions, the Refuge outplants rare species. Since 1987, close to 4,000 endangered plants have been outplanted on the HFU (USFWS, unpubl.). Approximately 1,029 endangered plant species were propagated or outplanted on the HFU in 2007 alone (USFWS 2007a). To date, no endangered or threatened species have been outplanted at the KFU due to the presence of ungulates.

Endangered and threatened plants occurring on Hawai„i Island are specifically threatened by nonnative species such as ungulates, invertebrates, and invasive plants. Other factors that have the potential to decrease plant populations include fire, recreational activities, military actions, disease, genetic limitations, and random events such as volcanic eruptions and hurricanes (USFWS 2008).

The Big Island Plant Cluster Recovery Plan (USFWS1996a) covers 22 endangered and threatened plant species. According to this plan, the following objectives need to be obtained to delist an endangered plant species:

- Total of 8 - 10 populations documented on the island;
- Each population must be naturally reproducing, stable, or increasing in number;
- Each population must be secure from threats;
- For long-lived and short-lived perennials, each population must have a minimum of 100 and 300 mature individuals, respectively;
- For annuals, each population must have a minimum of 500 mature individuals; and
- Each population should persist at this level for a minimum of 5 consecutive years.

The Addendum to the Recovery Plan to the Big Island Plant Cluster Recovery Plan (1998a) addresses 13 plant species on the island, including three that occur or potentially occur on the Hakalau Forest NWR (*Cyanea platyphylla, Phyllostegia racemosa, and P. velutina*). *Asplenium peruvianum* var. *insulare* is covered in the Recovery Plan for Four Species of Hawaiian Ferns (1998b). Specific delisting and downlisting criteria for these species are discussed below.

Table 4-5. Endangered and Threatened Plant Species that Occur (or Potentially Occur) at Hakalau Forest NWR.

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Aspleniaceae	**Spleenwort family**			
Asplenium peruvianum var. *insulare*	--	E		X
Campanulaceae	**Bellflowers family**			
Clermontia lindseyana	„oha wai	E	X (CH)	X
Clermontia peleana	„oha wai	E	P (CH)	
Clermontia pyrularia	„oha wai	E	X (CH)	
Cyanea hamatiflora subsp. *carlsonii*	hāhā	E		P (CH)
Cyanea platyphylla	„aku„aku	E	P	
Cyanea shipmannii	hāhā	E	X (CH)	
Cyanea stictophylla	hāhā	E		X
Caryophyllaceae	**Pink family**			
Silene hawaiiensis	--	T		P
Curcurbitaceae	**Gourd family**			
Sicyos macrophyllus	„anunu	C		X
Gesneriaceae	**African violet family**			
Cyrtandra tintinnabula	ha„iwale	E	X (CH)	
Lamiaceae	**Mint family**			
Phyllostegia floribunda	--	C		P
Phyllostegia racemosa	kiponapona	E	X (CH)	
Phyllostegia velutina	--	E	X (CH)	P
Portulacaceae	**Purslane family**			
Portulaca sclerocarpa	po„e	E		P
Solanaceae	**Nightshade family**			
Nothocestrum breviflorum	„aiea	E		P

Status: E = Endangered; T = Threatened; C = Candidate.
Occurrence: X = Individuals known to occur on the unit; P = Potentially occurs on the unit; CH = Critical habitat designated on the unit.

4.9.1 *Asplenium peruvianum* var. *insulare*

Asplenium peruvianum is a fern native to the Andes in South America. The Hawaiian variety, var. *insulare*, is a federally listed endangered species. It was originally listed as *Asplenium fragile* var. *insulare* in 1994. This delicate fern has glabrous fronds measuring between 6 - 18 in long and 0.4-1.2 in wide. The upper surfaces of the fronds have dull gray or brown stripes with two greenish ridges. The long, narrow blades on the fronds are 1-pinnate and pale green to dark green. The sori, or spore-producing bodies, are close to the main vein, with one to two on the lower side and two to four on the upper side. *Asplenium peruvianum* var. *insulare* has creeping rhizomes measuring between 0.12-0.5 in in diameter. Compared to the variety in South America, the coarser Hawaiian variety is larger in size and the midribs of the fern blades (rachises) are thicker. In addition, almost all of the pinnae (primary division of the compound blade) have a superior basal lobe (Palmer 2003).

Asplenium peruvianum var. *insulare* is present on East Maui and Hawai„i Island between 5,413-7,218 ft (Palmer 2003). The species historically occurred on the upper slopes of Mauna Loa above Kipuka Ahiu, Pu„u Wa„awa„a on Hualālai, near Hilo, as well as at Kalaieha, Laumai„a, Keanakolu, and „Umikoa on Mauna Kea (USFWS 1998b). Currently, it is known at Pu„u Huluhulu, Pōhakuloa Training Area (PTA), Kūlani Correctional Facility, Keauhou, the Mauna Loa Strip Road in Hawai„i Volcanoes National Park, Kapāpala Forest Reserve, Ka„ū Forest Reserve, and the summit area of Hualālai. The largest population occurs at PTA. It is comprised of approximately 200 individuals within 9 subpopulations (USFWS 1998b). The population at the Kapāpala Forest Reserve was comprised of 300 mature individuals in 2003 (Federal Register 2003b). It is also found on the KFU. On Maui, *A. peruvianum* var. *insulare* was recently reported in the Hanawī Natural Area Reserve (NAR) and has been previously sited on the north slope of Haleakalā and Kanahau Hill (USFWS 1998b).

The species grows almost exclusively in dark, moist environments such as rock crevices or in lava tube openings (Palmer 2002) within montane wet, mesic, or dry forests, as well as subalpine dry forest and shrublands (USFWS 1998b). The fern prefers areas receiving between 48-100 in per year. It is often associated with mosses and liverworts (USFWS 1998b).

Palmer (2002, 2003) proposes that morphological and habitat differences within the species suggest *Asplenium peruvianum* var. *insulare* may be divided into two taxa. One form is delicate, nonproliferous, longer, narrower, and light green in color. This form is often found in lava tubes openings. In contrast, a coarser, proliferous, shorter, wider, darker green form is usually found in more open areas (Palmer 2002, 2003).

Critical habitat is designated on both islands where *Asplenium peruvianum* var. *insulare* is present. On Hawai„i Island, the critical habitat area encompasses 2,241 ac in the Pāhala watershed, which is the southernmost critical habitat within the species" historical range. In addition, two populations were given critical habitat designation on Maui (Federal Register 2003b).

Habitat degradation and browsing by sheep and goats are identified as the main threat to this species existence. Cattle may also negatively impact *A. peruvianum* var. *insulare*. Nonnative fountain grass is known to invade *A. peruvianum* var. *insulare* habitat. Some populations are also threatened by military operations and fires that result from these operations, as well as construction activities (USFWS 1998b).

The downlisting criteria established in the Recovery Plan for Four Species of Hawaiian Ferns (1998b) requires 5-7 populations on both islands that are naturally reproducing, stable or increasing in number, and secure. Each population must have a minimum of 300 mature individuals for 5 consecutive years. In order to delist the species, a total of 8-10 naturally reproducing, stable populations must be documented on both Maui and Hawai„i Island. Each population must contain at least 300 mature individuals per population for 5 consecutive years.

4.9.2 *Clermontia lindseyana*

Clermontia lindseyana is an endemic, small tree that was listed as endangered in April 1994. Species within this genus are often referred to by the Hawaiian name „oha wai. The species grows between 8.2-20 ft in height and can occur as an epiphyte or terrestrial dweller. The oblance shaped leaves are dark green on the upper surface and pale green to purple on the underside. *Clermontia lindseyana* can be distinguished from other species in the genus by its larger leaves and hairy undersurface. It has round, orange berries measuring between 1-1.6 in in diameter. Fruiting occurs from June-October.

Clermontia lindseyana occurs in wet „ōhi„a and mesic koa/„ōhi„a forests on the islands of Maui and Hawai„i. On Maui, a single population of approximately 300 individuals is known to occur on the eastern part of the island around 4,500 ft. Historically, it also occurred on the southern slope of Haleakalā. On Hawai„i Island, an estimated 11 populations occur between 4,680-6,200 ft. Currently, these populations are comprised of a total of 86 individuals. The populations occur on or near the following locations: Pīhā, Laupāhoehoe, Makahanaloa, Kukuiopa„e, Pu„u O„o, Kūlani Correctional Facility, Kahikinui, Kūlani Boys Home, Ka„ū Forest Reserve, and both units of the Hakalau Forest NWR. The largest population on the island (19 individuals) is found on the Ka„ū Forest Reserve. Historical records show *C. lindseyana* occurring on the eastern slope of Mauna Kea and throughout the slopes of Mauna Loa (USFWS 1996a).

At the HFU, wild individuals occur in the Upper Maulua (2), Lower Honohina Tract (4) and the Hakalau Tract (4). Between 1999 and 2008, an estimated 988 *C. lindseyana* were outplanted in the Upper Honohina, Maulua, Pua „Ākala, and Hakalau Tracts. The majority of these (286 plants) were outplanted in 2001 (USFWS, unpubl., Jeffrey et al. 2001).

In 2003, three critical habitat units encompassing roughly 10,459 ac were designated for *C. lindseyana* on the Island of Hawai„i. Critical habitat was also previously designated for two populations on Maui. Of the total critical habitat area, 2,202 ac occur within the HFU (Federal Register 2003b).

Invasive species, such as cattle, goats, pigs, rats, nonnative invertebrates and invasive plants, are the primary threats to *C. lindseyana*. Animal species can trample and graze plants, or facilitate the spread of nonnative plants. Both kikuyu grass and banana poka are known to directly compete with *C. lindseyana* (USFWS 1996a). Rats are known to have eaten all of the fruit and seeds from the wild individuals of *C. lindseyana* (USFWS 1996b).

4.9.3 *Clermontia peleana*

Listed as federally endangered in April 1994, *Clermontia peleana* is endemic to Hawai„i Island. It can grow on the ground or as an epiphyte on „ōhi„a, koa, „ōlapa, and „ama„u. The leaves are oblong to elliptic and alternately arranged. The petals and flower parts are fused into a tube and curved down. Flowers can be two colors depending on subspecies – *peleana* is black to purple and *singuliflora* is green to white. Flowering has been observed between June-November. The orange fruits are berries measuring 1.2 in wide.

Clermontia peleana is historically known from the northeastern and southeastern slopes of Mauna Kea, as well as the eastern slopes of Mauna Loa. The subspecies *singuliflora* was previously found on the northern slope of Mauna Kea and at Haleakalā on the island of Maui; however, it is now presumed extirpated (USFWS 1996a). Approximately four populations of *peleana* currently occur in montane wet „ōhi„a forests at Keanakolu, Pāpa„aloa, and Pi„ihonua on the Island of Hawai„i. These populations are estimated to contain roughly eight individuals (USFWS 1996a).

The taxon grows in wet forests dominated by koa, „ōhi„a, and tree ferns at elevations between 1,800-3,800 ft. The native plants kolokolo mokihana and naupaka kuahiwi are known to occur with this species (USFWS 1996a).

According to the Big Island Plant Cluster Recovery Plan (1996a), ungulates, rats, and humans were identified as the main threats to *C. peleana*. Habitat has been disturbed by ungulates and humans planting marijuana. Reproductive ability of *C. peleana* may be reduced due to a lack of pollinators. In addition, random natural events could eliminate the small population size.

A total of 38,664 ac of critical habitat were designated for *Clermontia peleana* on Hawai„i Island. Only four individuals existed within the three critical habitat units at the time of designation. Although one unit lies mostly within Hakalau Forest NWR (as well as a small section of the Hilo Forest Reserve), *C. peleana* is not currently known to occur there. No critical habitat has been designated on Maui (Federal Register 2003b). In December 2008, in coordination with the Plant Extinction Prevention Program, over 800 *C. peleana* were outplanted in six gulch areas at approximately 5,000 ft elevation at the HFU.

4.9.4 *Clermontia pyrularia*

Clermontia pyrularia is an endangered lobeliad that reaches a height of 9.8-13 ft. The toothed leaf blades are narrow and elliptical. The blades are attached to winged petioles, or stalks. Each flower is suspended by a flower stalk and attached to a cluster of 2-5 flowers. The species name is derived from *pyrus* (pear) because of its orange, pear-shaped berries.

Currently, *C. pyrularia* is found between 5,900-6,240 ft on the Hawai„i Island, although it is able to survive at elevations as low as 3,000 ft and as high as 7,000 ft. It occurs in montane wet and mesic „ōhi„a and koa forests in North Hilo at Laupāhoehoe and Pīhā, the State land adjacent to the HFU. Subalpine dry forests dominated by „ōhi„a can also provide suitable habitat (Federal Register 2003b).

The previously found population in the Laupāhoehoe Natural Area Reserve no longer exists (USFWS 1996a, 1996b). One individual from the population at Pīhā died from unknown causes in 1995; however, an additional 14 individuals were found in the area by 2001 (Jeffrey et al. 2001). Using seeds from these plants, the Refuge experimentally outplanted 30 *C. pyrularia* seedlings in two exclosures at HFU in 1990 and 1992 (USFWS 1996a, 1996b). By 2001, 12 individuals at 7 sites were still living. To date a total of 846 *C. pyrularia* have been outplanted within the Refuge (USFWS, unpubl.). Subalpine dry forests dominated by „ōhi„a can also provide suitable habitat (Federal Register 2003b).

It was found that although *C. pyrularia* seeds will grow slowly at 3,800 ft, this species grows best between 6,000-6,400 ft. Seeds of this species will not germinate below 2,000 ft (USFWS 1996b).

Nonnative vegetation has contributed to population declines of *C. pyrularia* in suitable habitat. For example, banana poka, which forms a dense curtain that shades out seedlings, is negatively impacting *C. pyrularia* in some areas. Pigs have been observed dispersing the fruits of banana poka and can also trample native flora. Ongoing other threats include rats, invertebrates, humans, and small disjunct populations with limited opportunities for pollination (USFWS 1996a).

In 2003, 6,823 ac of critical habitat were designated for *C. pyrularia*. Critical habitat has been designated at the HFU. The critical habitat unit located completely within the HFU provides habitat for three populations of 300 individuals; however, no individuals occurred on the unit at the time of designation. The south and north-central portion of the second critical habitat unit is also located within the Refuge unit (Federal Register 2003b). *Ex situ*, or offsite, planting is needed to increase population numbers at these areas (USFWS, publ.).

4.9.5 Hāhā (*Cyanea hamatiflora*)

Several species within the *Cyanea* genus are referred to by the Hawaiian name hāhā. The genus is endemic to the Hawaiian Islands, with 11 species and 5 subspecies on Hawai„i Island. *Cyanea hamatiflora* subsp. *carlsonii* is an endangered species typically found in montane wet „ōhi„a and mesic koa/„ōhi„a forests of the west side of the island. This palm-like tree can grow between 9.8-26 ft in height. The sessile leaves average between 20-31 in long and the flowers cluster in groups of 5-10 (USFWS 1996a). The sepals and magenta petals of *C. hamatiflora* subsp. *carlsonii* are fused into an oval tube. The berries are oval and purplish red in color. The other subspecies – *hamatiflora* – is common throughout East Maui. The Hawai„i Island subspecies can be distinguished by its stalkless leaves, larger flower stalks, and longer calyx lobes (USFWS 1996a, Mitchell et al. 2005).

The current distribution of the species ranges from 5,220-5,700 ft on the western slopes of Hualālai (Mitchell et al. 2005). In 2003, 14 individuals existed in the Honua„ula Forest Reserve within the Wai„aha watershed and a single individual was known from the Kīpāhoehoe NAR within the Ki„ilae watershed (Federal Register 2003b). Currently, populations occur at the Honua„ula Forest Reserve and at privately owned land at Kēōkea in South Kona. In 2005, about 16 plants were recorded at „Ōlelomoana. Fifty-one individuals were outplanted within the native range at the Honua„ula Forest Reserve and Pu„u Wa„awa„a. These outplantings have not been successful and the population has declined to roughly 3-4 individuals (Mitchell et al. 2005).

Although no *C. hamatiflora carlsonii* are currently known from the KFU, the area is considered a key potential habitat for the species (Federal Register 2003b). No individuals have been found in the areas since the 1960s (USFWS, unpubl.). Approximately 2,583 ac of land in South Kona were designated as critical habitat for this species in 2003. Of this total, approximately 1,475 ac lie within KFU (USFWS 2008). Three additional critical habitat units were designated in the Honua„ula Forest Reserve, South Kona Forest Reserve, and Kīpāhoehoe NAR (Federal Register 2003b).

Potential risks to *C. hamatiflora* include cattle, rats, nonnative plants, and small, disjunct populations (USFWS 1996a). Ungulate disturbance provides an opportunity for invasive plants, such as banana poka, to take over an area and directly compete with *C. hamatiflora carlsonii*. In addition, reproductive success is reduced by a limited gene pool and further depleted by birds and rats that eat the seeds. Caterpillar seed damage has also been observed on this species (USFWS 1996a).

4.9.6 ‘Aku‘aku (*Cyanea platyphylla*)

Cyanea platyphylla, or „aku„aku, is a small unbranched shrub endemic to the island of Hawai„i. The palm-like shrub reaches between 3-10 ft tall and is covered by short spines on the upper portion of the stems. The leaves of juvenile plants have prickles on the leaves and stalks and measure between 4.1-10 in long and 1.6 -3 in wide. Adult plants have only sparsely prickled leaves. Adult leaves are larger, measuring 13-34 in long and 2.8-8.7 in wide. The inflorescence is a cluster of 6-25 flowers. Compared to other species within the genus, the flowers of *C. platyphylla* are small. The bases of the flower parts (sepals, petals, and stamens) are fused together in a structure known as a hypanthium. The petals are white or yellowish with magenta strips and there are five triangular sepals. The pale orange berries measure 0.3-0.4 in long and 0.2-0.3 in wide (Mitchell et al. 2005).

Historically, *C. platyphylla* was known to occur in the following areas: Waipio Valley, Kohala Mountains, Laupāhoehoe; in the mountains above Hilo, Pahoa, Glenwood, and Honaunau; and at the unknown location named "Kalanilehua." According to the Addendum to the Big Island Plant Cluster Recovery Plan (1998a), two naturally occurring *C. platyphylla* populations consisting of nine individuals existed in the late 20th century. These occurred in the Laupāhoehoe NAR and along Saddle Road. In 2003, six occurrences of *C. platyphylla* were known (Federal Register 2003b). More recent estimates suggest that there are 4-6 populations consisting of 50-100 plants. In 2004, 2 individuals were found at a population near Kilau Stream and 11 plants were found in the Laupāhoehoe NAR. No individuals are known from Hakalau Forest NWR. Additional surveys in the historical range and likely habitat areas are needed to determine the exact distribution of the species (Mitchell et al. 2005).

Montane wet „ōhi„a forests are the preferred habitat of *C. platyphylla*, although it can be found in lowland areas. It has been reported to occur between 390-3,000 ft in association with hāpu„u, ho„i„o, hame, „oha wai, pilo, and ha„iwale (USFWS 1998a).

Two critical habitat units were designated in 2003, encompassing 7,234 ac. The first unit is located primarily within the Laupāhoehoe NAR, with a small portion in the northwest in the Hilo Forest Reserve. The second unit is within the Wailuku watershed in the Hilo Forest Reserve (Federal Register 2003b).

Competition with introduced plants has resulted in *C. platyphylla* population declines. Nonnative mammals, such as rats and pigs, also threaten existing populations by modifying habitat and eating the fruit (USFWS 1998a). Hawai„i‟s Comprehensive Wildlife Conservation Strategy (2005) and the Addendum to the Big Island Plant Cluster Recovery Plan (1998a) also identify volcanic activity, stochastic events, and reduced reproduction vigor as threats.

The downlisting criterion established in the Addendum to the Big Island Plant Cluster Recovery Plan (1998a) requires 5-7 populations of at least 100 mature plants each that are sustained for a 5-year period. The delisting criterion requires 8-10 populations of *C. platyphylla* with at least 200 mature plants each. These populations must be sustained for 5 consecutive years.

4.9.7 *Cyanea shipmanii*

Cyanea shipmanii is a small, palm-like understory species. The shrub can be unbranched or have few branches and reaches a maximum height of 13 ft. *Cyanea shipmannii* is characterized by its slender stems and pinnately lobed leaves. The stalked leaves are deeply cut into 20-30 lobes per leaf (Mitchell et al. 2005). Young plants have sharp projections on their stems and leaves, typically only up to about 3.5 ft. This may be an evolved defense against flightless geese or ducks that once existed on the island (Jeffrey, pers. comm.). The flowers of *C. shipmanii* have fine hairs and are grouped in clusters of 10-15. The flower petals are whitish green and fused into a curved, five-lobed tube. The orange berry is ellipsoid in shape (Mitchell et al. 2005).

This species occurs on the eastern slope of Mauna Kea and south across the Waiākea Forest Reserve and into the lands of the Kūlani Correctional Facility on the southeastern slope of Mauna Loa, in montane wet „ōhi„a and mesic koa/„ōhi„a forest habitat. The elevational range is 5,400-6,200 ft. Additional native species that have been observed with *C. shipmanii* are kōlea and kāwa„u. In 1840, approximately 50 individuals were found and only one was mature. In the late 1990s a single plant was found in a ravine in the Upper Waiākea Forest Reserve. A small fence was constructed to protect the plant from pigs (USFWS 1996a, Mitchell et al. 2005). Another single individual was known in the Mauna Loa Forest Reserve (Federal Register 2003b). Five *C. shipmanii* were found in the Pua „Ākala and Hakalau Tracts of the HFU in 1993 (USFWS 1996a, Van Driesche and Van Driesche 2000, Jeffrey et al. 2001, Mitchell et al. 2005). All but one individual had died by 2000 and the remaining plant was too young to reproduce. Using seed from Waiākea, 109 *C. shipmanii* were outplanted at the Refuge (HFU) from 1999-2001 (Jeffrey et al. 2001). From 2002-2008, an additional 602 *C. shipmanii* were outplanted (USFWS, unpubl.).

Of the 6,088 ac of critical habitat designated for *C. shipmanii*, over 64 percent occurs within the HFU. This area encompasses Pua „Ākala and portions of „Āwehi, Honoli„i, and Kapue streams. Two additional units were designated on land within the „Ōla„a-Kīlauea Partnership (now the Three Mountain Alliance) and in the Mauna Loa Forest Reserve (Federal Register 2003b).

Pigs are known to impact the reproduction of this species and destroy the natural seed bank (Van Driesche and Van Driesche 2000). Existing populations are also threatened by invasive plants and rats. In the early 1990s rats were known to have eaten all of the fruit and seeds from the known individuals of the endangered *C. shipmanii* at the HFU (USFWS 1996b). Although sporadic rodent control has been employed, these remote areas are difficult to access (Jeffrey et al. 2001). Due to the small population size, the species is also in danger of extinction from random events, loss of reproduction vigor, or reduced pollination (Mitchell et al. 2005).

4.9.8 *Cyanea stictophylla*

The endangered *Cyanea stictophylla* is a small tree or shrub with a height from 2-20 ft. The stems often possess sharp projections and have few branches. The long and narrow leaves have lobed or toothed blades that are 7.8-15 in long. Five or six large, deeply lobed flowers cluster at the tip of the main flower stalk. The hypanthium is oval and slightly hairy. The petals are yellowish white or purple, while the berries are orange (USFWS 1996a).

Historical records show that *C. stictophylla* occurred on the western, southern, and eastern slopes of Mauna Loa. Three existing populations occur in montane wet „ōhi„a and mesic koa/„ōhi„a forests between 2,500-6,400 ft. These population contain about 15 individuals and are located at Keauhou in Ka„ū, Kohae in South Kona, and Pu„u Wa„awa„a in North Kona. Six plants occur at Kukui o Pa„e and 10 at Olelomoana (USFWS 1996a). An additional 46 have been planted in enclosures at the Ka„ū Forest Reserve and Pu„u Wa„awa„a (Mitchell et al. 2005). Alani and opuhe occur in association with this species (USFWS 1996a).

Two *C. stictophylla* were known from lava tube skylights at the KFU. Both were thought to have died from rat damage in 2007 (Jeffrey, pers. comm.).

Four critical habitat units have been allocated for the *C. stictophylla*, of which two are occupied. These areas include the South Kona Forest Reserve, Kīpāhoehoe NAR, Ka„ū Forest Reserve, and lands within the „Ōla„a-Kīlauea Partnership. The total critical habitat area is 95,484 ac (Federal Register 2003b).

Cyanea stictophylla is threatened by a limited population, which makes it vulnerable to random events and decreased reproduction vigor. Cattle, pigs, and rats are the primary invasive mammals that adversely impact this species (USFWS 1996a).

4.9.9 Ha'iwale *(Cyrtandra tintinnabula)*

The small *Cyrtandra tintinnabula* shrub, or ha„iwale, grows to 3.3-6.6 ft in height. The papery leaf blades are oval shaped and have yellow brown hairs, especially on the lower surface. The blades are toothed and range from 2-4.9 in wide and 5-10 in long. Three to six flowers group together at the main stalk. The bracts (modified leaves) are oval or heart-shaped, while the five white petals are fused into a soft, hairy, tube. The bell-shaped calyx (sepals) distinguishes *C. tintinnabula* from other species in the genus. The calyx is densely hairy and pale green (USFWS 1996a).

Ha„iwale survives in wet forest dominated by koa, „ōhi„a, and hāpu„u. It has been reported to occur with pili and other species in the *Cyrtandra* genus at elevations of 2,100-3,400 ft (USFWS 1996a).

Since the early 1900s, ha„iwale has been reported at three locations on the northeastern slopes of Mauna Kea. Currently, there are approximately 25 known individuals at the HFU within the Middle Maulua Unit at elevations above 4,600 ft (Jeffrey, pers. comm.). A single plant was found at Honohina in the HFU in 1976 (USFWS 1996a). Off the Refuge, a population is found at Kilau Stream in the Laupāhoehoe area. Roughly 16 individuals were found at 2,400 ft on the stream and an additional individual was found at 2,940 ft. Attempts to germinate the seeds and propagate this species at the Refuge greenhouse have not been successful (Jeffrey et al. 2001).

Two critical habitat units were created for the species in 2003. This included areas in the Laupāhoehoe NAR and the Hilo Forest Reserve. The total critical habitat area encompasses 6,672 ac (Federal Register 2003b).

Anthropogenic activities, as well as impacts from goats and pigs are listed as the key threats to the taxa. Pigs and goats directly damage the plant by browsing and indirectly impact the habitat by facilitating the spread of invasive plant species. Random events also threaten the existence of ha„iwale (USFWS 1996a).

4.9.10 'Aiea (*Nothocestrum breviflorum*)

Nothocestrum breviflorum, also referred by the Hawaiian name of „aiea, is a long-lived perennial endemic to the Island of Hawai„i. The tree was listed as endangered in March 1994. Reaching between 33-39 ft in height, „aiea has a soft, dark brown trunk. The thick, stalked leaves are oblong to elliptic in shape and are shed seasonally. The lower surface is densely pubescent, while the upper surface is glabrous to lightly pubescent. More than three flowers are clustered on spur-like branches. The greenish-yellow petals have four lobes and are hairy on the outside. The round berries, which are enclosed by the calyx, are orange to red and measure 0.2-0.3 in in diameter. These fruits have been observed December - January.

„Aiea has been documented at the western, southern, and eastern slopes of Mauna Loa, at the southern Kohala mountains, and the northern slopes of Hualālai. The elevational range is between 260-6,000 ft. Current „aiea populations are restricted to the western side of the island from South Kohala to Kamā„oa-Pu„u„eo. An estimated six populations currently exist, with few individuals (1-4 plants) in each population (USFWS 1996a). In 2003, roughly 6 individuals were known within the Kohala Forest Reserve and 165 individuals were identified near Po„ohoho„o summit (Federal Register 2003b). Although no „aiea is known to currently occur on the KFU, plants do exist in adjacent areas (McCandless Ranch).

The primary habitats for „aiea are lowland dry forest, montane dry forest, and montane mesic forests dominated by „ōhi„a and koa, as well as uluhe. Several other endangered plants are known to occur with this species (USFWS 1996a).

Three critical habitat units were established for „aiea in 2003, covering 12,708 ac. The largest unit is within the Kīholo watershed, which is the southwestern most portion of the historical range. Additional land is designated in the Kohala Forest Reserve and between the Kohala Forest Reserve and the Waimanu Estuarine Research Reserve (Federal Register 2003b).

The following threats are identified in the Big Island Plant Cluster Recovery Plan (1996a): cattle, sheep, nonnative plants, fire, and human impact. Christmas berry, fountain grass, lantana, and koa haole have been noted as contributing to the decline of this species by increasing the risk of fire (USFWS 1996a).

4.9.11 *Phyllostegia floribunda*

The erect subshrub *Phyllostegia floribunda* is a candidate species for listing as threatened or endangered. As a candidate species, *P. floribunda* is not protected by the ESA or covered by the Big Island Plant Cluster Recovery Plan (USFWS 1996a) or Addendum (USFWS 1998a). However, the populations within the HAVO are provided some protection under the National Park Service Act (16 U.S.C. §§1-18f-1) and the enabling legislation for the Park (16 U.S.C. § 396) (Pub. Law 95-635, 16 U.S.C. § 1132).

The ovate to elliptic leaves of *P. floribunda* are moderately hairy and pale on the lower surface. They measure 4.7-9.4 in long and 1.8-3.3 in wide. The flowers are maroon to red and white at the base of the floral tube. The flowers are clustered in pairs to form unbranched inflorescences. Similar to other species in the genus *Phyllostegia,* the flowers are fragrant and predominantly insect pollinated. The dry and hard fruit is a nut measuring 0.12-0.14 in long.

This species was previously found in a wide variety of locations, including the Kohala Mountains, Ka„ū, North and South Kona, the windward sides of Mauna Loa and Kīlauea, and the windward side of Mauna Kea (including the Laupāhoehoe Natural Area Reserve, Waiākea Forest Reserve, and private land at Pa„auilo) (NatureServe 2007). It occurs between 1,410-3,700 ft in elevation in moist to wet forests (Wagner et al. 1999). The current total population is believed to consist of less than 100 naturally occurring individuals and 170 outplanted individuals in 10 locations (Federal Register 2007). Most of the populations occur within the Laupāhoehoe NAR and Hawai„i Volcanoes National Park, with additional populations in the „Ōla„a Forest Reserve, Waiākea Forest Reserves, Pu„u Maka„ala NAR, and Kīpāhoehoe NAR. Only the populations at the Laupāhoehoe and Pu„u Maka„ala NAR are naturally occurring. The Nature Conservancy (TNC) also outplanted 20 individuals at

Honomalino in South Kona. Most of the populations are comprised of fewer than 10 individuals and 7 populations are protected by fences (USFWS 2007b). Specimens found on the KFU are currently pending verification, based on cuttings being grown at the Volcano Rare Plant Facility (Jeffrey, pers. comm.).

Pigs have been identified as the primary threat to the survival of this species. In addition, various nonnative plants directly compete with naturally and outplanted populations of *P. floribunda*. Human threats include ranching, logging, agriculture, urban development, and homesteading. Natural threats include volcanic activity and fires ignited by volcanic activity (Federal Register 2007b, USFWS 2007).

4.9.12 Kīponapona (*Phyllostegia racemosa*)

Phyllostegia racemosa, or kīponapona, is an endangered climbing vine with square stems. The opposite leaves are oblong shaped and covered with short, soft hairs. The leaves have rounded teeth and measure 1.3-2.4 in long and 0.6-1.7 in wide. The white flowers are clustered in groups of 6-12 at the base of the leaves and the stems and densely covered with short hairs. The hard, dry fruit is typically 0.06-0.08 in in length. This plant is also characterized by the spicy odor of its foliage.

Located from 4,650-6,070 ft, kīponapona primarily occurs in montane wet or mesic forest dominated by „ōhi„a and koa, as well as hāpu„u. Other associated taxa include „ōhelo, „ākala, and lau kahi (USFWS 1998a).

It was historically found near Mauna Kea in the Hakalau and Saddle Road areas, as well as near Mauna Loa in Kūlani/Keauhou and Kīpuka„āhiu areas. Four populations are known to presently occur in the Kūlani/Keauhou area, at the HFU, and at Hawai„i Volcanoes National Park. These populations are comprised of 25-45 individuals (Mitchell et al. 2005). Seven individuals were present on the HFU in 2001 within the Upper Maulua and Hakalau Units (Jeffrey et al. 2001). To date, roughly 1,043 kīponapona have been outplanted at the HFU. Of this total, nearly 775 were outplanted in 2007 (USFWS, unpubl.).

Over 2,317 ac of critical habitat has been designated at the HFU, including Pua „Ākala and portions of „Āwehi, Honoli„i, and Kapu„e streams. Areas within the Hilo Forest Reserve and land managed by the „Ōla„a-Kīlauea Partnership have also been designated. Although no individuals exist within the „Ōla„a-Kīlauea Partnership lands, these areas were deemed critical habitat because 12 individuals occur on the adjacent Kamehameha Schools land (Federal Register 2003b).

Ungulates, such as pigs and cattle, are a key threat to the species. Ungulates have destroyed at least four plants in the HFU since 1994 (Jeffrey et al. 2001). Nonnative plant competition, logging, and volcanic activity are also suspected as reasons for population decline (USFWS 1998a).

The downlisting objectives listed in the Addendum to the Big Island Plant Cluster Recovery Plan (1998a) state a total of 5-7 populations need to be documented, with a minimum of 300 mature individuals per population. For delisting, 8-10 populations are required, with at least 300 mature plants each. These populations need to persist for 5 consecutive years (USFWS 1998a).

4.9.13 *Phyllostegia velutina*

Phyllostegia velutina is an endangered climbing vine. The thick leaves are slightly egg shaped with serrate margins. The leaves measure 3.6-6.9 in long and 1-2 in wide. The leaves have dense, straight hairs, while the square stems have downward pointing hairs. The white flowers are compactly clustered in groups of 6-10 in the axils of the leaves. The dry fruit is divided into four nutlets. The fruit is larger than the previous *Phyllostegia* described, with a length of 0.1-0.2 in.

Historically, *P. velutina* was reported on the southern slopes of Hualālai and various slopes of Mauna Loa. In 2003, there were 5 populations consisting of 63-116 plants. These populations were located at the Honua„ula Forest Reserve, near the Waiea tract in South Kona, in Pu„u Wa„awa„a, and near and at the Kūlani Correctional Facility (USFWS 1998a). Current estimates published in the Federal Register (2003b) list eight occurrences, with an unknown number of individuals in the Ka„ū Forest Reserve and seven individuals within the Ka„ahakini watershed near the Kūlani summit and on adjacent Kamehameha Schools land. Only a single *P. velutina* is known to occur in a gulch within the HFU. One hundred and twelve *P. velutina* have been outplanted at the HFU from 1999-2007 (USFWS, unpubl.). *P. velutina* potentially occurs in the KFU (USFWS, unpubl.).

The preferred habitat for *P. velutina* is montane mesic and wet forests dominated by koa and „ōhi„a. It occurs between 4,900-6,000 ft. The following species have been recorded with *P. velutina*: hāpu„u, „ōhelo, „akala, lau-kahi, „ōlapa, māmaki, kōlea, and kāwa„u (USFWS 1998a).

Phyllostegis velutina is threatened by ungulates, such as cattle, pigs, and sheep. Logging, road clearing, prison expansion, and other human activities have also caused population declines. Growth of nonnative plant species (*Pennisetum setaceum*, *Rubus ellipticus*, *Paspalum urvillei*, and *Pennisetum clandestinum*) has impacted the species. In addition, fire and volcanic activity has contributed to the decline (USFWS 1998a).

The 9,009 ac critical habitat area for *P. velutina* has the potential to support 10 populations, each with 300 mature, reproducing individuals. These units include land in the Ka„ū Forest Reserve within the Pahala watershed and land managed by the „Ōla„a–Kīlauea Partnership within the Ka„ahakini watershed (Federal Register 2003b). No critical habitat has been designated at the HFU.

4.9.14 Po‘e (*Portulaca sclerocarpa*)

Portulaca sclerocarpa, or po„e, is a perennial herb that was listed as federally endangered in 1994. The prostrate stems reach up to 8 in tall. The sessile leaves are gray to pale green and linear shaped. There is a tuft of yellowish brown hairs in the axil. The flowers are arranged in cyme inflorescences composed of 3-6 white or pink blossoms. The taproot is fleshy and tuberous, but becomes woody. Approximately 0.16-0.18 in long, the fruit is a capsule (dry and dehiscent) containing dark reddish brown seeds. This species closely resembles *P. villosa* but can be distinguished by its thicker fruit.

Po„e occurs on Hawai„i Island and at one location on the Island of Lāna„i. On Lāna„i, it occurs in coastal habitat on Po„opo„o Islet. The population is located on private land and contains about 10 plants (Federal Register 2003a). On Hawai„i Island, po„e is found between 3,087-5,360 ft where it grows in weathered Mauna Kea soils, cinder cones, or geologically young lavas. It is known to occur near stream vents and in montane dry forest and shrubland dominated by koa, „ōhi„a, and māmane. The species is known to occur with „a„ali„i and nehe.

On Hawai„i Island, po„e historically occurs in the Kohala Mountains, the northern slopes of Hualālai, the northwestern slopes of Mauna Loa, and near Kīlauea Crater (USFWS 1996a). There are estimated to be 24 occurrences of po„e on Hawai„i Island currently. The population in Hawai„i Volcanoes National Park consisted of 900 individuals in 2003 (Federal Register 2003b). Populations also occur at the PTA and Parker Ranch. Although no po„e have been found the KFU, plants are known from the adjacent area.

The critical habitat unit for po„e covers 10,848 ac of Hawai„i Volcanoes National Park. It contains the Keanakāko„i, Koko„olau, and Puhimau craters, as well as Lele o Kalihipa„a Pali and a portion of the 1921 lava flow. Roughly 19 ac of critical habitat were also designated for the population on Lāna„i (Federal Register 2003a, 2003b).

Invasive mammals (goats, pigs, sheep) and invasive plants threaten populations of this species. Fountain grass and broomsedge are particular threats to po„e as a result of competition. Furthermore, existing populations occur in fire-prone areas that are susceptible to human impacts (USFWS 1996a). The coastal Lāna„i population is threatened by invasive plants, fire, and larval herbivory by a nonnative sphinx moth (Federal Register 2003a).

4.9.15 ‘Ānunu (*Sicyos macrophyllus*)

Sicyos macrophyllus, also known as „ānunu, is a candidate for the list of threatened and endangered species. It does not receive protection under the ESA or Hawai„i's endangered species law nor is it covered in a recovery plan. This perennial vine has long stems reaching almost 50 ft. These stems are sparsely hairy and have black spots. The leaves are heart-shaped with a notch at the base and attached to coiling tendrils. Each leaf has 3-5 lobes and the central lobe is sharply pointed. The flowers occur in hairy, branched inflorescences. The green fruit is rounded and ribbed.

This species is found in montane wet „ōhi„a forests, mesic koa/„ōhi„a forests, and subalpine māmane/naio forests. It occurs between 4,000 -6,600 ft elevation on the Island of Hawai„i (USFWS 2007c).

The historical distribution of „ānunu includes Pu„u Wa„awa„a, Laupāhoehoe, Puna, and South Kona. The current distribution of the species encompasses six populations of several hundred individuals in the Kohala and Mauna Kea areas. One population occurs at Kīpuka Kī in Hawai„i Volcanoes National Park. The remainder are located in State-owned game management areas in Pu„u Huluhulu, South Kona, Pu„u Wa„awa„a, Pu„u Mali, and Waika (Federal Register 2007, USFWS 2007c). One „ānunu is known to occur within the KFU.

The species is susceptible to pigs, cattle, and sheep that degrade and destroy habitat. Nonnative plants also compete for space, nutrients, water, air, and light. Although pigs are excluded in some areas by fencing, the fences are not sheep-proof and must be continually maintained (Federal Register 2007, USFWS 2007c).

4.9.16 *Silene hawaiiensis*

Silene hawaiiensis is a sprawling shrub federally listed as threatened. The climbing stems are typically 6-16 in long and slightly hairy. The leaves are slender, with hairs concentrated along the margins and toward the base. The flowers, which are arranged in branched inflorescences, are greenish white and maroon below. These clusters are extremely sticky. Pale brown seeds are enclosed in a capsule (dry fruit) that is 0.26-0.31 in in length. The enlarged root is spindle-shaped.

Silene hawaiiensis is endemic to the Island of Hawai„i from 3,352-7,915 ft. It occurs within montane and subalpine dry shrubland on weathered lava, on various aged lava flows, and cinder substrates (Federal Register 2003b). Historically, *S. hawaiiensis* could be found on the western slope of Mauna Kea, the Humu„ula Saddle, near Kīlauea Crater, and along the slopes of Mauna Loa. Current populations exist in the Hāmākua District, on Humu„ula Saddle, at PTA, north of Pu„u Keanui, and in Hawai„i Volcanoes National Park (Federal Register 2003, Mitchell et al. 2005). In 2003, there are 156 occurrences of *S. hawaiiensis*. From 5,651-5,751 individuals were found at Hawai„i Volcanoes National Park. The specimen identified on the KFU is currently pending verification. The shrub is found in association with the following native flora: „ōhi„a, māmane, „a„ali„i, pūkiawe, pāwale, and „ōhelo (Federal Register 2003b).

Two critical habitat units covering 6,908 ac were designated for the species within Hawai„i Volcanoes National Park. These areas contain portions of Kīlauea Crater, Kīpukakulalio, Uwēkahuna Bluff, Halema„uma„u Crater, and segments of the lava flows of 1919, 1921, and 1961 (Federal Register 2003b).

Significant threats to *S. hawaiiensis* include grazing and trampling by goats, pigs, and sheep. Ungulates easily break the branches and stems of this species. Competition with nonnative plants, especially fountain grass, is another issue. The populations are also susceptible to human impacts such as fire and disturbance due to military exercise (USFWS 1996a, Mitchell et al. 2005). No *S. hawaiiensis* are known from Refuge lands, however it is known to be above the HFU at approximately 7,000 ft.-10,000 ft in elevation

4.10 Other Native Plants

The plants now considered native to Hawai„i arrived to the archipelago via natural means such as wind, water, or birds. According to Wagner et al. (1999), the native Hawaiian flora is comprised of roughly 956 species within 87 families. Approximately 89 percent of these species are endemic (found only in Hawai„i), while the remainder are indigenous (naturally found in Hawai„i and elsewhere). Table 4-6 lists the native plant species found on either Refuge unit.

Table 4-6. Native Hawaiian Plants Found on the Units of the Hakalau Forest NWR.

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Amaranthaceae	**Amaranth family**			
Charpentiera obovata	pāpala	E	X	
Apiaceae	**Parsley family**			
Sanicula sandwicensis	--	E*		X
Apocynaceae	**Dogbane family**			
Alyxia oliviformis	maile	E	X	
Aquifoliaceae	**Holly family**			
Ilex anomala	kāwa„u, „aiea	I	X	X
Araliaceae	**Panax family**			
Cheirodendron trigynum	„ōlapa	E	X	X
Tetraplasandra oahuensis	„ohe mauka	E		X
Arecaceae	**Palm family**			
Pritchardia beccariana	loulu	E	X	
Aspleniaceae	**Spleenwort family**			
Asplenium aethiopicum	„iwa„iwaa kāne	I	X	
Asplenium contiguum	--	E	X	
Asplenium lobulatum	pi„ipi„i lau manamana	I	X	X
Asplenium macraei	„iwa„iwa lau li„i	E	X	
Asplenium normale	--	I	X	
Asplenium schizophyllum	--	E*	X	
Asplenium unilaterale	pāmoho	I	X	
Athyriaceae	**Lady fern family**			
Athyrium microphyllum	„akolea	E	X	
Diplazium sandwichianum	ho„i„o	E	X	
Blechnaceae	**Blechnum fern family**			
Sadleria cyatheoides	„ama„u	E	X	X
Sadleria pallida	„ama„u	E	X	X
Sadleria souleyetiana	„ama„u	E	X	
Sadleria squarrosa	„ama„u	E	X	
Campanulaceae	**Lobelia family**			
Clermontia spp.	„oha kepau, „oha wai			X
Cyanea marksii	hāhā	E*		X
Cyperaceae	**Sedge family**			
Carex alligata	--	E	X	
Carex macloviana	--	I	X	
Carex wahuensis var. *rubiginosa*	--	E	X	
Eleocharis obtusa	--	I	X	
Machaerina angustifolia	„uki	I	X	
Uncinia uncinata	--	I	X	

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Dennstaedtiaceae	**Hay-scented fern family**			
Hypolepis hawaiiensis	olua	E	X	
Microlepia strigosa	palapalai	I	X	
Pteridium aquilinum var. *decompositum*	kīlau, kīlau pueo, bracken fern	E	X	
Dicksoniaceae	**Tree fern family**			
Cibotium chamissoi	hāpu„u	E	X	
Cibotium glaucum	hāpu„u, hāpu„u pulu	E	X	
Dryopteridaceae	**Wood fern family**			
Arachniodes insularis	--	E	X	
Cyrtomium caryotideum	kā„ape„ape	I	X	X
Dryopteris fusco-atra	„i„i	E	X	
Dryopteris glabra	kīlau, hohiu	E	X	
Dryopteris hawaiiensis	--	E	X	
Dryopteris wallichiana	laukahi, „i„onui	I	X	
Dryopteris unidentata	„akole	E	X	
Nothoperanema rubiginosa	--	E	X	
Polystichum hillebrandii	ka„upu, papa„oi	E	X	X
Ebenaceae	**Persimmon family**			
Diospyros spp.	lama			
Elaphoglossaceae	**Stag's tongue fern family**			
Elaphoglossum alatum	„ēkaha	E	X	
Elaphoglossum crassifolium	„ēkaha	E		
Elaphoglossum hirtum	„ēkaha	E		
Elaphoglossum wawrae	„ēkaha, laukahi	E		
Flacourtiaceae	**Flacourtia family**			
Xylosma hawaiiense	maua	E		X
Geraniaceae	**Geranium family**			
Geranium cuneatum	nohoanu	E		X
Gesneriaceae	**African violet family**			
Cyrtandra lysiosepala	ha„iwale	E		X
Cyrtandra menziesii	ha„iwale	E*		X
Gleicheniaceae	**False staghorn fern family**			
Dicranopteris linearis	uluhe	I	X	
Diplopterygium pinnatum	uluhe lau nui	E	X	
Sticherus owhyensis	uluhe, unuhe	E	X	
Grammitidaceae	**Finger fern family**			
Adenophorus hymenophylloides	pai, palai huna	E	X	
Adenophorus pinnatifidus	kihi, kihe	E	X	
Adenophorus tamariscinus	wahine noho mauna	E	X	
Adenophorus tripinnatifidus	--	E	X	
Grammitis hookeri	māku„e lau li„i	I	X	
Grammitis tenella	kolokolo, mahinalua	E	X	

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Lellingeria saffordii	kihe	E	X	
Lepisorus thunbergianus	pākahakaha, „ēkaha, „ākōlea	I	X	
Hymenophyllaceae	**Filmy fern family**			
Mecodium recurvum	„ōhi„a kū	E	X	
Sphaerocionium lanceolatum	palai hinahina	E	X	
Sphaerocionium obtusum	palai lau li„i	E	X	
Vandenboschia davallioides	palai hihi, kīlau	E	X	
Iridaceae	**Iris family**			
Sisyrinchium acre	ma„u ho„ula „ili	E*		X
Joinvilleaceae				
Joinvillea ascendens subsp. *ascendens*	„ohe	E	X	
Juncaceae	**Rush family**			
Luzula hawaiiensis	--	E	X	
Lamiaceae	**Mint family**			
Phyllostegia ambigua	--	E		X
Phyllostegia brevidens	--	E*	X	
Phyllostegia vestita	--	E*	X	
Stenogyne calaminthoides	--	E		X
Stenogyne macrantha	--	E*		X
Stenogyne sessilis	--	E		X
Liliaceae	**Lily family**			
Astelia menziesiana	pa„iniu	E	X	
Lindsaeaceae	**Lace fern family**			
Sphenomeris chinensis	pala„ā, palapala„ā	I	X	
Loganiaceae	**Strychnine family**			
Labordia hedyosmifolia	kāmakahala	E		X
Lycopodiaceae	**Club moss family**			
Huperzia erubescens	--	I	X	
Huperzia serrata	--	I	X	
Lycopodiella cernua	wawae„iole	I	X	
Marattiaceae	**Marattia family**			
Marattia douglasii	pala, kapua„ilio	E	X	X
Nephrolepidaceae	**Sword fern family**			
Nephrolepis cordifolia	--	I	X	
Orchidaceae	**Orchid family**			
Liparis hawaiensis	„awapuhiakanaloa	E	X	
Pandanaceae	**Screw pine family**			
Freycinetia arborea	„ie„ie	E	X	X
Phytolaccaceae	**Pokeweed family**			
Phytolacca sandwicensis	pōpolo ku mai	E*	X	X
Pittosporaceae	**Pittosporum family**			
Pittosporum hosmeri	hō „awa	E		X

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Poaceae	**Grass family**			
Deschampsia nubigena	--	E	X	
Isachne distichophylla	„ohe	E	X	
Polygonaceae	**Buckwheat family**			
Rumex giganteus	pāwale, uhauhakō	E		X
Polypodiaceae	**Polypody fern family**			
Polypodium pellucidum	„ae, „ae lau nui	E	X	
Psilotaceae	**Whisk fern family**			
Psilotum complanatum	moa	I	X	
Psilotum nudum	moa, pipi	I	X	
Pteridaceae	**Pteris fern family**			
Adiantum capillus-veneris	„iwa„iwa	I	X	
Coniogramme pilosa	lo„ulu	E	X	
Pteris cretica	„ōali	I	X	
Pteris excelsa	waimakanui, „iwa	I	X	
Pteris irregularis	mānā, ā„hewa	E	X	
Ranunculaceae	**Buttercup family**			
Ranunculus hawaiensis	makou	E*	X	
Rosaceae	**Rose family**			
Fragaria chiloensis	„ōhelo papa	I*		X
Rubus hawaiiensis	„ākala, kala	E		
Rubus macraei	„ākala, kala	E*		X
Rubiaceae	**Coffee family**			
Coprosma spp.	pilo	E		X
Hedyotis terminalis	manono	E		X
Rutaceae	**Rue family**			
Platydesma remyi	pilo kea	E	X	
Santalaceae				
Santalum paniculatum	„iliahi, sandalwood	E		X
Selaginellaceae	**Spikemoss family**			
Selaginella arbuscula	lepelepe a moa	E	X	
Smilacaceae	**Catbriar family**			
Smilax melastomifolia	**hoi kuahiwi**	E	X	
Solanaceae	**Tomato, potato family**			
Nothocestrum longifolium	„aiea	E		X
Theaceae	**Camellia family**			
Eurya sandwicensis	ānini	E*	X	
Thelypteridaceae	**Maiden fern family**			
Amauropelta globulifera	palapalai a kamapua„a	E	X	
Christella cyatheoides	kikawaiō, kikawaioa	E	X	
Pseudophegopteris keraudreniana	waimakanui, „ākōlea	E	X	
Pneumatopteris sandwicensis	hō„i„okula	E	X	
Urticaceae	**Nettle family**			

Scientific Name	Common & Hawaiian Name(s)	Status	Hakalau Unit	Kona Unit
Pipturus albidus	māmaki, waimea	E		X
Urera glabra	ōpuhe, hōpue	E		X
Woodsiaceae				
Cystopteris douglasii	--	E*		X

Status: E = Endemic; I = Indigenous; * = Species of Concern (former candidate endangered species, or species otherwise considered rare by refuge officials).
Sources: Stone et al. 1991, USFWS 2002b, USFWS 2008.

Since humans came to the islands, populations of Hawai„i"s native vegetation have greatly declined. Native plant taxa in Hawai„i evolved on the islands without common plant defenses such as poisonous compounds, prickles, and spines (Lindqvist et al. 2003). The absence of these defenses leaves native plants especially vulnerable to ungulates and other nonnative herbivores. In addition, introduced species are better adapted to fire than native plants. Although some native species appear to be tolerant (koa, māmane, naio, „a„ali„i, „ōheb), no native Hawaiian plants require fire in order to regenerate (Smith and Tunison 1992, USFWS 1996, USFWS 2002a). More recently, competition from nonnative vegetation has suppressed regrowth or success of native plants. Native plant species richness and cover decreased with elevation (Barnett and Simonson 2008).

In the pasture areas of the HFU, native plant populations were historically altered by grazing, logging, and possibly fire, eliminating the native seed bank. At lower elevations the native seed bank was reduced because of continued cattle grazing and pig disturbance for well over 100 years (Jeffrey, pers. comm.). Similarly, the KFU has been exposed to grazing, browsing, and pig disturbance; however, because the forest canopy is intact and some rare native plants located in skylights on the unit have been protected from ungulates, a seed bank for most species still exists.

Since 1987, the Refuge has been conducting extensive reforestation research, ungulate control, nonnative plant control, and native plant and tree planting activities to help facilitate natural regeneration of native plant communities and natural processes of succession at the Refuge. Over 400,000 native trees are planted in mauka to makai corridors to provide foraging cover, and nesting sites for native forest birds on Mauna Kea. The planting restoration effort is largely concentrated in the upper portions of the Refuge 5,500 - 6,600 ft as these areas have been the most heavily disturbed by ranching and other human activities (USFWS 1996b).

Between 2006-2007, roughly 122 ac of upland habitat was restored on the HFU (USFWS 2006, 2007). Supplemental funding and supplies for restoration have come from Natural Resources Defense Council (NRDC), Hilo Rotary Club, American Forestry Association, Waimea State Tree Nursery, and DOFAW. Volunteers are an integral part of the effort, donating over 7,000 person-hours annually. These volunteers collect seeds; plant and fertilize native species; assist with monitoring and surveys of flora and fauna, the annual open house, and nonnative weed control (USFWS unpub.). Exclosure studies have shown that rapid regeneration of native species, especially koa and „ōhi„a, does occur in the absence of ungulates where a seed bank exists (USFWS, unpub. data).

Table 4-7. Total Native Seedlings Outplanted at the HFU 1987 - 2007.

Native Species	Total Seedlings Planted (1987-2007)
Acacia koa	328,827
Metrosideros polymorpha	30,232
Myrsine sp.	3,150
Cheirodendron trigynum	2,268
Sophora chrysophylla	1,997
Coprosma ochracea	1,911
Coprosma montana	1,856
Coprosma rhynchocarpa	1,699
Myoporum sandwicense	1,687
Rubus sp.	1,304
Ilex anomala	920
Leptecophylla tameiameiae	698
Vaccinium calycinum	665
Chenopodium oahuensis	397
Ranunculus hawaiiensis	395
Phyllostegia brevidens	304
Coprosma sp.	280
Vaccinium reticulatum	278
Vaccinium sp.	188
Stenogyne calaminthoides	84

Source: USFWS, unpubl.

4.10.1 Koa (*Acacia koa*)

Koa (*Acacia koa*) is endemic to the islands of Hawai„i, Moloka„i, Maui, Lāna„i, O„ahu, and Kaua„i. Although it can be found between 200-6,760 ft, its current distribution is mainly restricted to areas above 2,000 ft due to introduced pests and diseases (Wagner et al. 1999, Elevitch et al. 2006). It tolerates a wide array of rainfall regimes and can withstand drought periods up to 5 months. The optimal temperature range of koa is between 48-70°F (Elevitch et al. 2006). Seedlings cannot endure frost, although protective techniques enhance survival (Scowcroft et al. 2000).

Koa is the largest native tree in the archipelago, reaching 50-80 ft in height (Elevitch et al. 2006). Mature trees, which can live for over 100 years, have a diameter at breast height (dbh) often measuring more than 3.27 ft (Leary et al. 2004). While koa seedlings have true leaves, mature koa trees have only phyllodes, or expanded petioles. The flattened seed pods contain 6-12 seeds. The seeds are typically gravity-dispersed and require scarification in order to germinate (USFWS 1996b). Koa seeds appear to remain viable for about 15 years (USFWS 1996b). At Hakalau, koa trees flower December - February and seeds ripen November-January (USFWS 1996b). Koa flowers are primarily insect-pollinated, but birds and wind are also possible pollinators.

Acacia koa is an important species for several reasons, providing habitat as well as food for native birds, insects, and plants. Banko and Peck (2008) collected over 78,000 arthropods from the branch tips of 160 koa trees. Pysllids (Homoptera) comprised over 90 percent of all individuals collected.

The koa specific longhorn beetle (Cerambicidae) has wood-boring larvae that require dying and dead koa as part of their life-history (Goldsmith 2007). These larvae are the primary food source for the „akiapōlā„au, an endangered Hawaiian honeycreeper that has evolved into a woodpecker-like niche (Pejchar and Jeffrey 2006). Downed trees function as nurse logs, which are important for forest regrowth. As these logs decay they provide microhabitat for forest seedling establishment (Leary et al. 2004). Economically, koa is highly valuable and sold commercially for furniture and other crafts; however, revenue can only be sustained when harvested selectively (Pejchar et al. 2005, TMA 2007). Historically, the wood was used by ancient Hawaiians for canoes (Elevitch et al. 2006).

Koa is also considered a pioneer species during secondary succession due to its ability to quickly regenerate on a disturbed site. Ecosystem disturbances, such as fire and soil removal, can stimulate koa seeds to germinate. Koa is also able to regenerate from buried seed, root sprouts, or root suckering. It can spread outward from parent trees at a rate of 1.5-8 ft per year (USFWS 1996b). Similar to other pioneer species, koa is unable to tolerate shady environments. As a result, it usually establishes in canopy gaps, replacing previously occurring koa trees (USFWS 1996b). An additional characteristic typical of pioneer species is fast growth. During the first 5 years, koa can grow at rates of 5 ft per year; however, growth is slower in less favorable environments (Elevitch et al. 2006). At the HFU, growth varies depending on elevation (USFWS 1996b); however, studies by Goldsmith (2007) suggest that koa grows equally well at the upper middle and highest elevation areas present on the Refuge.

Koa has also been referred to as a “forest engineer” due to its ability to create favorable understory conditions. Typical in legume species, koa develops nitrogen-fixing root nodules that enhance nitrogen availability in the soil. The rate of nitrogen fixation declines as the trees age (Goldsmith 2007). The Draft Reforestation Management Plan for Hakalau (1996b) suggests that the nitrogen-fixing capacity of koa may prevent „ōhi„a dieback. Koa also adds organic matter to the soil and acidifies the soil. By providing canopy, the tree moderates light, temperature, and moisture for understory species (Scowcroft and Jeffrey 1999). Additionally, koa generates leaf litter that suppresses weedy grasses and also traps moisture that collects as fog drip (Jeffrey, pers. comm.).

Threats to koa seedlings at Hakalau Forest NWR include grass competition, frost, drought, pig rooting, and cattle browsing. Various seed predators (weevils and seed worms), fungi (*Fusarium* spp.), moths (*Scotorythra paludicola*), and twig borers (*Xylosandrus compactus* and *Xyloborus* spp.) also threaten koa populations. Koa wilt is a disease that causes rapid loss of canopy and death within a few months. This disease is more prevalent in young trees below 2,500 ft (TMA 2007). In addition, rats (*Rattus* spp.) have been implicated in stripping the bark off koa stands less than 6 years old. This causes deformation and greater probability of infection (Scowcroft and Sakai 1984). Wild turkeys are also known to forage on seedling leaves, and pull recently planted seedlings out of the ground (USFWS unpub data).

Hundreds of thousands of native koa seedlings have been planted at the HFU to restore native forest and habitat for endangered bird species. The first planting occurred in 1988 on Magnetic Hill at 6,500 ft and ongoing plantings are concentrated in the pasture areas of the Refuge (USFWS 1996b, 2002a). The Refuge, with the help of volunteers, germinates seeds picked from trees growing on or adjacent to the Refuge, and plant koa seedlings in mauka to makai (uphill to downhill corridors). Koa growth at HFU is slower and varies depending on elevation. After 10 years of growth, native forest birds have been observed foraging within some planted stands. Pejchar et al. (2007) found that of three habitat types studied, the koa plantation supported the highest density of the endangered

„akiapōlā„au. In addition, natural regeneration of koa through root sprouting and seed is also occurring in planting areas (USFWS 1996b).

The survival rates of these koa reforestation efforts and studies have produced varying results, with differences mainly attributed to microsite conditions such as soil depth, moisture content, rockiness, and exposure to weather and sunlight. Survival rates are also affected by elevation, drought, spacing, topography, and other annual climatic differences (USFWS 1996b). In general, poorer survival rates occur at higher elevations than lower elevations as a result of frost. Frost protection devices have been designed to enhance seedling survival and growth. Set up on the east side of the seedling, these devices are the most cost-effective and least labor intensive technique (USFWS 1996b, Jeffrey, pers. comm.). Scowcroft and Jeffrey (1999) found that use of this device increased survival from 15-100 percent. By blocking the night sky, the frost protection devices reduce radiative cooling and moderate leaf temperatures (Scowcroft et al. 2000). They also increase moisture by catching fog or mist. Spacing may have a minor affect on survival rates, with 84 percent survival for seedlings spaced 6.6 ft apart and 74 percent survival for seedlings spaced 8.2 ft apart (USFWS 1996b). The average spacing for corridor plantings at the Refuge is a grid of 12 ft.

Seedling survival is also dependent on site preparation methods. In an experiment where discing, burning, herbicide treatment, hand scarifying, and no treatment were used, discing a continuous 6.6 ft strip proved to be the most effective method for preparing a site for planting, but erosion proved to be a problem (USFWS 1996b). When an existing seed bank is present, mechanical soil scarification can also enhance koa regeneration (USFWS 1996b, Jeffrey, pers. comm.). Since 1996, the Refuge has used a modified bulldozer blade attachment to scarify the ground for koa outplanting. A 3-ft wide "mini blade" is attached to the bulldozer blade. As the dozer moves forward, the blade is dropped, scraping the grass off a 3 ft wide by 3 ft long area, exposing the top soil. Koa seedlings grown in dibble tubes are then planted in the sites by volunteers. The planters follow the bulldozer tracks through the grasslands, poking holes in the ground within the scarified sites with a dibble stick. Three holes, 8 in deep and a 1 ft apart are made at each site. The koa seedling is planted into the center hole and fertilizer is placed in the other two.

4.10.2 ʻŌhiʻa (*Metrosideros polymorpha*)

„Ōhi„a (*Metrosideros polymorpha*) is the dominant species on lava flows and in mature native rain forests in the Hawaiian Islands. Occurring from sea level-9,515 ft, „ōhi„a has a wide ecological distribution colonizing habitats of various elevations, substrate ages, soil moistures, and temperatures (Cordell et al. 1997, Mueller-Dombois and Fosberg 1998, Friday and Herbst 2006, Crawford et al. 2008). „Ōhi„a is reported in dry areas with less than 16 in of annual precipitation, as well as wet forests with more than 400 in per year. Furthermore, „ōhi„a can thrive in various soil types, including nutrient-poor sites, and are shade tolerant (Friday and Herbst 2006, Crawford et al. 2008). This endemic tree is considered a pioneer species because it is one of the first species to establish on recent volcanic lava flows. As a result, „ōhi„a forests tend to be comprised of relatively even-aged trees (USFWS 1996b, Mueller- Dombois and Fosberg 1998).

„Ōhi„a is a slow growing species. On average, „ōhi„a are estimated to grow 12 - 24 in in height annually and by 0.04 - 0.12 in in diameter each year (Hatfield et al.1996, Friday and Herbst 2006). Seedlings grow between 2 - 4 in each year (USFWS 1996b). In spite of the slow growth rates, „ōhi„a can grow up to 100 ft tall and reach a peak diameter of 85 in (Wagner et al. 1999, Friday and Herbst 2006). Thus, the species has a relatively long lifespan. Some trees have been dated to approximately

600 years or older and are considered the oldest angiosperm in the Northern hemisphere (P.J. Hart, UH Hilo in press). Growth rates and height increase in areas with organic seedbeds, such as fallen logs and stumps (USFWS 1996b).

An abundant amount of seeds are produced by „ōhi„a. These seeds are small, lightweight, and easily dispersed by wind (Burton 1982, Stemmerman 1983, USFWS 1996b). „Ōhi„a seeds are able to germinate quickly in diverse environmental conditions, even under low light levels. In general, germination is exceptionally high when seeds were sown on the surface rather than under a layer of soil. The optimal germination temperature for „ōhi„a is between 61-72°F. Different varieties exhibit different germination characteristics. Seeds from pubescent plants are more successful at germinating rapidly and in high temperatures; thus, pubescent „ōhi„a are considered more successful pioneers. Due to the thin seed coat, seeds lose viability after several months, suggesting that there is not a persistent soil seed bank (Drake 1993). Due to the abundant and continuous seed supply, „ōhi„a have a competitive advantage over koa (USFWS 1996b).

„Ōhi„a is a polymorphic species, meaning it has distinct morphological varieties. Flowers can range in color from red to yellow and leaf shape is highly inconsistent. Eight „ōhi„a varieties are recognized – *dieteri, glaberrima, incana, macrophylla, newellii, polymorpha, pseudorugosa*, and *pumila* (Wagner et al. 1999). These varieties occur in distinct or overlapping habitats, elevations, and soil moisture regimes (Crawford et al. 2008). Pubescent varieties (var. *polymorpha*) occur in drier, higher elevation sites with younger substrates compared to glabrous varieties (var. *glaberrima*) (Stemmerman 1983, Drake 1993, Cordell et al. 1997, Wagner et al. 1999, Hoof et al. 2008). Leaf pubescence may assist plants in stressful environments by reducing transpiration, freezing, and herbivory rates (Hoof et al. 2008). Varieties with smaller leaf size, petiole length, and internode length are generally observed in higher elevation areas. Thus, these measurements are inversely related to elevation (Cordell et al. 1998). Stomata are larger and more dense on glabrous than pubescent trees (Hoof et al. 2008). The fixed morphological attributes of „ōhi„a are likely the result of consistent and strong selective pressures. Although the morphological variation of „ōhi„a is partially based on environmental conditions (Burton 1982, Stemmerman 1986), these distinct characteristics also appear to be genetically determined (Cordell et al. 1997).

At Hakalau Forest NWR, „ōhi„a trees play a vital role in ecosystem function. „Ōhi„a help sustain forest bird populations and insect populations by providing nesting sites and cavities, harboring insects, and producing nectar (USFWS 1996b). Flowers are present year-round at the HFU, with peaks during the winter and spring (USFWS 1996b). The endangered „akiapōlā„au takes sap of particular „ōhi„a trees by drilling holes in the trunks and branches of specific trees. These trees, termed "aki trees," have higher sap flow than other „ōhi„a. Functioning as an alternative food source to nectar and insects, "aki trees" may play an important role in the diet of „akiapōlā„au during low food periods (Pejchar and Jeffrey 2004).

During the mid 1960s, „ōhi„a forests experienced a dieback of the tree canopy, referred to as „ōhi„a dieback. This loss of crown foliage across the entire landscape occurred in the montane areas of Mauna Kea in both poorly drained and well-drained areas. Extensive research was conducted into the cause of dieback (Jacobi et al. 1983, Mueller-Dombois 1983, Mueller-Dombois and Fosberg 1998) and was determined to be a common, natural phenomenon resulting from aging and environmental stress (USFWS 1996b). Regeneration of the canopy was found to occur following initial canopy loss (Jacobi et al. 1983, Stemmerman 1983). Dieback has occurred in the wet „ōhi„a forest at the HFU and a small portion of the wet koa/ „ōhi„a forest (USFWS 1996b).

Outplanting of „ōhi„a throughout Hawai„i Island has not been as extensive as koa, due to failed restoration efforts (Scowcroft and Jeffrey 1999). Since 1997 over 30,000 „ōhi„a trees were planted on the HFU (USFWS, unpubl.). These trees were planted in the understory of the previously planted koa corridors, which increases survival. Experimental plantings in open pastures resulted in nearly 100 percent mortality, possibly due to grass competition. Planting on downed logs in open areas and under canopy also increased survival but is not efficient because of the lack of substrate logs.

4.10.3 Māmane (*Sophora chrysophylla*)

The ecological characteristics of māmane have not been as extensively studied as koa or „ōhi„a. Māmane is an important component of certain native forests and a valuable food source for native birds, particularly the listed palila. Māmane is a polymorphic species and can be found throughout Hawai„i as a shrub or tree in both dry and wet conditions. On the eastern slope of Mauna Kea at the drier, upper portions of the Refuge (above 6,000 ft), māmane is codominant with koa. As the elevation continues to increase, koa drops out and māmane becomes more abundant. Koa-māmane forest type is transitional between the taller, mesic koa-„ōhi„a stand type and the drier, lower stature subalpine māmane forest. Understory species for this forest type include naio, pūkiawe, „a„ali„i, „ōhelo, and native ferns and grasses. Ecologically, māmane has much in common with koa. It is pollinated by insects and birds and is also a leguminous, nitrogen-fixing species whose seeds are primarily gravity dispersed. It is also able to spread through root sprouting and by seed. Growth rates are likely to be faster at the lower elevation koa-māmane communities at the Refuge.

4.11 Cave Resources

According to the Federal Cave Resources Protection and Management Act of 1988, as amended, a cave is a naturally occurring void, cavity, recess, or system of interconnected passages that occurs beneath the Earth‟s surface or within a cliff or ledge. Cave resources are any material or substance occurring naturally in caves, including animals, plants, paleontological deposits, sediments, minerals, and relief features (16 U.S.C. §§ 4301-4310). In Hawai„i, caves can occur in limestone or basaltic lava (Howarth 1983) and are generally more extensive in pahoehoe lava flows (Howarth et al. 2007). These dark ecosystems are typically wet, with high levels of CO_2 and low levels of O_2. The temperature inside the cave typically reflects the annual temperature at the surface of the cave; however, caves that extend downslope from the entrance often have cooler temperatures (Howarth 1983).

Caves, including lava tubes, have historically been considered inhospitable habitats not favorable to fauna (Howarth 1979, 1983). In reality, these habitats provide refuge for rare and highly specialized invertebrates, such as insects, spiders, and other arthropods. Cave animals can be divided into four categories. Obligate cave species, or troglobites, are unable to survive outside of cave ecosystems and typically exist within deep, damp cave areas that are protected from surface air. Obligate cave species known to occur on the Island of Hawai„i include the endemic moths and spiders (*Sinella yoshiia*, *Schrankia* sp., *Littorophiloscia* sp.). Facultative species, or troglophiles, have the ability to live and reproduce in caves but are also capable of surviving in other similar environments. The third cave type of cave species are the trogloxenes. These species regularly inhabit caves, but return to the surface to feed. Finally, accidental visitors are fauna that inadvertently enter caves and are unable to survive in the habitat (Howarth 1973, 1983, Howarth et al. 2007). In general, cave species can occur in deep, extensive interconnect passages or small voids. Species diversity tends to increase with the age of the cave; however, individuals can disperse to younger, more recent caves (Howarth et al. 2007).

Obligate and facultative cave animals often have unique characteristics because they have adapted to subterranean habitats. Morphological adaptations include a loss or reduction of eyes, pale coloring, wings, and longer appendages. Behavioral traits have also evolved as efficiency tactics in these energy-poor environments. These include slow movements, a lower metabolism, a circadian rhythm, and consuming large amounts in a single feeding. It is difficult to find cave animals because of their cryptic behavior. Many of the cave species are rare; however, the only two endangered cave species occur on the island on Kaua„i (Howarth 1983, Howarth et al. 2007).

Species within these caves receive their energy from several different sources: deep-rooted plants; surface animals that accidentally fall or are washed into the caves; oozes deposited by percolating ground water and reworked by microorganisms; and other organic material such as flood debris. Plant roots are the primary energy source for cave species. In particular, the pioneer „ōhi„a tree is a key food species, because it is the first to colonize young lava. Plant roots also provide shelter and building materials for cave animals (Howarth et al. 2007).

In addition to invertebrates, rare and unusual plants can occur in lava tube skylights. These plants may thrive in moist microclimates and survive due to protection provided by the steep rock walls of the tubes making these sites unavailable to grazing ungulates. Cave ecosystems can also contain minerals, as well as cultural and paleontological remains (USFWS 1997). The twilight zone was often used by early Hawaiians for specialized uses, such as for water catchment or shelter (Howarth and Stone 1998). Archaeologists have found artifacts and prehistoric features within caves throughout the islands (Ziegler 2002). To date no cultural sites have been found in lava tube systems at the KFU. There are no known lava tube systems at the HFU.

Cave habitats on the KFU are extensive. A reconnaissance survey of these caves was conducted by Dr. Howarth and Stone in 1998. Four distinct cave systems consisting of 22 cave entrances were found at the unit, although only three systems were surveyed. The caves are of intermediate age (less than 4,000 years old) and have a thick overburden of rock and soil. Most entrances occur as vertical pits. The cave passages explored by Howarth and Stone were primarily in twilight and transition zones, which are characteristic of caves that have multiple entrances. However, a few other areas likely enter deep zone habitats, where the specialized cave-adapted animals thrive (Howarth and Stone 1998).

It is estimated that only about 20 percent of the caves have been mapped (Ball, pers. comm.). Although caves throughout the site have only been partially surveyed, they are known to support rare and unusual species adapted for life in subterranean ecosystems. Some resident species have persisted because the caves are generally inaccessible to ungulates (USFWS 2002b). Additional cave features likely occur that have surface openings not large enough for humans to enter. The cave locations at the KFU are kept confidential under U.S. cave law (Howarth, pers. comm.).

Due to the cryptic nature of the species, relatively few arthropods were seen during the 1998 KFU survey. Endemic cave fauna and evidence observed by Howarth and Stone included the following: cave carabid ground beetle (*Mecyclothorax?* sp.), *Schrankia* root moths, a *Carposina* fruit moth (probably *gracillima*), Linyphiid spider webs, and trails of the native *Limonia* crane flies. In addition, several dead moths, probably native agrotine noctuids, were found. Nonnative species recorded during the survey included the millipede *Oxidus gracilis*, *Rhopalosiphoninus latysiphon* aphids, *Porcellio* isopods, and shells of the garlic snail *Oxychilus alliarius*. Furthermore, dung of the black rat (*Rattus rattus*) was found in the entrances; these animals can navigate through dark cave passages.

The cave system skylights in the KFU support a variety of diverse native flora including „ākala, *Pipturus*, *Phyllostegia, Cyrtandra, Ilex*, *Cyanea*, *Metrosideros* roots, and a variety of ferns (Howarth and Stone 1998). The endangered *Cyanea stictophylla* previously occurred in a cave at the KFU; however, it was destroyed by rat predation. The native plant „ōlapa is also known to occur in and around the caves at the unit. Cattle often eat „ōlapa growing from the caves (Ball, pers. comm.). Paleo-ornithological surveys by the Smithsonian Institute have found hundreds of subfossil bird bones (geese and rails) in the KFU caves. Most of these species are extinct, while some are considered new to science (USFWS 2008). Howarth and Stone (1998) found roughly 15 flightless goose skeletons, as well as additional bird skeletons during their reconnaissance survey. None of the caves surveyed by Raymond and Valentine (2007) in the KFU contain artifacts or other cultural material.

Cave resources can be drastically altered by physical and biological changes or disturbance over the surface. Toxins or pollutants on the surface can affect the subterranean ecosystem (Howarth and Stone 1998). The input of soil and debris restrict water and nutrients from reaching deeper voids. Herbivore grazing, mining, and chemical pollution are also threats to the subterranean ecosystems (Howarth et al. 2007).

Nonnative species can alter the native ecosystem and adversely impact native species (e.g., through predation). Nonnative taxa especially impact host specific animals, such as cixiid planthoppers, that only utilize a single native species. People can directly impact cave resources by trampling vegetation during exploration and management activities or through deliberate vandalism. Human activity can also indirectly impact the ecosystem by inadvertently creating pathways for nonnative species to invade the habitat (Howarth and Stone 1998).

At the KFU, staff minimize research and trespassing in the caves because heavy foot traffic increases routes for pigs and other ungulates (Ball, pers. comm.). Any future surveys of the caves at the KFU should be done with care to ensure as little damage as possible to the cave walls and floor (Howarth and Stone 1998). Above ground management techniques to help protect these resources include creating protected reserves around significant caves, controlling invasive plant species, and encouraging the recovery of deep-rooted native species (Howarth et al. 2007).

4.12 Threats

Most of the habitats of the Hawaiian Islands have been drastically altered by humans, with less than 40 percent of native habitats remaining in the State (most of which are on the Island of Hawai„i). The first Polynesians to arrive are believed to have brought coconut, taro, and Polynesian pigs. Europeans arrived later and brought sheep, cattle, goats, and game birds. Before human arrival, the estimated rate of successful new colonizations was 1 species every 25,000 years. Over the last 2 centuries alone, the rate of plant introductions alone has been more than 40 species per year. It is estimated that over 6,000 introduced terrestrial and aquatic species are now established, and that of all the species currently in Hawai„i, approximately 26 - 30 percent are nonnative. While many introductions do not pose a threat to native habitats, approximately 10 percent of the established nonnative species are highly invasive or pose significant threats to Hawaiian ecosystems (Mitchell et al 2005). In addition to the already established introduced species, numerous species currently not found on the islands are poised to invade island ecosystems. Over a 9-month period, a Pest Risk Assessment conducted at Kahului Airport by the State Department of Agriculture discovered over 100 nonnative species entering via air cargo (Mitchell et al 2005). In addition to invasive species, wildlife and plant diseases and parasites are also on the rise and include mosquito borne avian diseases such as avian malaria and pox and „ōhi„a rust, which if the right strain reaches the islands could decimate our native „ōhi„a forests. Rust fungi endemic to koa has already been found at the Refuge.

An invasive species is defined as a species whose migration and growth within a new range is causing detrimental effects to the native biota in that range (Pattison et al. 1998). Mammals, amphibians, invertebrates, and plants can all be considered invasive. These species become invasive because their population and growth are no longer balanced by natural predators or biological processes that kept them in balance in their native ecosystems. In the absence of restraints, invasive species have the potential to compete with native species for limited resources, alter or destroy habitats, shift ecological relationships, and transmit diseases (Ikuma et al. 2002). Islands tend to be more exposed to invasive species due to an abundance of trade, tourism, and agriculture (Van Driesche and Van Driesche 2004). Hawai„i, which existed in isolation for millions of years, is an exceptionally ideal environment for invasive species. Most native species throughout the Hawaiian Islands lost their natural defense mechanisms and are more vulnerable to introduced species (Ikuma et al. 2002). Numerous invasive animal populations and a variety of invasive plants occur at the Refuge.

4.12.1 Introduced Forest Birds

Since 1850, more than 130 species of birds have been introduced to Hawai„i. Of these, 15 game species and 30 nongame birds have established populations. Most of the introduced species were from three orders: Galliformes (game birds), Columbiformes (doves and pigeons), and Passeriformes (passerines or perching birds) (Moulton et al. 2001). All three orders of introduced avian species are present both at the HFU and the KFU. Tables 4-8 and 4-9 list introduced birds present in each area. Game birds are discussed in Section 4.12.2 and listed in Table 4-9.

At the central windward region of Hawai„i, the trends of the nonnative species densities were generally decreasing in Kūlani-Keauhou, mixed in „Ōla„a and East Rift, and increasing in Mauna Loa Strip. Japanese white-eyes appeared to be undergoing a decline in occurrence and density in the Kūlani-Keauhou study area. This was the only area where this species demonstrated downward trends. Elsewhere, Japanese white-eyes have shown markedly increasing occurrence and density. Red-billed leiothrix numbers appeared to be declining in the Kūlani-Keauhou and „Ōla„a study areas, and highly variable with nonsignificant trends in Mauna Loa Strip. Northern cardinals appeared to be in decline in Kūlani-Keauhou and East Rift, but possibly increasing in the „Ōla„a and Mauna Loa Strip study areas. The house finch was uncommon to rare and highly variable in all study areas, and analyses of its trends were inconclusive. The Japanese bush-warbler, which became established on Hawai„i Island in recent years and is present at Waiākea not far to the north, has not yet been detected in the central windward region of Hawai„i (Gorresen et al. 2005). Several Japanese bush-warblers have been detected on or near the Refuge since 2002 (Jeffrey, pers. comm.).

At the HFU, hwamei are uncommon but found at highest densities in lower elevation, open-canopy, midstature forests. The red-billed leiothrix is common, widespread, and occurs at highest densities in upper-elevation, closed-canopy, high-stature forests. The widespread Japanese white-eye occurs at highest densities in lower-elevation, open-canopy, mid-stature forests, and heterogeneous vegetation types. The northern cardinal is uncommon, but fairly widespread, occurring at highest densities in the lower and uppermost elevation, open-canopy, high-stature forests, and heterogeneous vegetation types. The house finch is common and occurs at highest densities in grasslands, drier koa-dominated woodland and forests, and heterogeneous vegetation types. Between 1977-2000, the northern cardinal and Japanese white-eye were found to have increased in density, while the hwamei, red-billed leiothrix, and house finch showed no changes in density over the 24-year study period (Camp et al. 2003, Hawai„i Forest Bird Database 2005).

Table 4-8. Introduced Forest Birds Present at HFU and KFU.

Common name	Scientific name	Hakalau Forest Unit	Kona Forest Unit
Doves and pigeons	**Columbiformes**		
Rock dove	*Columba livia*	X	
Spotted dove	*Geopelia striata*	X	X
Zebra dove	*Streptopelia chinensis*		X
Owls	**Strigiformes**		
Barn owl	*Tyto alba*	X	X
Passerines	**Passeriformes**		
Sky lark	*Alauda arvensis*	X	X
Japanese bush-warbler	*Cettia diphone*	X	X
Hwamei	*Garrulax canorus*	X	X
Red-billed leiothrix	*Leiothrix lutea*	X	X
Japanese white-eye	*Zosterops japonicus*	X	X
Northern mockingbird	*Mimus polyglottos*		X
Common myna	*Acridotheres tristis*	X	X
Saffron finch	*Sicalis flaveola*		X
Northern cardinal	*Cardinalis cardinalis*	X	X
House finch	*Carpodacus mexicanus*	X	X
Yellow-fronted canary	*Serinus mozambicus*	X	X
House sparrow	*Passer domesticus*	X	X
African silverbill	*Lonchura cantans*	X	X
Nutmeg mannikin	*Lonchura punctulata*	X	X
Java sparrow	*Padda oryzivora*		X

Of the introduced bird species, the barn owl, Japanese white-eye, red-billed leiothrix, and various gallinaceous birds are the species of most concern. Barn owls probably compete with the native pueo for introduced rats and mice. The Japanese white-eye likely competes for food with native forest birds such as the common „amakihi (van Riper 1984), Hawai„i „elepaio, and „i„iwi. Introduced forest birds, especially the Japanese white-eye and red-billed leiothrix, distribute seeds of nonnative plants such as blackberry, *Photenia* and English holly at the Refuge and fire tree and banana poka in Hawai„i‟s natural areas (Mountainspring and Scott 1985). Nonnative birds are also reservoirs for avian diseases such as malaria and avian pox, though the prevalence of disease in native birds is often higher since these diseases are new to Hawai„i and the native birds have not developed resistance (Samuel et al. 2007, Atkinson et al. 2005).

4.12.2 Introduced Game Birds

Approximately 15 species of nonnative game birds (Galliformes) have established populations in the Hawaiian Islands (Moulton et al. 2001). These birds have negative impacts on native ecosystems. Ring-necked pheasants, Kalij pheasants, and other gallinaceous birds are known to disperse the seeds of invasive plants such as fire tree and banana poka in Hawai„i's natural areas (Mountainspring and Scott 1985). Turkey also eat koa seedlings. They also consume native plant species used by nēnē (Cole et al. 1995).

On the other hand, introduced game birds, such as chukar and pheasants, may occupy a niche previously filled by extinct Hawaiian birds by helping with the dispersal and germination of native seeds (Cole et al. 1995).

Table 4-9. Introduced Game Birds Present at HFU and KFU.

Common name	Scientific name	Hakalau Forest Unit	Kona Forest Unit
Game birds	**Galliformes**		
California quail	*Callipepla californica*	X	
Chukar	*Alectoris chukar*	X	
Erckel"s francolin	*Francolinus erckelii*	X	X
Japanese quail	*Coturnix japonica*	X	
Kalij pheasant	*Lophura leucomelanos*	X	X
Ring-necked pheasant	*Phasianus colchicus*	X	X
Wild turkey	*Meleagris gallopavo*	X	X

4.12.3 Introduced Mammals

Mammals adversely impact the Hawaiian Islands as herbivores, predators, and omnivores. As herbivores, mammals can consume large amounts of native vegetation (Courchamp et al. 2002) and serve as an agent in the spread of invasive nonnative weed species. Because native Hawaiian flora did not evolve with mammals, these species are not adapted to grazing by herbivores (Stone 1985, Scowcroft and Conrad 1992, Stone et al. 1992). Predatory mammals, such as cats, prey on a variety of species throughout the islands. Furthermore, omnivorous mammals (rats), can severely impact island ecosystems by consuming both flora and fauna (Courchamp et al. 2000).

Both units of the Hakalau Forest NWR are threatened by introduced mammals to varying degrees. Currently, the HFU has 45 miles of pig- and cattle-proof fence. The HFU is divided into eight ungulate management units to facilitate easier control. Additional units, located in the lower elevations of the Refuge, are planned to be fenced in the future as funding and staffing allow. As new land was added to the Refuge, commercial cattle grazing was phased out (as in the Upper Honohina Tract, domestic grazing occurred within 1,034 ac of this Tract until April 1996). Ungulate grazing is no longer allowed on the Refuge.

Within KFU, the Refuge estimates that currently there are more than 300 wild cattle and an unknown number of pigs, sheep, mouflon, donkeys, and horses. These ungulates are primarily concentrated in the mesic belt (Ball, pers. comm.), which receives between 50-75 in of annual rainfall. Physical, chemical, and biological population control methods are used on invasive mammals and their removal, while frequently justified biologically, is not without controversy. The elimination of grazers in altered habitats can also release other species from browsing pressure and result in an increase in nonnative and invasive plant species (Scowcroft and Conrad 1992, Cabin et al. 2000, Van Driesche and Van Driesche 2000). At the KFU, the removal of ungulates may be controversial because eliminating grazers will increase the potential for fire. This could both eliminate native habitat and impact adjacent landowners. Wildfire Management Plans (2002a, 2002b) have been developed for both units. Additionally, a strategy in this CCP identifies developing a fire prevention program for both units.

Cattle (*Bos taurus*)

Cattle were released on the Island of Hawai„i in 1793 by Captain Vancouver (USFWS 1996b). Currently, cattle exist on the all of the main Hawaiian Islands except for Kaho„olawe. These feral animals have a wide distribution, ranging from lowland dry forests to montane grasslands and subalpine scrub (Tomich 1986, Atkinson and Atkinson 2005).

Cattle ranching was the primary historical land use on the HFU for over 100 years, although other forms of ranching may have occurred. Reports of cattle at Hakalau first occurred in the early to mid-1800s. Intensive grazing occurred primarily above 5,400 ft (USFWS 1996b). Cattle grazing has been eliminated on the HFU; however, cattle remain throughout adjacent properties.

At the KFU, cattle are the most widespread ungulates. Recent estimates suggest roughly 300 wild cattle inhabit the KFU boundaries at all elevations. Historically, cattle grazing was the primary land use of the former 60,000 acre McCandless Ranch. The Three Mountain Alliance Management Plan (2007), a landscape level effort that spans large areas and multiple ownerships of Hawai„i Island, considers the KFU as a high priority area for feral cattle control.

Due to their large size, cattle can have a large impact on native ecosystems (USFWS 2008). Cattle have been regarded as the “single most destructive agent to Hawaiian ecosystems, particularly to koa forests” (Atkinson and Atkinson 2005). These ungulates can degrade native forest by eating or trampling native vegetation, accelerating erosion, and promoting the invasion of nonnative plants (USFWS 2008). In particular, cattle suppress regeneration of koa and the growth of māmane forests (Atkinson and Atkinson 2005). Soil properties are also altered due to the presence of cattle. The animals can change soil structure and pH, as well as its ability to retain water and nutrients (USFWS 1996b).

The impact of cattle is apparent on both units of Hakalau Forest NWR. Nearly all the trees have been eliminated on the HFU areas above 6,000 ft as a result of over 100 years of grazing. Certain areas covered by old a„a lava flows have more forest, suggesting that cattle were less able to transverse this substrate and degrade the forest (USFWS 1996b). On the other hand, removing cattle on the HFU has increased the nonnative grass fuel load considerably (USFWS 2002a).

Pigs (*Sus scrofa*)

Pigs that occur in Hawai„i are likely to be a blend descended from two ancestral types introduced on separate occasions. Polynesians first brought pigs to the islands as a food source around 1,500 years ago. Captain Cook subsequently brought European pigs to the islands in 1778 (Tomich 1986). Pigs descended from European strains were generally larger, more fecund, and more nomadic than their Polynesian counterparts (Van Driesche and Van Driesche 2000). Although pigs have been eradicated from numerous islands worldwide, these animals remain highly abundant in Hawaiian island ecosystems (Courchamp et al. 2003, Crux et al. 2005). They occupy every main island in the Hawaiian archipelago. The pig population is largest on Hawai„i Island (Tomich 1986, USFWS 2007a).

Pigs are long and narrow in shape and predominately black in color and are generally hairy. They measure 3.5 - 4.5 ft in length and average 2 ft in height. Pigs are elusive animals. They have been reported to be highly active in the early morning and late afternoon in tropical climates (Diong 1982). In the HFU, the maximum age of male pigs (boars) is 60 months, while females (sows) live a maximum of 48 months (Hess et al. 2006).

The reproductive potential of pigs contributes to their invasive potential. These animals are polyestrous, meaning that adult females have more than one estrus cycle (21 days) in a breeding season (McGaw and Mitchell 1998). Pregnancy can occur year-round with peaks January - March (Hess et al. 2006). The average sow in Hawai„i has 1.1 litters per year (Caley 1997). Reproductive rates peak between 2- 4 years, but breeding has occurred by 10 month-old sows (Hess et al. 2006).

Although all ungulates have a negative impact in Hawaiian forests, it is generally agreed that pigs pose the greatest threat to the survival of Hawai„i‟s forest birds and their habitats (Scott et al. 1986, Van Driesche and Van Driesche 2000, USFWS 2008). Pigs are an omnivorous species that consume fruits, seeds, plant material, as well as some invertebrates. In Hawai„i, pigs consume and damage plant material in both wet and dry habitats and in agricultural and natural area settings. They root and trample native vegetation, digging up the soil for earthworms, as well as underground plant parts such as rhizomes and tubers (Stone et al. 1992). At Hakalau Forest NWR, pigs also eat native Hawaiian plants such as bracken fern roots and hāpu„u (Jeffrey, pers. comm.). Pigs degrade habitat for native invertebrate species such as the endangered picture-wing fly (Mitchell et al. 2005).

These animals facilitate the spread of seeds of nonnative species. Pigs act as vectors for invasive plant species dispersing nonnative plants such as strawberry guava and banana poka (LaRosa 1992, Stone et al. 1992, Barnett and Simonson 2008). On the Island of Hawai„i, areas without grazing ungulates show a more diverse plant community with greater coverage of native overstory and understory species (Cabin et al. 2000). However, the removal of pigs from Hawaiian forests does not ensure reductions of nonnative plants (Anderson et al. 1992).

Pigs contribute to the prevalence of avian diseases by increasing breeding sites for mosquitoes. Both on and adjacent to the HFU and KFU, pigs create abundant habitats for mosquito larvae by knocking down and hollowing tree ferns to eat the starchy cores, leaving behind troughs that catch water and provide mosquito breeding sites. By increasing the availability of standing water, pigs increase mosquito populations and potentially increase infection rates of avian malaria and pox in native forest birds. Most native forest birds have little resistance to these diseases (Van Driesche and Van Driesche 2000, Atkinson et al. 2005). Some scientists believe that pig management should be emphasized in the lower portions of the HFU and KFU to minimize and halt the spread of mosquitoes into higher elevation forested areas (Van Driesche and Van Driesche 2000).

Other ecosystem effects can be attributed to pig activity. Rooting and compaction can deplete the soil of needed oxygen (Van Driesche and Van Driesche 2000). The behavior of pigs causes erosion of cliff and stream banks. As a result, the quality of both fresh and brackish water system can be degraded (USFWS 2008).

Most of the fenced portions of the HFU are pig free. Pig removal began at the HFU in 1988; however, the 5,001.4 ac enclosure was not completed until 1992. The estimated density of this area in 1992 was 4.7 pigs/mi^2. The unmanaged area of Middle Maulua and Unit 3 had predicted densities 2.5 times greater. The population of Unit 3 was 118 ± 36 in 2004, while Unit 6 contained 24 ± 20 pigs (Hess et al. 2006). The lowland area of the HFU (which is not fenced) most likely supports a high-density pig population (Jeffrey, pers. comm.). Within this area, the highest pig densities occur in the closed canopy forest (USFWS 1996b). In addition, the adjacent State-owned Pīhā Game Management Area contains a high pig population.

The efficacy of the pig removal program at HFU from 1987-2004 is described by Hess et al. (2006). During this study it was determined that greater than 41-43 percent of the population at HFU must be removed annually in order to effect a decline in pigs. To reduce the population by 50 percent in following years, roughly 70 percent of the population must be removed annually; otherwise there is a sustained population. Eradication at the HFU with dogs was estimated to require 11.8 worker-hours per pig; this number is similar to estimates generated for the Hawai„i Volcanoes National Park, which required 20 worker-hours per pig. Hunting with dogs is expensive because of intensive labor costs and high maintenance and veterinarian costs. In addition, hunting dogs were killing nēnē on the Refuge (Jeffrey, pers. comm.). In contrast, the eradication rate at HFU using snares was estimated at 4.9 worker-hours per pig. After the first 9 years of staff pig hunting in HFU, pig activity remained between 25-30 percent. Within 18 months of first setting pig snares, no pig activity was observed by Refuge staff through ungulate surveys. Pig snares were first tested at HFU in 1999 (Van Driesche and Van Driesche 2000) and are now permanently deployed throughout the units. Snares have been determined to be cost efficient. The snares are usually set in groups of 10, and average about 1 snare per acre with a unit and cost roughly $17 each. Snares are anchored to trees and placed in areas of high pig activity. Subsequently, the snare sets are inspected every 6 months, and replaced and reset as needed. Pig carcasses are not removed, but are left in the forest as the cost of removal is high and the carcasses often act as bait (Jeffrey, pers. comm.).

Pigs are abundant on the KFU, with recent estimates suggesting up to 1,000 pigs freely roaming the property. They are found at all elevations of the unit (USFWS 2007A, 2008). The Refuge plans to remove these animals once an ungulate proof fence is completed.

Rats (*Rattus*)

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

Globally, introduced rats have caused the decline, extirpation, or extinction of insular bird species (Moors and Atkinson 1984, Atkinson 1985). In the main Hawaiian Islands, Atkinson (1977) suggested that black rats caused the accelerated decline or extinction of many native forest birds between 1870-1930. Polynesian rats are speculated to have been a contributing factor in the large-scale extinction of Hawaiian bird species during prehistoric Polynesian occupation (Olson and James 1982). Rats continue to be a major threat to waterbirds, seabirds, and forest birds in the Hawaiian Islands (Mitchell et al. 2005). All three species in Hawai„i are known predators of eggs, nestlings, young, and occasionally adults of endangered waterbirds (ae„o, „alae ke„oke„o, „alae ula, koloa maoli), seabirds („a„o or Newell"s shearwater, „ua„u kani or wedge-tailed shearwaters, moli or Laysan albatross), migratory shorebirds, and forest birds (Harrison et al. 1984, Brisbin et al. 2002, Engilis et al. 2002, Mitchell et al. 2005, USFWS 2005a, USFWS 2005b). Ground and burrow-nesting seabirds are particularly vulnerable to rat predation, even by the arboreal black rat (Smith et al. 2006).

Rats also consume plants, insects, mollusks, herpetofauna, and other invertebrates. As herbivores, rats consume seeds and fruits and prevent the regeneration of rare and endangered plants. These mammals have also been observed causing indirect damage to young koa by stripping the bark off seedlings (Scowcroft and Sakai 1984). Because invertebrate and plant species are also eaten by birds, a reduction in these populations may indirectly affect avian populations (Nelson et al. 2002).

In the early 1990s rats were known to consume leaves and fruit of the few known endangered *Cyanea shipanii* at HFU. Rats were thought to have killed at least two of the four remaining plants. At KFU, some of the last remaining *Cyanea sticophylla* were known to be girdled by rats (USFWS, unpubl.). The USGS-BRD conducted a study at Hakalau Forest NWR in the mid-1990s eradicating rats from a 0.02 m^2 area and compared it with an adjacent area where no rats were removed. During the first year of the study, a 25-75 percent increase in nesting success, depending on bird species, was seen in the rat-free area (Fancy, pers. comm.)

The use of diphacinone rodenticide has been shown to have a positive effect in native bird survival in the main Hawaiian Islands (VanderWerf and Smith 2002, Nelson et al. 2002) but is not currently being used on the HFU.

Cats (*Felis catus*)

Cats are found on all the main Hawaiian Islands from sea level to nearly 10,000 ft (Tomich 1986). They occur in montane wet forest, subalpine dry forests, and lowland dry forests (Smucker et al. 2000). Cats can breed year-round in Hawai„i due to the climate, producing between 2-3 litters annually and 4-6 kittens per litter (Winter 2003, Winter and Wallace 2006).

Food habits of cats in Hawai„i include grasses, plant seeds, insects, centipedes, marine crustaceans, lizards, mice, rats, and „ōpe„ape„a. They are also known to consume young and adult birds and their eggs. Bird prey consists of four endangered Hawaiian waterbirds, migratory shorebirds, nesting seabirds, and Hawaiian forest birds (Tomich 1986, Snetsinger et al. 1994, Mostello 1996, Smucker et al. 2000, Brisbin et al. 2002, Engilis et al. 2002, Mitchell et al. 2005, USFWS 2005a, USFWS 2005b). At the HFU, rats were found to be the dominant food item for cats, occurring in 75 percent of sampled scats (Smucker et al. 2000). Cats are one of the main predators feeding on nēnē eggs and goslings at the HFU.

Cats have a universally damaging effect on insular forest birds and nesting seabirds (Moors and Atkinson 1984, Statterfield et al. 1998, USFWS 2005a). Species with low reproductive rates and high parental investment are particularly susceptible. In addition, cats are known to carry the protozoan that causes toxoplasmosis. This disease is caused by the protozoan *Toxoplasma gondii* that has been known to kill the endangered „alala and nēnē (TMA 2007). Several captive released „alala in the early 1990s that died were diagnosed with toxoplasmosis (Ball, pers. comm). It is recommended that all cats be removed prior to additional „alala releases at the KFU (Winter and Wallace 2006).

At HFU, live-trapping and removal is used for control of cats during the nēnē breeding season October-April. Traps baited with sardines are deployed around primary nēnē nesting areas. These traps are equipped with "gosling guards" which are placed in front of the opening to inhibit young nēnē from entering the traps, and yet allow predators to enter. Traps are checked once a day and predators that are caught are humanely euthanized using CO_2 (Jeffrey, pers. comm.). Three cats were trapped in 2007 (USFWS 2007a). No cat control method is currently used at the KFU.

Goats (*Capra hircus*)

Goats were introduced to Hawai„i around 1778 by European explorers. Large herds were present by the 1850s. Tomich (1986) identifies goats in Hawai„i as the subspecies *Capra hircus hircus*. Wild goats are established on Hawai„i, Maui, Kaua„i, Moloka„i, and Kaho„olawe (Scowcroft and Hobdy 1987). The first known major goat control began at Hawai„i Volcanoes National Park in the 1960s (Spatz and Mueller-Dombois 1973). Goats are not known from the HFU but a few dozen goats are currently present on KFU (USFWS 2008). Goats prefer open habitat, such as grasslands, and scrub but will take cover in open forests. They typically move in groups, with males more nomadic than females. The home ranges of goats vary from 328 ft to 12 mi wide (Atkinson and Atkinson 2005).

Similar to other ungulates in the Hawaiian Islands, goats are considered to be habitat modifiers. Goats have been implicated in causing declines of native woody legume species, such as the nutritious māmane (Tomich 1986) and koa. They have been observed consuming the shoots and root suckers of koa and therefore inhibiting reproduction (Scowcroft and Hobdy 1987). By removing native species, goats also help facilitate the invasion of noxious plant species, reducing native habitat, cover, and food resources for native species that depend upon these plants (USFWS 2008).

Sheep (*Ovis aries*)

Sheep were brought to the Hawaiian Islands by Captain Cook in 1778. Populations became established on Hawai„i Island and formerly Kaho„olawe (Atkinson and Atkinson 2005). Sheep populations that had established in Mauna Kea‟s subalpine woodland in 1825 reached about 40,000 animals by the early 1930s. Public hunting in the area decreased the population to about 5,000 sheep in 1955, and by 1970 the sheep population had dropped to 1,500 (Scowcroft and Conrad 1992). Because sheep populations were having an impact on the endangered palila, the State of Hawai„i was charged with violating the ESA, and all sheep were court ordered to be removed from the māmane forest portions of Mauna Kea. The removal was never completed and today sheep are still present in the area (Scowcroft and Conrad 1992).

The Refuge estimates that more than 50 sheep are present on the KFU. These animals exist only above 5,000 ft (USFWS 2008). The impacts of these animals are similar to other ungulates present in the Hawaiian Islands. They consume the bark, leaves, and seedlings of native plant species, allow the invasion of noxious weeds, and increase erosion by exposing soil. In particular, sheep have a preference for legumes such as koa and māmane trees (Scowcroft and Conrad 1992).

Mouflon (*Ovis musimon*)

Native to the islands of Sardina and Corsica, mouflon are considered to be a wild species of sheep. These animals have become established on Lāna„i and Hawai„i Island, although the origin of these populations is unknown (Tomich 1986). In 1962, mouflon were released in the Mauna Kea Forest Reserve. By 1986, the entire population was estimated to be around 500, with the largest concentrations occurring on the southeastern and northwestern flanks (Scowcroft and Conrad 1992). Unlike sheep and goats, mouflon were not included in the court ruling to remove these species from Mauna Kea during the late 1970s and early 1980s, but were added to the ruling later. Currently, the highest concentrations of mouflon occur on the eastern slope of Mauna Kea (Tomich 1986) and the western and southern slope of Mauna Loa. These animals are also present on the KFU (USFWS 2008).

The food habits, grazing and browsing behavior, and ecological impacts of mouflon are similar to sheep (Scowcroft and Conrad 1992). They generally travel in small groups and have become adapted to rugged ridges and gully habitats (Tomich 1986).

Donkeys (*Equus asinus*)

Donkeys are native to northeast Africa and were first recorded in the Hawaiian Islands in 1825. In 1965, two populations of donkeys existed on the Island of Hawai„i. Approximately 50-60 donkeys were recorded on McCandless Ranch, part of which is now the KFU. An additional 19 donkeys occurred in the Ka„ūpūlehu-Kīholo lava fields in North Kona (Tomich 1986). Roughly 7-10 donkeys were later recorded on the KFU (Ball, pers.comm.).

Physically, a donkey resembles a horse with a larger head and longer ears. They thrive in warm, dry climates. The diet of donkeys primarily consists of grass, but other plants are also eaten. Adult donkeys have been documented to eat approximately 6,000 pounds of forage annually. Females produce only 1 young each year and they have been documented to live 25 years on average.

Although donkeys do contribute to ecosystem change and degradation, primary literature on the impacts of donkeys is sparse. In the Galapagos, donkeys have been reported to cause declines in plant populations (Carrion et al. 2007). Donkeys have been removed from several islands worldwide, including San Miguel Island in California and several others in Mexico. Aerial hunting has proven to be effective in areas with an open canopy, but ground hunting and contraceptive vaccines have also been used (Carrion et al. 2007).

Horses (*Equus caballus caballus*)

Though impacts from horses to the KFU ecosystem are unknown, horses have been recorded wandering from neighboring ranch lands into this Unit. Horses do crop and trample vegetation as well as deplete soils. Horses were first brought to the islands of Hawai„i and Maui in 1803. Though horses were found in abundance after their introduction to the islands, the first report of feral horses was by C.S. Judd when he talked about feral horses being driven out of the Mauna Kea forest reserve in 1932. Horses were less prolific and unlike feral cattle, were unable to survive in the forest or high in the mountains. Consequently, there is little historical evidence of feral horses in large numbers as have been recorded for feral pigs, goats, sheep, and cattle. Horses are hooved mammals which humans began to domesticate around 4,000 BC. They are capable of reproduction at 18 months with gestation lasting for 11 months, with 1 foal given birth to at a time.

Small Indian Mongooses (*Herpestees auropuntatus*)

The small Indian mongoose was intentionally introduced to numerous island ecosystems during the 1800s and 1900s and has since expanded to large portions of Asia, Africa, Europe, Oceania, and the Americas (Hays and Conant 2007). In 1883, the species was introduced to the main Hawaiian Islands as a biocontrol agent against rats in sugarcane fields. Mongooses inhabit all habitat types from sea level to nearly 10,000 ft on the islands of Hawai„i, Maui, O„ahu, and Moloka„i (Tomich 1986, Staples and Cowie 2001). In other areas of the world, mongooses appear to avoid wet areas; however, in Hawai„i, dense populations of mongooses are concentrated in wet habitats.

The small Indian mongoose is an agile light brownish-gray animal. It has short legs, small rounded ears, and a bushy tail. The mean home range of a female mongoose in Hawai„i is approximately 3.5 ac and the main reproductive period occurs between February-August. Males can travel long distances. The high density of mongooses in the Hawaiian Islands is due to the lack of natural predators and diseases (Hays and Conant 2007).

The mongoose is a voracious omnivore, consuming insects, reptiles, mammals, amphibians, crabs, plants, and birds. In Hawai„i, mongooses are diurnal predators that primarily prey on invertebrates and secondly on small mammals (Hays and Conant 2007). They are a major threat to any ground-dwelling and nesting species in Hawai„i. These mammals are known to prey on eggs, young, and adults of four endangered Hawaiian waterbirds, nēnē, various seabirds, and migratory shorebirds (Harrison et al. 1984, Moor and Atkinson 1984, Tomich 1986, Staples and Cowie 2001, Brisbin et al. 2002, Engilis et al. 2002, Mitchell et al. 2005). Mongoose populations are managed using traps and diphacinone rodenticide. Hays and Conant (2007) warn that the use of traps may be ineffective because they can lure mongooses into unoccupied habitat areas.

Trapping efforts on HFU during nēnē breeding season, October-April, yield primarily mongooses. Approximately 23 mongooses were caught by traps at the HFU in 2007 (USFWS 2007a). Mongooses are the main predator on nēnē eggs and goslings at the HFU.

4.12.4 Introduced Reptiles and Amphibians

About 27 species of reptiles and amphibians have become established on the Hawaiian Islands. In spite of this number, the impacts of these nonnative species in island ecosystems are generally understudied (Sin et al. 2008). Several species of nonnative reptiles and amphibians exist in substantial numbers on the Island of Hawai„i and may have the potential to threaten native ecosystems such as the Hakalau Forest NWR.

Coqui Frogs (*Eleutherodactylus coqui*)

The coqui frog, endemic to Puerto Rico, was unintentionally introduced to Hawai„i in the late 1980s through the nursery industry. This frog measures about 1 inch long. The back of the coqui ranges in color from light to dark brown, while its belly is white to yellow. The frog can survive between sea level-4,000 ft and is primarily spread by humans translocating infested vegetation. The current distribution of the coqui frog encompasses 250 populations on all four main islands; however, the largest concentration occurs on the Island of Hawai„i, where the frog has infested about 10 mi^2 based on 2007 estimates (HISC 2007). In certain areas of Hawai„i, the coqui frog has reached densities of 50,000 frogs per acre (Sin et al. 2008).

In contrast to other nonnative reptiles, the coqui frog has received an ample amount of attention because its loud mating call has adversely impacted the economy of Hawai„i (Kraus and Campbell 2002). This loud “Ko-KEE” call is produced only by the males and is most vocal after sunset and during rainfall. Research has found that they consume a large amount of small invertebrates, especially insects. They have been observed eating invertebrates on vegetation at night and in the litter during the day. This generalist predator species has been found to eat about 350,000 invertebrates per 2.47 acres each night (Staples and Cowie 2001, Sin et al. 2008). Although the coqui primarily consumes nonnative insects, they could also reduce endemic invertebrate populations in Hawai„i.

Indirect impacts are also observed. The presence of coqui frogs lowers herbivory rates by decreasing the amount of herbivorous insects. Coqui have also been shown to increase nutrient cycling rates by increasing concentrations of several nutrients, increased leaf litter decomposition rates, and increasing the number of new leaves on an invasive plant species. This acceleration of the nutrient cycle could negatively affect slow-growing native plant species while giving nonnative species a competitive advantage (Sin et al. 2008).

Although coqui studies have not been conducted at the KFU, frogs may potentially be on the Refuge. Coqui frogs are known to occur at high numbers at the nearby Waiea Transfer Station (Ball, pers. comm.).

The Coqui Frog Working Group is a partnership of various agencies and organizations that conduct ongoing coqui frog research and control. This group includes the University of Hawai„i, Big Island Invasive Species Committee (BIISC), Hawai„i DLNR, Hawai„i Department of Agriculture, County of Hawai„i, Hawai„i Island Economic Development Board, USDA, and the Service. Extensive research has been done on a wide variety of surfactants, registered insecticides, pharmaceutical products, and food additives that could be used to control frogs. Originally, coqui frog control was limited to hand-capture until the EPA granted certified pest-control operators an emergency registration to hand-spray caffeine for control in limited situations (Kraus and Campbell 2002).

Currently, both chemical (citric acid) and nonchemical (hand-capture and hot shower) control methods are available to the general public. Hydrated lime was previously used against the frogs; however, as of April 2008, it is illegal to use hydrated lime to control coqui frogs in Hawai„i until the EPA permit is renewed (*http://www.ctahr.hawaii.edu/coqui/control.asp*). Community interest in coqui control remains high although public funding for local programs has been cut and/or eliminated in recent years. The current tools and resources for controlling the coqui frog are not sufficient to eradicate populations. New technology, such as thermal heat treatment units and new hot water showers for nursery plants being shipped to the mainland are being developed (HISC 2007).

Jackson's Chameleons (*Chamaeleo jacksonii*)

Jackson‟s chameleon was introduced to Hawai„i from East Africa in 1972. The current distribution is from sea level- 2,000 ft on the main Hawaiian Islands. They prefer shrub or arboreal habitats with a daytime temperature between 70-90°F and a nighttime temperature between 50-68°F. The initial law that prohibited individuals from possessing Jackson‟s chameleons in Hawai„i was overturned in 1994. Jackson‟s chameleon is characterized by its ability to rapidly change color and pattern and its long tongue that helps to capture prey. The sticky tip of the tongue can reach small invertebrates (e.g., insects, spiders, and small snails) in 0.06 seconds (Waring 1997). Prey capture is facilitated by independently rotating eyes. They average 10 in in total body length (Staples and Cowie 2001). The reproductive capabilities of Jackson‟s chameleon contribute to its invasive potential. The average clutch is 28.7 eggs and each female has a maximum of 5 clutches (Masurat and Masurat 1996).

Although the elevational range of this species is generally below the Refuge units, Jackson‟s chameleons are known to occur at lower elevations below the KFU and could impact the forested areas of both units as a result of global climate change. The Jackson‟s chameleon consumes both native insects and bird eggs (Staples and Cowie 2002).

4.12.5 Introduced Arthropods

Invasive arthropods in Hawai„i include insects, spiders, mites, centipedes, and millipedes. An estimated 20 arthropod species invade and establish themselves in the Hawaiian Islands each year (Messing et al. 2007). Haines and Foote (2005) found that the abundance of invasive insects decreased with increasing native insect diversity at the KFU.

Southern House Mosquitoes (*Culex quinquefasciatus*)

The southern house mosquito was introduced to the Hawaiian Islands around the 1820s and occurs from sea level-4,921 ft on the Island of Hawai„i (Ahumada et al. 2004). Elevation plays a large role in the population dynamics of mosquitos. At lower elevations, the southern house mosquito has been found to occur in high numbers and populations consistent throughout the year. In contrast, mosquito populations in middle and high elevation areas are relatively low and show biannual extremes; high numbers occur from August-September and lower numbers occur between February-May (LaPointe 2000).

Mosquito distributions are also affected by ambient temperature, with population growth rates increasing with temperature. Ahumada et al. (2004) estimated that mosquito populations on Hawai„i Island can survive in areas with an annual temperature of 58.3°F and a summer temperature of 55.8°F. LaPointe (2000) found that the southern house mosquito can complete larval development at 53.6°F. As a result of these temperature restrictions, mosquitoes on the Island of Hawai„i can survive up to approximately 4,839 ft. This range could extend to 5,625 ft during the summer. Rainfall also influences mosquito prevalence and survival because adults require water filled cavities to breed and larval stages are highly susceptible to drought (Ahumada et al. 2004). Additional factors, such as size, can contribute to survival rate. Larger individuals have a higher feeding success, survivorship, and infection potential (LaPointe 2000).

The southern house mosquito is a primary vector for several diseases that impact native Hawaiian birds. Mosquito-borne avian diseases, principally avian malaria and the avian pox, have been implicated as the main reason for mortality of the native Hawaiian forest birds (Van Riper et al. 2002, LaPointe et al. 2005, Reiter and LaPoint 2007). As a result, some bird species are only able to survive at higher elevations, above the mosquito zone. Other mosquito species have been shown to carry both diseases to a lesser degree (LaPointe et al. 2005).

Although mosquitoes are able to persist and complete their life cycle at higher elevations, avian malaria oocysts may not be able to develop in cooler temperatures. Benning et al. (2002) estimated that the threshold temperature for transmission of avian malaria is 55.4°F. Avian malaria prevalence is highest in mid-elevation forests with annual temperatures of 63°F. Thus, mosquitoes living at higher elevations may not be able to transmit avian malaria (Ahumada et al. 2004).

Western Yellowjacket Wasps (*Vespula pensylvanica*)

Western yellowjacket wasps were first recorded in the Hawaiian Islands in 1919, although they did not become established on Hawai„i Island until the 1970s. The annual cycle of the western yellowjacket wasps is regulated by climate (Gambino and Loope 1992). The queen, which hibernates during the winter months, establishes a colony in spring, and populations subsequently peak in the summer. However, because of Hawai„i‟s warmer climate, overwintering colonies occur irregularly in the Hawaiian Islands (Gambino and Loope 1992, Nishida and Evenhuis 2000, Haines and Foote 2005).

This wasp species threatens native insect communities by preying on native species, especially larvae and pupae. This includes rare and endangered species such as *Drosophila* flies (Mitchell et al. 2005) and the koa bug (Johnson et al. 2005). In addition, the wasps compete with native predators and pollinators for various food resources. This may in turn have a larger ecosystem impact by removing prey for native species (Haines and Foote 2005). It has been suggested, but there is no evidence, that the wasps may feed on native birds or their eggs and nestlings (Jeffrey, pers. comm.).

Preliminary work on the distribution of western yellowjacket wasps at the HFU has been conducted (Foote 2002, Howarth et al. 2003). The prevalence of these wasps on the HFU is cyclic (USFWS unpubl.). Trapping during the early 1990s shows that during wet years, few western yellowjacket wasps are observed, and populations increase during dry years (Jeffrey, pers. comm.).

At the KFU, populations of western yellowjacket wasps have been monitored using plastic yellowjacket traps hung from branches and baited with heptyl butyrate (Haines and Foote 2005). The wasps are widely established throughout the unit, except between 3,500-5,453 ft. The relative abundances of western yellowjacket wasps varied over time, with peaks during autumn (September-December) at the lower elevations and peaks during winter (August- February) at the upper reaches. These seasonal fluctuations are typical of western yellowjacket wasp populations observed in other mesic forests (Haines and Foote 2005).

Western yellowjacket wasp populations can be reduced by directly applying a pesticide to an active nest or by using a combination of bait (e.g., canned tuna cat food) and chemical toxicant (0.5 percent microencapsulated diazinon). This was found to be particularly effective in controlling populations (Nishida and Evenhuis 2000).

Two-spotted Leafhoppers (*Sophonia rufofascia*)

The two-spotted leafhopper has been implicated in the dieback of uluhe and „ōhi„a (Haines and Foote 2005). The leafhopper is present on the KFU, especially between elevations of 1,900-4,500 ft. Within the lower reaches, additional concentrations occur specifically at about 2,297-3,117 ft.

Rainfall, temperature, and vegetation differences may play a role in these distributional trends (Haines and Foote 2005). Currently, a management strategy has not been developed to control the two-spotted leafhopper.

Ants

More than 40 nonnative ant species have colonized Hawai„i (Hawaii Ant Group 2007). Ants have been labeled as the "the greatest arthropod threat to conservation in the Pacific" (Nishida and Evenhuis 2000) due to their impact to native flora and fauna. Ants are plant predators that harvest seeds, prune foliage, and directly compete with native invertebrates and vertebrate species, creating favorable conditions for other invasive biota (Nishida and Evenhuis 2000).

Four ant species were collected from the KFU: *Cardiocondyla wroughtoni*, *Paratrechina bourbonica*, *Solenopsis papuana*, and *Tetramorium bicarinatum.* Ant abundances were measured at the KFU using protein bait (canned cat food) and carbohydrate bait (guava jam). Two of these species (*P. bourbonica* and *S. papuana*) were found in high numbers at KFU (Haines and Foote 2005). Occurring between 1,900-3,050 ft, these species were observed only in the lower reaches of KFU. Only a few specimens of the two additional ant species (*C. wroughtoni* and *T. bicarinatum*) were noted (Haines and Foote 2005).

Ant control is difficult in dense forests, and current control methods have proved ineffective. The use of baits with pesticides helps to control population, but entail aerial application of a bait product. This technique is not permitted in Hawai„i (Haines and Foote 2005).

4.12.6 Introduced Plants

Invasive species are recognized as a major threat to native ecosystems and to the survival of threatened and endangered species (Pimental 2005). At the ecosystem level, invasive plants have been shown to be capable of changing fire regimes (D""Antonio and Vitosek 1992), altering nutrient cycling patterns (Vitousek 1990), and modifying the surface runoff of water (Vitousek 1992).

Invasive plants can physically displace native species, and/or supersede them by competition for water, nutrients, or other limited resources. Nonnative plants can also be vectors and hosts for introduced pests and diseases to which the native species lack natural defenses (Jui et al. 2007). Some invasive plants have allelopathic properties. Furthermore, compared to native plants, introduced plants lack their natural enemies in the introduced range, which again gives them a competitive edge over native species. Some invasive plants are faster growing and can therefore easily and quickly colonize, establish, and displace native species (Blossey and Notzold 1995).

Island ecosystems are particularly vulnerable to biological invasions (Loope and Muller-Dombois 1989, Denslow 2003). In spite of a multitude of plant species that have been introduced to Hawai„i, only about 1 percent (130 of 13,000 species) of them are considered invasive and have a negative impact on the native habitats; however, the Hawai„i DLNR anticipates that an additional 200 - 300 species already present in the State may become problems in the future (*http://www.state.hi.us/dlnr/dofaw/hortweeds/*). In general, detrimental invasive plant species exhibit a lag phase in which the species will exist at low concentrations for a period of time before spreading across the landscape (Hobbs and Humphries 1995).

Invasive plants are successful in island ecosystems due to a multitude of traits. According to Staples et al. (2000), invasive plants in Hawai„i share the following biological and reproductive characteristics:

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

As a result of these traits, control and eradication of introduced weeds has been a top priority of natural resource managers in Hawai„i (Jacobi and Price 2007). For this reason, several databases have been developed to assist in invasive plant species control. The Hawai„i-Pacific Weed Risk Assessment (HPWRA) is a research project conducted by the University of Hawai„i and the USDA Forest Service to identify plants that pose a high risk in Hawai„i and other Pacific Islands. This database provides detailed species information and scores species based on the risk of invasion. HPWRA score for species on the Hakalau Forest NWR are provided in Table 4-10.

Table 4-10. List of Invasive Plant Species Known to Currently Occur at Hakalau Forest NWR.

Species	Common Name(s)	Hakalau Forest	Kona Forest	HPWRA Score
Anacardiaceae	**Mango family**			
Schinus terebinthefolius	Christmas berry		X	19
Aquifoliaceae	**Holly family**			
Ilex aquafolia	English holly	X		
Asteraceae	**Sunflower family**			
Hypochaeris radicata	hairy cat‟s ear	X	X	
Senecio madagascariensis	fireweed	X		23
Senecio mikanioides	German ivy	X	X	
Caprifoliaceae	**Honeysuckle family**			
Lonicera japonica	Japanese honeysuckle	X		12
Cucurbitaceae	**Gourd family**			
Coccinia grandis	ivy gourd		X	
Cupressaceae	**Cypress family**			
Cryptomeria japonica	Sugi pine	X		-3
Euphorbiaceae	**Spurge family**			
Ricinus communis	castor bean		X	
Fabaceae	**Bean, pea family**			
Ulex europaeus	gorse	X		20
Juncaceae	**Rush family**			
Juncus effuses	Japanese mat rush, common rush	X		
Melastomataceae	**Melastoma family**			
Clidemia hirta	Koster‟s curse		X	
Tibouchina herbacea	glorybush, cane tibouchina	X		24
Tibouchina urvilleana	--		X	10
Myricaceae	**Bayberry family**			
Morella faya	firetree			
Myrtaceae	**Myrtle family**			
Eucalyptus spp.	eucalyptus	X		
Psidium cattleianum	strawberry guava	X	X	18
Onagraceae	**Evening primrose family**			
Fuchsia spp.	fuchsia	X		
Passifloraceae	**Passion flower family**			
Passiflora mollissima	banana poka	X	X	
Pinaceae	**Pine family**			
Pinus spp.	pine	X		
Poaceae	**Grass family**			
Andropogon virginicus	broomsedge	X		
Anthoxanthum odoratum	sweet vernalgrass	X		
Agrostis alba	redtop	X		
Axonopus fissifolius	narrow-leaved carpetgrass	X		16
Ehrharta stipoides	weeping grass, meadow ricegrass	X	X	

Species	Common Name(s)	Hakalau Forest	Kona Forest	HPWRA Score
Holcus lanatus	velvetgrass	X		
Paspalum dilatatum	dallis grass	X		12
Pennisetum clandestinum	Kikuyu grass	X		18
Polygonaceae	**Buckwheat family**			
Rumex acetosella	common sheep sorrel	X		
Proteaceae	**Protea family**			
Grevillea robusta	silky oak		X	5
Ranunculaceae	**Buttercup family**			
Anemone hupehensis	Japanese anemone	X		
Roseaceae				
Photinia davidiana	photinia	X		-2
Rubus argutus	Florida blackberry	X	X	21.5
Rubus rosifolius	Thimbleberry	X	X	
Zingiberaceae	**Ginger family**			
Hedychium gardnerianum	Kahili ginger	X	X	16

Source: Jacobi and Price (2007), Barnett and Simonson (2008).

Hakalau Forest Unit

Numerous invasive plant surveys have been conducted at HFU (Stone et al. 1991, Jacobi and Price 2007, Barnett and Simonson 2008), where approximately 45 nonnative plant species have been recorded. Although similar nonnative species occur at all elevations, the highest concentration of nonnatives are found at the higher elevations from 5,000-5,500 ft compared to the lower elevation forest (Barnett and Simonson 2008). This trend has also been observed in other Hawaiian forests (D"Antonio et al. 2000); in comparison to high-elevation sites, middle elevations have steeper topography and greater precipitation, resulting in denser forests that are less accessible to humans, ungulates, and nonnative plant species (Pejchar and Press 2006).

At the HFU, historical anthropogenic impacts that occurred at higher elevations, such as cattle ranching, logging, and fire, removed the native forest and allowed for the invasion of nonnative plant species (Scowcroft and Jeffrey 1999, Barnett and Simonson 2008). Adjacent land uses also increase the continued problem of invasive species. Invasive plants are abundant at the adjacent Pīhā Game Management Area due to the presence of pigs that act as vectors (Jeffrey, pers. comm.).

Jacobi and Price (2007) focused on 25 invasive plant species that pose a serious threat by displacing native plants and disrupting native ecosystems. Three species (*Ehrharta stipoides*, *Juncus effuses*, and *Rubus argutus*) showed an increase in frequency from 1987-2007. Barnett and Simonson (2008) found a negative relationship between nonnative species cover and native canopy cover suggesting that disturbances that reduce canopy cover increase the ability of invasion. Pattison et al. (1998) found a similar trend and suggested that invasive species have a higher ability to capture and utilize light resources, particularly in high-light, disturbed areas.

Invasive plants such as gorse, Florida blackberry, English holly, *Photinea,* and banana poka are being controlled at the HFU using a combination of mechanical and chemical removal. Additional invasive plant control techniques include removal of ungulates and reforestation with native species.

Figure 4-7 demonstrates an example of the survey and monitoring scheme for invasive weeds at the HFU utilizing existing transect lines also utilized for forest bird and ungulate surveys.

Kona Forest Unit

The results of the invasive plant surveys conducted on the KFU have not been compiled. The Final Environmental Assessment for Fencing of the Kona Forest Unit of the Hakalau Forest National Wildlife Refuge (2008) identifies the following nonnative plants as management concerns: strawberry guava, Christmas berry, banana poka, Koster‟s curse, Florida blackberry, German ivy, and nonnative pasture grasses.

Invasive plant control has not been conducted at the KFU, but will commence following the construction of an ungulate-proof fence and with staffing/funding. After fencing, the Refuge will work with available staffing and partners (e.g., Three Mountain Alliance) to survey and conduct control efforts as needed. Weed management will be mostly above 3,600 ft because understory below this elevation is mostly invasive plants and is too degraded. This work will be conducted from higher elevation to lower elevations to reduce further spread of invasives.

Banana Poka (*Passiflora mollissima*)

Banana poka, a vine native to South America, was introduced to the Hawaiian Islands in the early 20th century. The plant tolerates a wide range of environmental conditions and has a rapid growth rate (LaRosa 1992). In Hawai„i, banana poka invades disturbed forest gaps and forms curtains that exclude available light for native forest trees (USFWS 1996b). Banana poka is dispersed by pigs, cattle, and game birds, which eat the fleshy fruit and disperse seeds (NRCS 2005).

A combination of herbicide, manual removal, and biocontrol has been used to control this species. Applying herbicide to cut stems has shown to control some infestations (LaRosa 1992). Banana poka infestations on Hawai„i Island have also been controlled by the introduced fungus *Septoria passiflorae*; however, this biocontrol agent is not effective on the Kona side of the island where acid rain inhibits the germination of *S. passiflorae* spores (Trujillo 2005). The passion vine butterfly was also introduced, but control was not successful (LaRosa 1992).

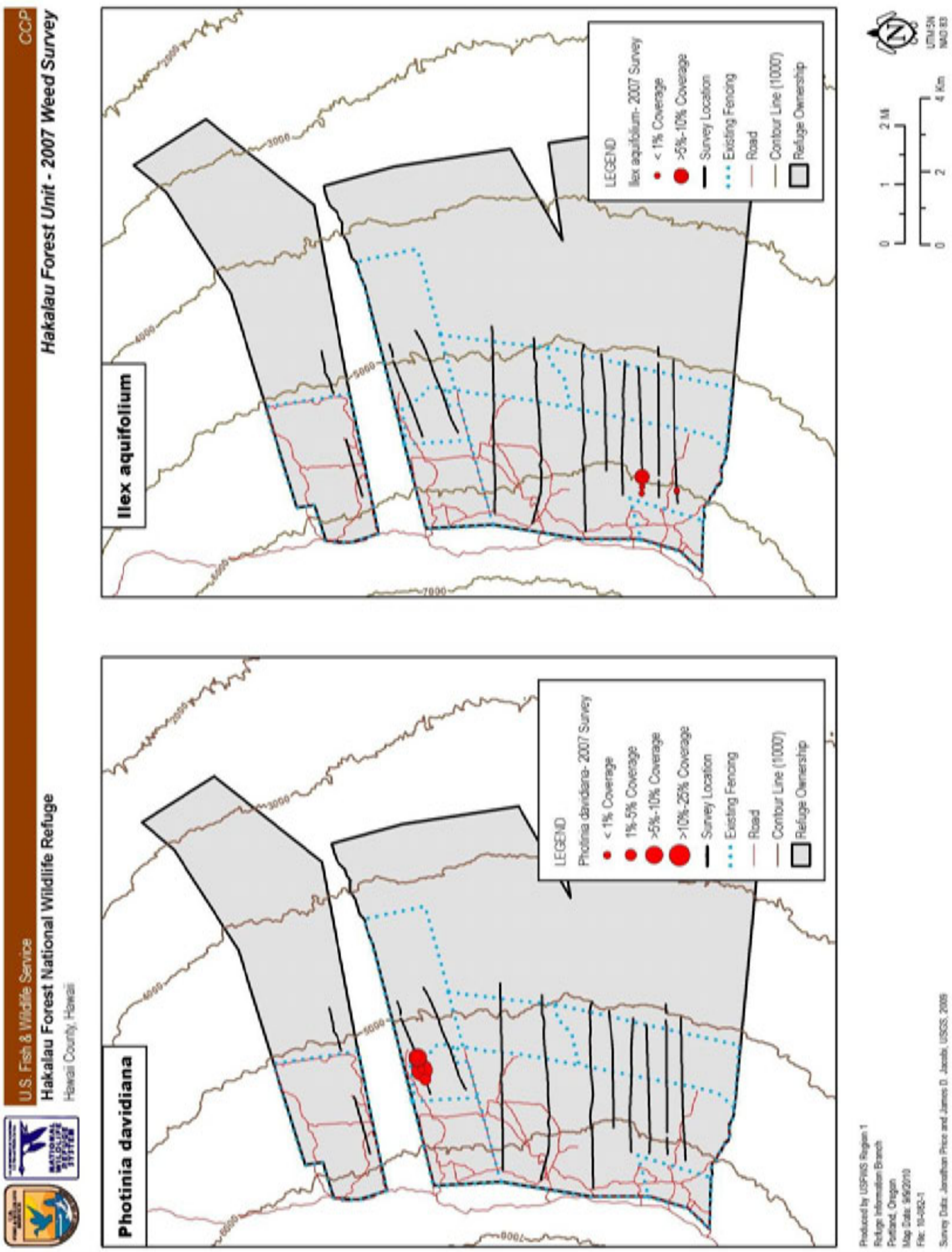
The species is largely concentrated in the Upper Maulua Tract of the HFU, initially infesting about 3,000 ac, but the area has been reduced by manual removal. A total of 210 ac were controlled from 2006-2007. The eradication of pigs has also contributed to its control (NRCS 2005). Grazing by cattle presently helps to control the spread of this species on the KFU; thus, banana poka control measures will be needed following the removal of cattle.

Investigations at the HFU found that banana poka nectar is three times more concentrated than „ōhi„a nectar. It provides the three main sugars (glucose, fructose, and sucrose). However, passerines do not express the digestive enzyme for the disaccharide sucrose and therefore can only obtain 5 percent “digestible” sugars from the banana poka nectar (Kapono, pers. comm).

Christmas Berry (*Schinus terebinthefolius*)

Christmas berry is an aggressive, rapidly spreading plant native to Argentina, Brazil, and Paraguay. It can grow as a tree or shrub up to 23 ft in height. Christmas berry has become naturalized in mesic,

Figure 4-7. Hakalau Forest Unit 2007 weed survey.



To preserve the quality of this figure, this side was left blank intentionally disturbed areas throughout the Hawaiian Islands. It can form dense thickets on steep slopes (Wagner et al. 1999).

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

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

English Holly (*Ilex aquafolia*)

English holly grows as a tree or shrub reaching over 16 ft in height. Growing in mesic to wet forests and open bogs, English holly shades out native groundcover species (Jacobi and Price 2007). Although this species is relatively slow growing, it is easily dispersed by birds due to the presence of red fleshy fruits (USFWS 1996b).

English holly was planted at the HFU by the previous landowners. Control activities began at the HFU when the holly infestation was estimated at 500 ac. Between 2006-2007, 102 ac were treated. This species can be controlled using EZJect®, which injects glyphosate-filled capsules into the tree cambium layer (Van Driesche and Van Driesche 2000, NRCS 2005). Treatment of germinating seeds must be continued to maintain control. Even if English holly is eliminated from HFU, birds will continue to bring seeds into the forest from nearby infected areas.

Florida Blackberry (*Rubus argutus*)

The Service considers Florida blackberry to be a primary invasive plant species of concern. Native to the central and eastern United States, Florida blackberry has been naturalized in the mesic and wet forests and subalpine grasslands in Hawai„i. It primarily occurs from 656-7,546 ft (Wagner et al. 1999). This shade-intolerant species grows into dense thickets in forested and disturbed areas lacking extensive understory. The stems of Florida blackberry are covered with straight or hooked thorns, and the fruit is bird-dispersed (USFWS 1996b). Once established, it spreads by underground rhizomes (Loope et al. 1992).

Blackberry is mainly treated at the HFU June-October using 0.5 percent Garlon 3A®, a foliar-applied spray that does not kill native plants (Jeffrey, pers. comm.). Estimates by the Natural Resources Conservation Service (2005) suggest that this species infests approximately 10,300 ac of open and closed canopy forest. In 2006, 774 ac were treated and an additional 350 ac were treated in 2007. Although intense control efforts have been in place for this species, a slight increase in the blackberry population (8.6 percent) occurred between 1987-2007 (Jacobi and Price 2007). This increase may be due to the removal of browsers (Van Driesche and Van Driesche 2000). Continued control efforts and monitoring are ongoing at the HFU.

German Ivy (*Senecio mikanioides*)

This fleshy perennial vine occurs in dry forests, moist forests, and coastal areas in the Hawaiian Islands. In particular, it climbs tall trees in the forest on Mauna Kea, Mauna Loa, and Hualālai (Motooka et al. 2003). German ivy prefers high light areas, where it can smother native vegetation (Wagner et al. 1999).

Various herbicides, such as triclopyr and foliar glyphosate, can be used to control German ivy. Effectiveness may be enhanced by cutting and drying the stems, while spraying the remaining parts with glyphosate (Motooka et al. 2003). No control work has been conducted for this species at either the HFU or KFU.

Gorse (*Ulex europaeus*)

Native to Western Europe and coastal areas of the Mediterranean, gorse was first recorded in Hawai„i in 1920. It has also spread to several other regions such as New Zealand, Australia, Chile, and California. This woody legume is spiny and can grow up to 10 ft in height (Davies et al. 2008). It is highly adapted to disturbed landscapes with low fertility and nutrient depleted soils, such as pastureland. It prefers more acidic soils, with a pH 4.5-5.0, and can acidify surrounding soils (Leary et al. 2006). In Hawai„i, flowering can occur for a 9-month period (Tarayre et al. 2007). Subsequently, a large number of seeds are produced in small pods (Davies et al. 2008).

Dense, impenetrable thickets of even-aged, mature plants grow on Maui and Hawai„i Island (Leary et al. 2006). However, unlike other invasives present on the Refuge, gorse infests high-elevation pasture areas rather than forest. The original gorse infestation on the HFU was estimated at 3,200 ac but was reduced to 75 ac by 1999. The infestation is largely concentrated in the southern portion of the Refuge near Pua „Ākala Ranch (Tomonari-Tuggle 1996). The current frequency of gorse on the Refuge is approximately 0.1 percent (Jacobi and Price 2007). Although the infestation of gorse on the HFU is minor, the adjacent Department of Hawaiian Home Lands (DHHL) ranch lands are heavily infested. The gorse infestation in this area increased from 4,942 ac in 1992 to over 9,884 ac in 2006 (Leary et al. 2006).

Thick gorse growth completely inhibits regeneration of native species. Perennial growth of this species can occur up to 30 years. Other characteristics that contribute to the invasive ability of gorse are its nitrogen fixing ability and large persistent soil seed bank. The seeds can remain in the seed bank for 30-60 years (Jeffrey, pers. comm.). Similar to the nonnative grass species, gorse serves as a fuel for fires by posing a risk of ignition and sustaining the spread of fires; a 12 in patch can produce 60 ft flame length (USFWS 2002a). As a result of these characteristics, it has been designated as a noxious weed species in the State of Hawai„i (Leary et al. 2006).

Spraying with an herbicide and then burning once the gorse is dead was originally used to control this invasive; however, the gorse sprouted vigorously from the trunk and seedlings were found to be stimulated using this technique. Currently, the Refuge controls gorse year-round (primarily September-May) by using a bulldozer with a rake to pull out large rooted plants and then spraying small plants with Garlon 3A at 3 percent foliar spray with Silwet (Jeffrey, pers. comm.). During

2006-2007, the Service controlled approximately 2,400 ac of gorse. Ongoing monitoring and treatment for seedlings and regrowth occurs in all treated areas. Gorse is not shade tolerant; reforestation efforts are expected to increase the dense canopy of native forest and prevent gorse from reestablishing. A partnership between the Refuge and DHHL has resulted in an attempt to contain the spread of gorse by planting native koa trees and thereby shading out the species in a 195-acre area immediately above and adjacent to the HFU.

The State Department of Agriculture has, over the past 20 years, released a host of biocontrol insects to control gorse. On Maui, an introduced caterpillar (that eats the flowers) reduced the reproductive potential of the species by 73 percent. In 1989, the moth *Agonopterix ulicitella* was introduced to control gorse by feeding on new shoots (Loope et al. 1992). The thrip *Sericothrips staphylinus* browses on gorse plants, but it is not yet clear how much this species will contribute to control in Hawai„i (Hill et al. 2001). The gorse seed weevil *Exapion ulicis*, which feeds on gorse foliage and flowers for most of the year, has also been introduced to Hawai„i (Davies et al. 2008).

Japanese Mat Rush (*Juncus effuses*)

Japanese mat rush is known to occur in shallow marshes and disturbed, moist areas around the globe. It is able to establish monospecific stands in former agricultural areas and in disturbed forest areas due to vigorous clonal growth and high seed production (Smolders et al. 2008). The light seeds allow for easy dispersal and the dense tussocks and culms of the rush expand underground by lateral rhizomes. In nutrient-poor areas, mowing has proven to be an effective removal technique (Smolders et al. 2008).

This species is common on the HFU. This perennial herb is naturalized along streams, ponds, and bogs in Hawai„i. It is known to occur between 3,280-6,562 ft (Wagner et al. 1999). From 1987-2007, the frequency of this species on the HFU rose by 13.7 percent (Jacobi and Price 2007). Japanese mat rush has also invaded native *Carex* bogs. Pigs eat the native sedge, removing the native plants and facilitating the increase and spread of Japanese mat rush (Jeffrey, pers. comm.).

Kikuyu Grass (*Pennisetum clandestinum*)

Kikuyu grass is a fast growing grass species that forms mats and spreads by rhizomes and stolons. Kikuyu grass is native to eastern Africa, but has spread throughout the tropics and subtropics (Holm et al. 1977). It occurs primarily in cool fertile areas (Scowcroft and Jeffrey 1999) between sea level-6,600 ft (2,000 m) elevation. It propagates vegetatively because the small, inflorescences rarely produce seeds (Holm et al. 1977). It is shade-tolerant, and the root morphology may also be altered in shaded areas (USFWS 1996b).

Kikuyu grass is a particular management concern because the species forms dense mats, preventing the establishment of native seedlings. It competes with native seedlings for nutrients, light, and water (Scowcroft 1992), and increases the frequency and intensity of fire (Smith and Tunison 1992). Kikuyu grass, in combination with gorse, was determined to be the primary fuel for wildland fires at the HFU in 2000. In addition, the plant can withstand defoliation by natural processes, such as frost, drought, hurricanes and treefalls, as well as grazing (Holm et al. 1977, USFWS 1996b). Furthermore, Kikuyu grass has been reported to possess allelopathic substances (Smith 1985). For these reasons, it is a federally listed noxious weed and according to the USFS and DOFAW it is considered a high-risk weed species for creating ecological and economic harm in Hawai„i.

Kikuyu grass occupies much of the upper portion of the HFU and is particularly dense in the Upper Maulua Unit. Kikuyu grass occurred with the highest frequency in sampled plots during a study by Barnett and Simonson (2008). Between 1987-2007, the frequency of Kikuyu grass at HFU decreased by 27.8 percent (Jacobi and Price 2007). Applications of the herbicide glyphosate have been tested to control Kikuyu grass in endangered plant outplanting sites and koa outplanting sites. In addition, the grass-selective herbicide Fluazifop-p-butyl (Fusilade) was tested as a post-plant application (Leary, pers. comm.).

Koster's Curse (*Clidemia hirta*)

Koster‟s curse is native to Central and South America and the Caribbean Islands. It has become naturalized in several Pacific Islands, Malaysia, India, and eastern Africa. It was first found on O„ahu in 1941 and subsequently spread to the other main Hawaiian Islands (DeWalt et al. 2004). On Hawai„i Island, infestations occur at the Waiākea Forest Reserve, Puna, Kohala Mountains, and above Laupāhoehoe (Smith 1992). The Koster‟s curse population at the KFU has increased rapidly over the last 10 years along the lower road (Ball, pers. comm.).

This woody shrub grows to an average height of 6.6 ft. The stems are covered with red bristles and the leaf surfaces are pleated (Whistler 1995). Koster‟s curse can be found in open pastures, riparian areas, and roadsides, as well as in forest gaps and understory up to 4,921 ft elevation (DeWalt et al. 2004).

Several characteristics of Koster‟s curse contribute to its invasive potential in Hawaiian forests. It is relatively shade tolerant and has no natural enemies in Hawai‟i. It is dispersed by a variety of organisms including humans, birds, pigs, and mongooses (Smith 1992). Each plant produces over 500 small berry fruits, each containing over 100 very tiny seeds. These seeds can remain dormant for up to 4 years. Furthermore, Koster‟s curse grows well in disturbed areas and can easily displace native understory species (Smith 1992). This species is considered a noxious weed by the Hawai„i Department of Agriculture.

Several biological control agents have been introduced against Koster‟s curse in the Pacific. On Hawai„i Island, this includes *Liothrips urichi*, a thrip that attacks the terminal leaves and internodes of Koster‟s curse (Hill et al. 2001, DeWalt et al. 2004). Because *L. urichi* prefers to lay eggs in open areas, the thrip has reduced populations in open areas, but not forested habitats. A leaf-mining beetle (*Lius poseidon*) and a fungus (*Colletotrichum gloeosporioides*) were also released throughout the island to control Koster‟s curse (DeWalt et al. 2004). *Collectotrichum gloeosporioides* has caused declines in Koster‟s curse on O„ahu; however, it requires repeated applications (Trujillo 2005). In addition, *Carposina bullata* (Carposinidae) feeds on flower buds and *Mompha trithalama* (Momphidae) feeds on flowers and berries (DeWalt 2006). None of these biocontrol agents have caused declines in Koster‟s curse abundance in Hawaiian forest understory (DeWalt 2006). Koster‟s curse is also susceptible to a number of herbicides (e.g., 2,4,5-T, 2,4-D, Trichlopyr) (Smith 1992).

Photinia *(Photinia davidiana)*

Photinia is listed as one of Hawai„i‟s worst invasive horticultural plants by DOFAW. The shrub threatens mesic forests on Hawai„i and O„ahu from 4,500-6,000 ft (*http://www.state.hi.us/dlnr/dofaw/hortweeds/species/phodav.htm*).

At the HFU, *photinia* has been shown to be spreading from its past distribution in 1987, in the upper elevation forests in the Nauhi Cabin area (Jacobi and Price 2007). Currently, it occurs in the forests both above and below Nauhi cabin, on both sides of Nauhi Stream, and at elevations 5,200-5,500 ft. *Photinia* produces a large number of red fleshy fruits that are dispersed by birds (Jacobi and Price 2007).

Strawberry Guava (*Psidium cattleianum*)

Strawberry guava is considered one of Hawai„i‟s worst invasive plant species (Wagner et al. 1999, Motooka et al. 2003, Uowolo and Denslow 2008). Introduced to Hawai„i in 1825, strawberry guava is widely distributed in the mesic and wet areas throughout the Hawaiian Islands. It tolerates a variety of habitats up to 4,265 ft elevation. Strawberry guava can form dense, monotypic stands consisting of trees 20 ft high. These stands suppress and exclude native species (Wagner et al. 1999, Motooka et al. 2003). Furthermore, strawberry guava has a rapid growth rate and is shade-tolerant. The red fruits of strawberry guava are eaten by rodents, pigs, and birds. These animals help to disperse and germinate the prolific seeds. In addition, strawberry guava fruits host crop-damaging fruit flies that economically impact the State‟s agriculture industry (Motooka et al. 2003, Tummons 2008, Uowolo and Denslow 2008, USFS 2008).

It has been estimated that strawberry guava has the potential to invade 47 percent of the land area of Hawai„i Island. At least 10 endangered species are restricted to habitats within this range (USFS 2008). As a result of these factors, strawberry guava is considered an important management concern at the KFU and the lower elevations of HFU. In 2003, one strawberry guava plant was found along the Alleyway fence line, in the Middle Honohina Unit, possibly introduced by the fence construction crew in 1986.

Current control methods are expensive, only temporarily effective, and cause harm to surrounding nontarget plants. Manually, strawberry guava can be removed by grubbing or using a weed wrench (USFS 2008). Strawberry guava can also be controlled using herbicides applied to foliage (triclopyr, dicamba, and 2,4-D), basal bark (triclopyr, 2,4-D, picloram), or cut stumps (triclopyr amine) (Motooka et al. 2003). Chemical and mechanical control efforts are likely most effective 3 months after the fruiting season because strawberry guava seeds will not survive beyond this time period (Uowolo and Denslow 2008). Controlling strawberry guava in natural areas on Hawai„i Island using only these techniques would cost roughly $18 million (Tummons 2008).

Tectococcus ovatus, a scale insect which reduces fruit and seed production in Brazil, is currently being studied as a biological control agent for strawberry guava (Uowolo and Denslow 2008). This insect produces leaf galls, limiting growth, fruiting, and seed production. The initial release site proposed is the „Ōla„a Forest Reserve on the Island of Hawai‟i (USFS 2008); however, the State draft environmental assessment is currently pending.

Sugi Pine (*Cryptomeria japonica*)

Sugi pine is an aromatic evergreen tree found at 2,500-6,000 ft on Kaua„i, Maui, and the Island of Hawai„i. Large stands exist along the old Volcano Road and in South Kona. This species is grown as an ornamental and windbreak and the wood is used for fence posts (Elbert and Skolmen 1989).

There are nine Sugi groves throughout the HFU (Jeffrey, pers. comm.), mostly in pasture areas, but a few occur in forest. The species has been shown to grow well in the upper reaches of HFU, especially under koa. This species was previously planted on the adjacent DHHL as buffer. Sugi pine is not currently recognized as invasive in Hawai„i; however, Jacobi and Price (2007) note that the ring of smaller individuals around the original planted sites suggests this species is spreading. Jacobi and Price have recommended the development of control methods for these groves. In addition, the Refuge Draft Restoration Management Plan (1996) aims to "to prevent the spread of exotic tree plantations," such as Sugi pine, in order to restore native forests. Roughly 42.8 ac, mostly in the Hakalau Tract, are planned to be removed and replaced with native trees over the next 5-10 years (NRCS 2005). Sugi pine groves are also potential roosting sites for the endangered „ōpe„ape„a (Menard, pers. comm.). Because of this unusual circumstance, care needs to be taken with whatever methods are used to remove the groves. Because Sugi pines are not highly invasive, they are a lower priority.

Sweet Vernalgrass (*Anthoxanthum odoratum*)

Sweet vernalgrass was ubiquitous during surveys by Stone et al. (1991) and Barnett and Simonson (2008). It was less often found in closed-canopy areas. Jacobi and Price (2007) stated that this species is "relatively ubiquitous and probably not a major concern for Refuge management." It is easily shaded out by native vegetation (Jeffrey, pers. comm.).

Weeping Grass or Meadow Ricegrass (*Ehrharta stipoides*)

Weeping grass or meadow ricegrass is found below 4,650 ft in the openings of wet forests and other moist areas (Wagner et al. 1999). At the HFU, this perennial grass is widespread below 5,000 ft in the shaded understory (Jacobi and Price 2007, Barnett and Simonson 2008). Weeping grass has increased in frequency at the Refuge rising from 69.9 percent in 1987 and to 80.3 percent in 2007 (Jacobi and Price 2007). This species spreads by seed and likely arrived at HFU by a shoelace (Barnett and Simonson 2008).

Australian Tree Fern (*Cyathea cooperi)*

The Australian tree fern was introduced to Hawai„i as an ornamental. It is a large tree fern up to 40 ft tall with large triangular leaves, and scaly brown stems that fall off when dead, leaving oval scars. The leaf stalks have white hairs unlike native hāpu„u, which have red hairs. The trunk does not have the thick, soft fiber wrapping like the native hāpu„u. The fronds form a thick overstory preventing germination and growth of native plants. The spores are wind-dispersed and can travel over 7 miles from the parent plant. It is fast growing and aggressively outcompetes native plants in the forest understory. It displaces native ferns, including the slower growing hāpu„u. The Pacific Islands Ecosystems at Risk (PIER) Assessment rates this plant as (8) "high risk." It is known on almost all of the main Hawaiian Islands, and on Hawai„i Island it is spreading from urban areas in Volcano, Laupāhoehoe, and other areas into native forests. Although this species is not currently found in either unit of the Hakalau Forest NWR, it is a species to watch for and remove immediately if detected.

4.12.7 Mollusks

Over 70 nonnative snail species (Staples and Cowie 2001) and 12 nonnative slug species (Joe and Daehler 2008) have been introduced to the Hawaiian Islands. Herbivorous mollusks can impact native plants and agricultural crops. These mollusks can have a large impact on plant communities by affecting seedling survival, shifting species abundances, and influencing succession. Invasive slug herbivory can harm native plant outplantings and restoration efforts, thus requiring local control at these sites (Joe and Daehler 2008). In addition, some nonnative mollusks prey on native land snails, as well as compete with native species for limited resources (Staples and Cowie 2001). Slugs have been seen girdling endangered plant seedlings and saplings and feeding on endangered plant flowers and fruit (Jeffrey, pers. comm.).

One nonnative land snail and three nonnative slugs were found at the HFU during invertebrate surveys. The garlic snail was abundant, especially in the Hakalau Tract, and may be a competitor for native birds and a predator to other native snails. *Arion intermedius* (glade slug) was also very common. These species were more abundant in areas disturbed by pigs (Howarth et al. 2003).

4.13 Special Designation Areas

The staff conducted a wilderness review (Appendix D), the results of which indicate that the HFU contains resources and lands that meet the basic criteria for inclusion in the National Wilderness Preservation System. The lower elevations of Hakalau Forest NWR will be designated as a Wilderness Study Area and additional information will be gathered and evaluated before a final determination is made (see Appendix D). The Service will make final wilderness recommendations for all Hawaiian and Pacific Island NWRs after the CCPs for all refuges have been completed.

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Chapter 5. Social and Economic Environment

Above: Volunteers pick koa seeds/USFWS
Right: Visitors enjoy the 100-year-old koa cabin at Pua ʻĀkala/
Ann Bell

Birders at Hakalau Forest NWR/Barry Stieglitz

Chapter 5. Social and Economic Environment

5.1 Refuge Infrastructure and Administrative Facilities

5.1.1 Hakalau Forest Unit

Facilities consolidated at the HFU administrative site include a bunkhouse for overnight staff work, volunteer (Figure 5-1) and research guest cabins, a power supply building, a garage, greenhouse, various storage sheds, a weather station, and an equipment storage building. Power is generated from a combined photovoltaic battery and generator system and distributed by underground power lines to the various cabins and structures. Water is provided by catchment systems that feed rainwater from building roofs into holding tanks. It is pumped to various structures after being treated by ultraviolet and sediment filters. The catchment system holds up to 80,000 gallons of water for drinking, other residential and greenhouse use, as well as fire suppression. The University of Hawai‘i (UH) maintains and operates a field station on Refuge land at the administration site to support research on the Refuge under a Memorandum of Agreement. The UH facility consists of a large building with quarters, laboratory, and classroom space.

At the Pua ‘Ākala area of HFU, facilities include the Pua ‘Ākala Cabin, which has been nominated for inclusion on the National Register of Historic Places, a tack shed near the cabin, and Pua ‘Ākala Barn. U.S. Geological Survey operates a weather station under as SUP. In addition, UH maintains a rain shelter at 6,200 ft elevation for field workers. Facilities located in other areas of the HFU include the Nauhi Cabin and storage building and the Maulua Cabin. The U.S. Forest Service (USFS) has a weather station in Middle Honohina under an SUP.

There are 40 miles (mi) of dirt and gravel roads and 0.67 mi of access easements within the HFU. Several access gates are located on the perimeter fence as well as internal fences for management purposes. The HFU has 45 mi of ungulate-proof fence and 14 mi of fire (fuel) break on the west and part of the north/south boundary (Figure 5-2).

Figure 5-1. Hakalau Forest volunteer cabin.

5.1.2 Kona Forest Unit

The KFU facilities consist of a field camp (Kona field camp) with two all-weather tents on platforms and a kitchen tent with limited space for equipment and material storage (Figure 5-3). Also included are 20 mi of dirt and gravel roads and 5 mi of access easements (gravel roads). Seventeen miles of fence are planned for construction as described in the Kona Forest Unit Fence Plan. As a part of the fence project, 14 miles of fence corridor will also serve as a firebreak.

5.1.3 Hilo Administrative Office

The Hakalau Forest NWR leases administrative office space in Hilo (Figure 1-1). The office is co-located with the USFS's Institute of Pacific Islands Forestry. The office functions first and foremost as an administrative site. Ten individual offices, a small conference room for staff meetings, and a small lobby area are leased annually. A large meeting room in the complex may be reserved for larger meetings (up to 50 people). Walk-in visitors are very few as the function of the office is not designed or set up to orient and welcome guests or provide interpretive displays. An occasional visitor from the mainland is guided to the office by calling ahead of time for directions or to verify the location of the Maulua tract and to get more information. No signs or other infrastructure are in place to attract visitors to the Refuge office or management areas.

5.2 Public Use Overview

The climate and geography of Hawaiʻi makes the islands a perfect location for various outdoor recreation activities. In addition, recreation is an important component of the lifestyle and economy of Hawaiʻi County (DLNR 2003). The State Comprehensive Outdoor Recreation Plan (2009) was developed to guide planning, development, and management of these outdoor recreation resources. The recreation section of the County of Hawaiʻi General Plan (2006) provides further recreational goals for the island and each district.

This section describes public use opportunities in the areas surrounding the HFU and KFU, as well as recreational activities currently occurring at the Refuge units. Islandwide recreational demands and potential recreational opportunities are also discussed.

5.2.1 Federal, State, and County Recreational Parks

Federal parks are administered by the National Park Service (NPS). The Island of Hawaiʻi features three national parks, including Hawaiʻi Volcanoes National Park (HAVO), Kaloko-Honokōhau National Historical Park, and Puʻuhonua O Hōnaunau National Historical Park. The HAVO is approximately 3 hours away from the HFU and 3 hours from the KFU. This park encompasses 207,634 ac and is the largest national park in the State. In addition, it is the single most popular visitor attraction on the island. The State Comprehensive Outdoor Recreation Plan (2009) identifies HAVO as a "significant recreation resource." Puʻu Honua O Hōnaunau National Historical Park, comprising 182 ac, is located south of KFU.

State parks are administered by the DLNR's Division of State Parks. The State park system on Hawaiʻi encompasses 15 parks covering approximately 2,687.3 ac (DLNR 2003). Use permits are

Figure 5-2. HFU administrative facilities and infrastructure.

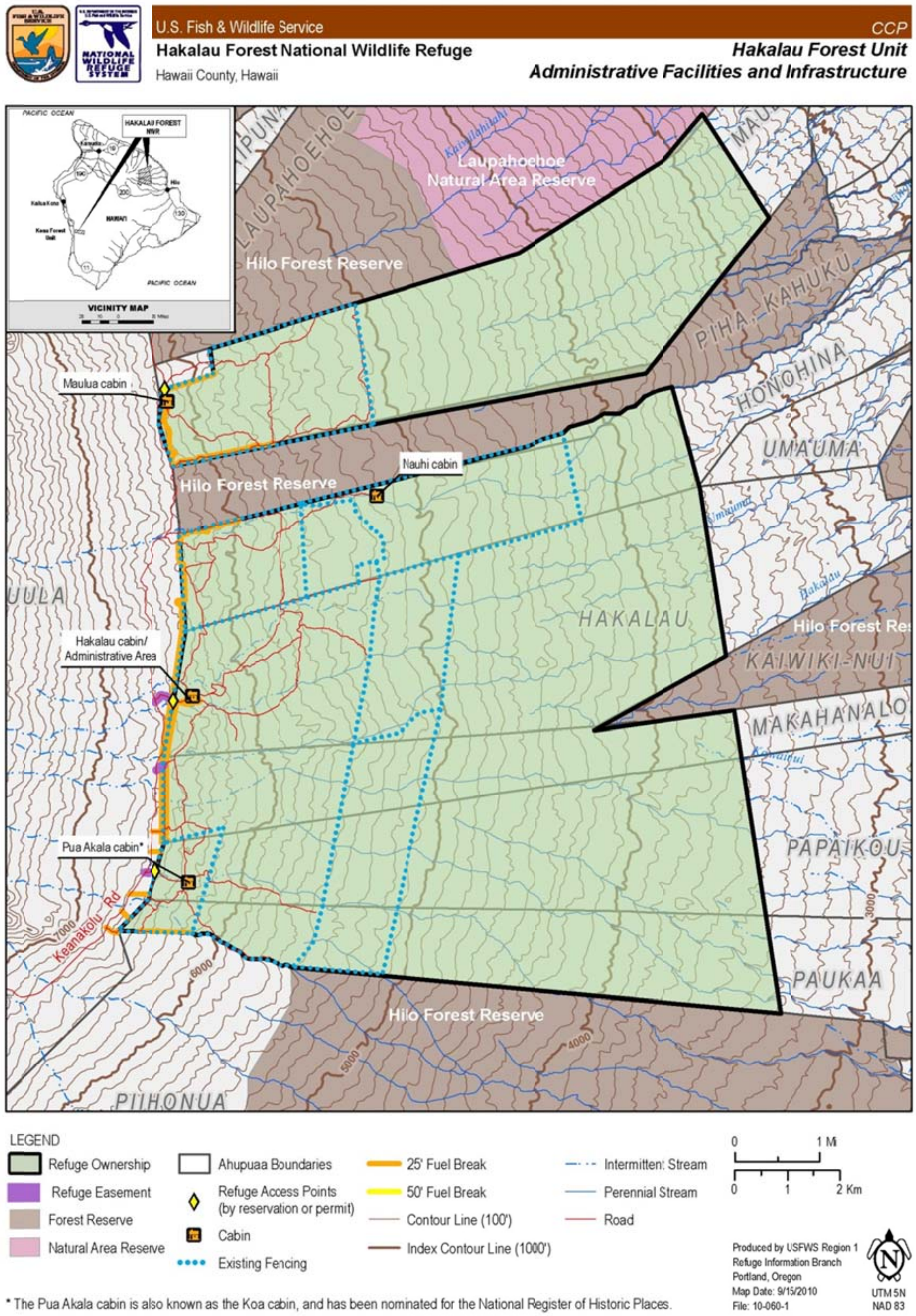

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Figure 5-3. KFU administrative facilities and infrastructure.

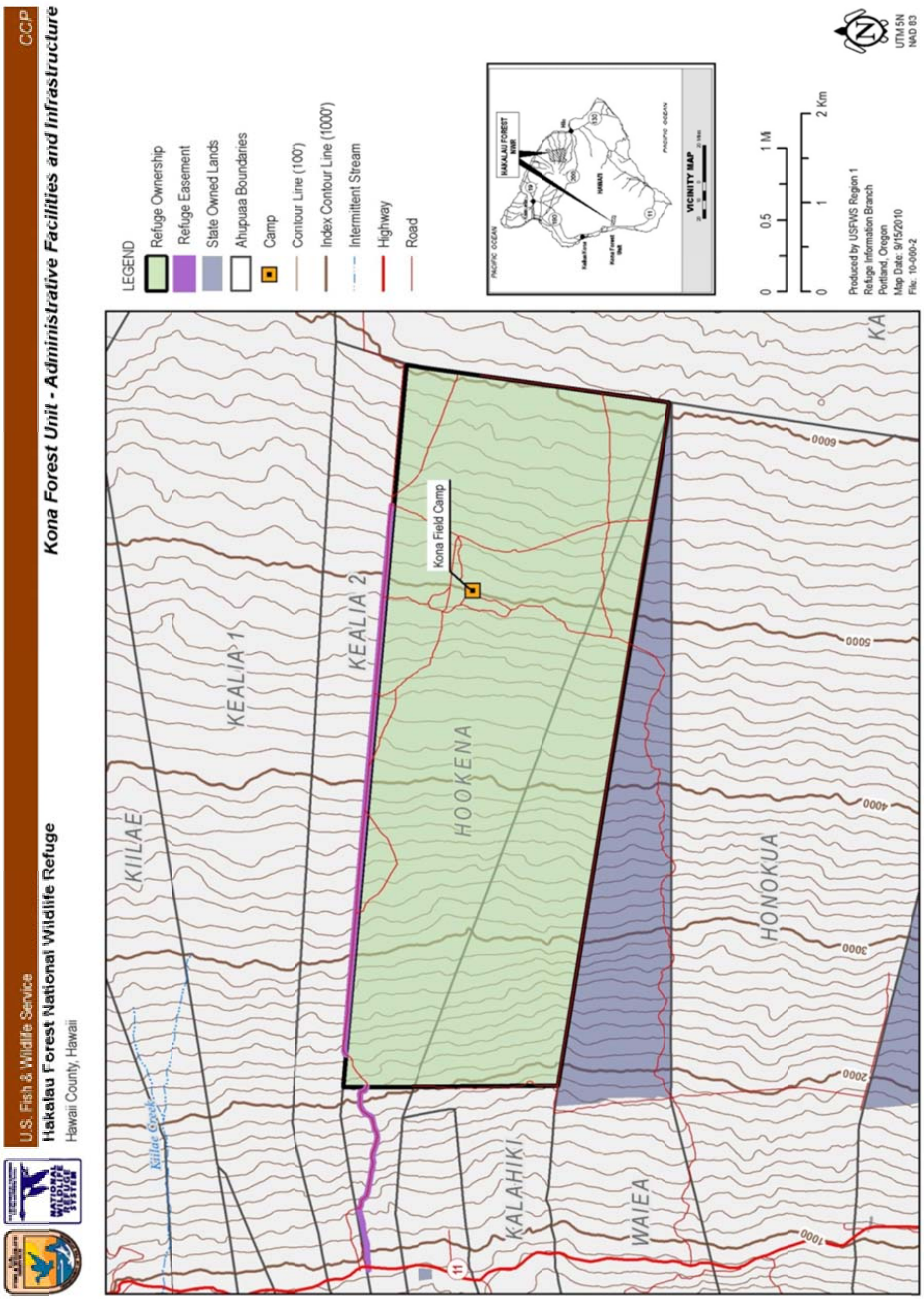

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Figure 5-4. Recreation opportunities on Hawai'i Island.

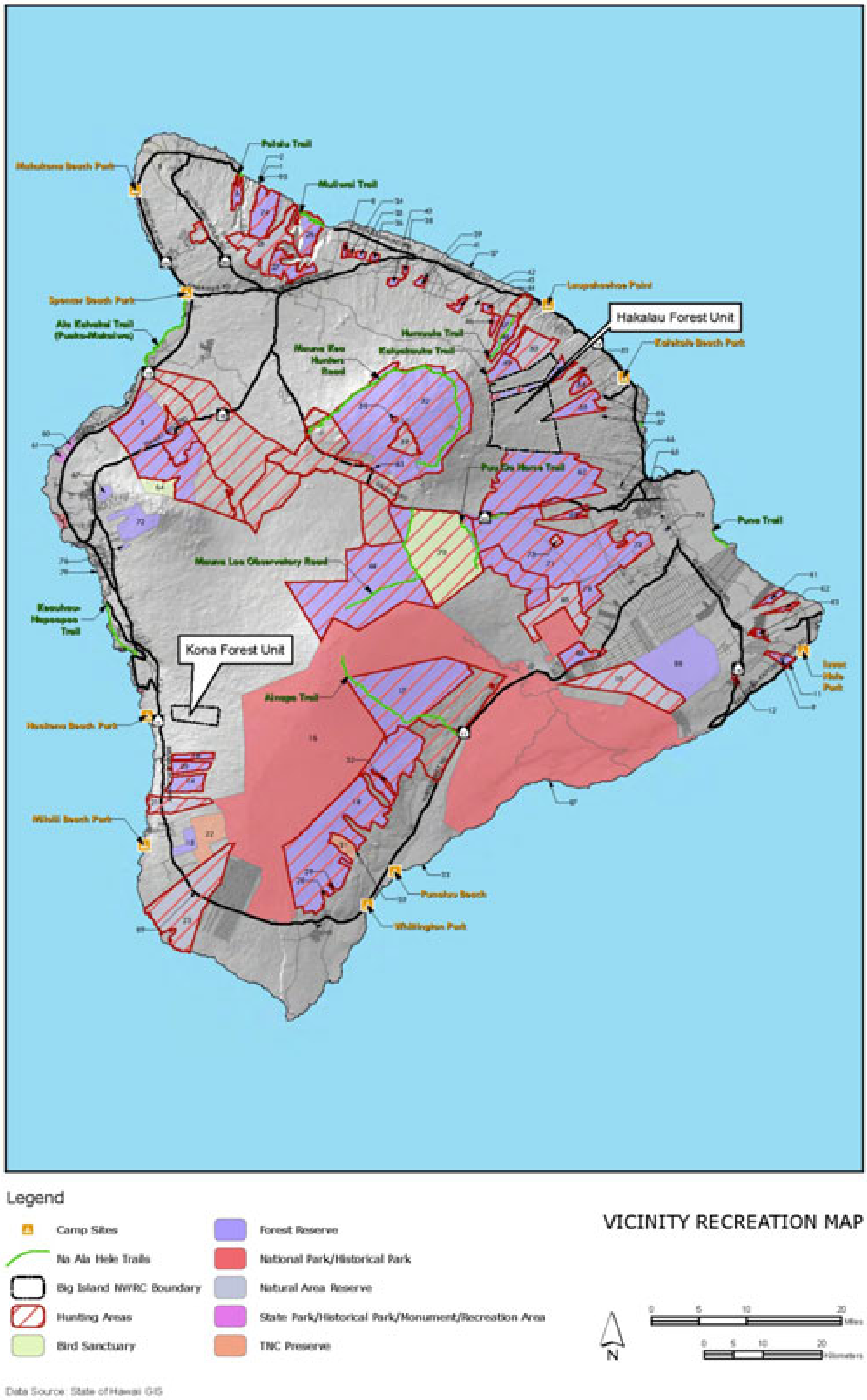

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Table 5-1. Legend ID and Facility Name for the Vicinity Recreation Map.

Map ID	Name	Manager	Definition
1	Mokupuku Island Sea Bird Sanctuary	DOFAW	Bird Sanctuary
2	Paoakalani Island Sea Bird Sanctuary	DOFAW	Bird Sanctuary
3	Pu‘u Wa‘awa‘a Forest Reserve	DOFAW	Forest Reserve
4	Kaloko-Honokōhau National Historical Park	USNPS	National Historical Park
5	Kohala Historic Sites State Monument	DOSP	State Monument
6	Kohala Forest Reserve (Pololū Sec.)	DOFAW	Forest Reserve
7	Lapakahi State Historic Park	DOSP	State Historic Park
8	Hāmākua Forest Reserve (Keaa Sec.)	DOFAW	Forest Reserve
9	Malama Kī Forest Reserve	DOFAW	Forest Reserve
10	Kahauale‘a Natural Area Reserve	DOFAW	Natural Area Reserve
11	Mackenzie State Recreation Area	DOSP	State Recreation Area
12	Keauohana Forest Reserve	DOFAW	Forest Reserve
13	Pu‘u Honau O Hōnaunau National Historical Park	USNPS	National Historical Park
14	South Kona Forest Reserve (Olelomoana ‘Opihihali Sec.)	DOFAW	Forest Reserve
15	South Kona Forest Reserve (Kapua-Manukā Sec.)	DOFAW	Forest Reserve
16	Hawai‘i Volcanoes National Park	USNPS	National Park
17	Kapāpala Forest Reserve	DOFAW	Forest Reserve
18	Ka‘ū Forest Reserve	DOFAW	Forest Reserve
19	South Kona Forest Reserve (Ka‘ohe Sec.)	DOFAW	Forest Reserve
20	South Kona Forest Reserve (Kukuiopa‘e Sec.)	DOFAW	Forest Reserve
21	Kīpāhoehoe Natural Area Reserve	DOFAW	Natural Area Reserve
22	Kona Hema Preserve	TNC	TNC Preserve
23	Manukā Natural Area Reserve	DOFAW	Natural Area Reserve
24	Kohala Forest Reserve	DOFAW	Forest Reserve
25	Pu‘u O ‘Umi Natural Area Reserve	DOFAW	Natural Area Reserve
26	Kohala Forest Reserve (Waimanu Sec.)	DOFAW	Forest Reserve
27	Kohala Watershed Forest Reserve	DOFAW	Forest Reserve
28	Ka‘ū Preserve	TNC	TNC Preserve
29	Ka‘ū Preserve	TNC	TNC Preserve
30	Ka‘ū Preserve	TNC	TNC Preserve
31	Ka‘ū Preserve	TNC	TNC Preserve
32	Ka‘ū Preserve	TNC	TNC Preserve
33	Kamehame Preserve	TNC	TNC Preserve
34	Hāmākua Forest Reserve (Hanapai Sec.)	DOFAW	Forest Reserve
35	Hāmākua Forest Reserve (Kapulena Sec.)	DOFAW	Forest Reserve
36	Hāmākua Forest Reserve (Honokaia Sec.)	DOFAW	Forest Reserve
37	Hauola Forest Reserve	DOFAW	Forest Reserve
38	Hāmākua Forest Reserve (Āhualoa Sec.)	DOFAW	Forest Reserve
39	Kalōpā State Recreation Area	DOSP	State Recreation Area
40	Hāmākua Forest Reserve (Nienie Sec.)	DOFAW	Forest Reserve

Map ID	Name	Manager	Definition
41	Hāmākua Forest Reserve (Kalōpā Sec.)	DOFAW	Forest Reserve
42	Hāmākua Forest Reserve (Pa‘auilo Sec.)	DOFAW	Forest Reserve
43	Hāmākua Forest Reserve (Kainehe Sec.)	DOFAW	Forest Reserve
44	Hāmākua Forest Reserve (Hō‘ea Kaao Sec.)	DOFAW	Forest Reserve
45	Hāpuna Beach State Recreation Area	DOSP	State Recreation Area
46/47	Manowaialee Forest Reserve	DOFAW	Forest Reserve
48	Hilo Forest Reserve (Humu‘ula Sec.)	DOFAW	Forest Reserve
49	Hilo Forest Reserve (Laupāhoehoe Sec.)	DOFAW	Forest Reserve
50	Laupāhoehoe Natural Area Reserve	DOFAW	Natural Area Reserve
51	Hilo Forest Reserve (Pīhā Sec.)	DOFAW	Forest Reserve
52	Mauna Kea Forest Reserve	DOFAW	Forest Reserve
53	Hilo Forest Reserve (Opea Sec.)	DOFAW	Forest Reserve
54	Hilo Forest Reserve (Kamaee Sec.)	DOFAW	Forest Reserve
55	Hilo Forest Reserve (Kaiwiki Sec.)	DOFAW	Forest Reserve
56	‘Akaka Falls State Park	DOSP	State Park
57	Hilo Forest Reserve (Ka‘uku Sec.)	DOFAW	Forest Reserve
58/59	Mauna Kea Ice Age Natural Area Reserve	DOFAW	Natural Area Reserve
60/61	Kekaha Kai State Park	DOSP	State Park
62	Hilo Watershed Forest Reserve	DOFAW	Forest Reserve
63	Mauna Kea State Recreation Area	DOSP	State Recreation Area
64	Pu‘u Wa‘awa‘a Forest Bird Sanctuary	DOFAW	Bird Sanctuary
65	Wailoa River State Recreation Area	DOSP	State Recreation Area
66	Wailuku River State Park	DOSP	State Park
67	Honua‘ula Forest Reserve	DOFAW	Forest Reserve
68	Mauna Loa Forest Reserve	DOFAW	Forest Reserve
69	Waiakea Forest Reserve (Kukua Sec.)	DOFAW	Forest Reserve
70	Kipuka Ainahou Nēnē Sanctuary	DOFAW	Bird Sanctuary
71	Upper Waiākea Forest Reserve	DOFAW	Forest Reserve
72	Honua‘ula Forest Reserve	DOFAW	Forest Reserve
73	Waiākea Forest Reserve	DOFAW	Forest Reserve
74	Panaewa Forest Reserve	DOFAW	Forest Reserve
75	Waiākea 1942 Lava Flow Natural Area Reserve	DOFAW	Natural Area Reserve
76	Wai‘aha Springs Forest Reserve	DOFAW	Forest Reserve
77	Old Kona Airport State Recreation Area	DOSP	State Recreation Area
78	‘Ōla‘a Forest Reserve	DOFAW	Forest Reserve
79	Keolonoahiki State Historic Park	DOSP	State Historic Park
80	Pu‘u Maka‘ala Natural Area Reserve	DOFAW	Natural Area Reserve
81	Nānāwale Forest Reserve	DOFAW	Forest Reserve
82	Nānāwale Forest Reserve (Halepuaa Sec.)	DOFAW	Forest Reserve
83	Nānāwale Forest Reserve	DOFAW	Forest Reserve
84	Lava Tree State Monument	DOSP	State Monument
85	‘Ōla‘a Forest Reserve (Mt. View Sec.)	DOFAW	Forest Reserve
86	Kealakekua Bay State Historic Park	DOSP	State Historic Park
87	Keaoi Island Sea Bird Sanctuary	DOFAW	Bird Sanctuary

Map ID	Name	Manager	Definition
88	Wao Kele ʻO Puna Forest Reserve	DOFAW/ OHA	Forest Reserve
89	Manukā State Wayside	DOSP	State Wayside
90	Paʻalaea Island Sea Bird Sanctuary	DOFAW	Bird Sanctuary

required for certain activities including group activities, pavilion usage, meetings, weddings, shows, community events, scientific research, and gathering of forest products (Division of State Parks 2008).

Several State parks are located near the HFU. The Mauna Kea State Recreation Area, consisting of 20.5 ac, offers wildlife observation and lodging opportunities at 6,500 ft on Mauna Kea. ʻAkaka Falls State Park has views of a 442 ft waterfall. This park also offers the ʻAkaka Falls Loop Trail, a path that goes through tropical areas. The 100 ac Kalōpā State Recreation Area provides hiking through the Kalōpā Nature Trail, as well as camping and lodging.

On the Kona side, two State parks are located near the KFU. Kealakekua Bay State Historical Park offers views of archaeological sites and the Captain Cook monument. The Manukā State Wayside is located south of the KFU in the Kaʻū District. This State wayside provides access to the 2 mi Manukā Nature Trail, which is located in the Manukā Natural Area Reserve. Camping is also permitted at this reserve through the State Division of Forestry and Wildlife (DOFAW).

County parks are managed by the County of Hawaiʻi, Department of Parks and Recreation. On Hawaiʻi Island, 137 county parks cover 1,471 ac. The following county parks are located in South Hilo: Bakers Beach, Carlsmith Beach Park, Coconut Island (Moku Ola), Hilo Bayfront Beach, Hilo Bayfront Park, Honoliʻi Beach Park, Hoʻokena Beach Park, James Kealoha Beach Park, Kalākaua Park, Kanakea Pond (Ice Pond), Kaūmana Caves, Kolekole Beach Park, Kuhio Kalanianaʻole Park, Lehia Beach Park, Leleiwi Beach Park, Liliʻuokalani Gardens, Moʻoheau Park, Onekahakaha Beach Park, Reeds Bay Beach Park, and Richardson Ocean Park. Only two county parks – Laupāhoehoe Point Beach Park and Waikaumalo Park – are located in the North Hilo District. County parks in the District of South Kona include: Hōnaunau Boat Ramp, Hoʻokena Beach Park, Manini Point (Napoʻopoʻo), Miloliʻi Beach Park, and Napoʻopoʻo Beach Park (County of Hawaiʻi 2007).

5.2.2 Wildlife Observation and Environmental Education

Opportunities for wildlife observation and environmental education are plentiful on the Island of Hawaiʻi. During 2006, it is estimated that 262,000 individuals (both residents and visitors) participated in wildlife watching in the State. Approximately 16 percent of the resident population in Hawaiʻi participated in wildlife watching activities during the time period (HDBEDT 2007). Tourists also enjoy natural resources on the island. Each year, roughly 50,000 visitors to Hawaiʻi Island purchase tours where they are exposed to native species (TMA 2007).

The State of Hawaiʻi Forest Reserve System, managed by DOFAW, consists of 22 Forest Reserves encompassing 448,000 ac. This system is guided by the Hawaiʻi State Constitution, Hawaiʻi Revised Statutes Chapter 183, and Hawaiʻi Administrative Rules, Chapter 104. Forest Reserves on the island are depicted in Figure 5.2. Camping, gathering activities, commercial harvest, hunting, and other uses are permitted on the forest reserves by permit (HAR § 13-104).

The Hilo Forest Reserve includes seven sections: Pīhā, Laupāhoehoe, Opea, Humuʻula, Kamaeʻe, Kaʻuku, and Kaiwiki. The Laupāhoehoe Section borders the upper tract of the Hakalau Forest Unit, while the Pīhā Section splits the Honohina and Maulua tracts. The Pīhā Section is primarily used by the public for hunting. The South Kona Forest Reserve is located south of the Kona Forest Unit. This reserve consists of four sections: ʻŌlelomoana ʻOpihihali, Kaʻohe, Kukuiopaʻe, and Kapua-Manukā.

The DOFAW is also responsible for the Natural Area Reserve System (NARS). Hiking and nature study (in groups of 10 or less) are permitted within these areas. All reserves are open to the public for recreational hunting, based on DLNR rules (HAR § 13-209-3). Environmental education programs occur on several of these reserves (DLNR 2003). The Laupāhoehoe NAR is located above the Maulua tract of the HFU adjacent to the Laupāhoehoe Section of the Hilo Forest Reserve. The Mauna Kea Ice Age NAR is located near the summit, west of the HFU. The Kīpāhoehoe NAR is directly south of the KFU and the Manukā NAR is further south on the southwest slope of Mauna Loa.

Several wildlife sanctuaries were established throughout the island to protect indigenous wildlife (HRS, Sections 13-125). These sanctuaries are managed by DOFAW. Within these sanctuaries, it is prohibited to remove, disturb, kill, or possess any form of plant or wildlife and to introduce any form of plant or animal life. Also, human activity is strictly limited. The Puʻu Waʻawaʻa Forest Bird Sanctuary is found within the Puʻu Waʻawaʻa Forest Reserve. The Kīpuka ʻĀinahou Nēnē Sanctuary is open to the public, except November-February. Birds and game mammals may be hunted within the Kīpuka ʻĀinahou Nēnē Sanctuary (HAR § 13-125).

Three islets off the coast of Hawaiʻi Island are designated as State Seabird Sanctuaries. The offshore islands include Mokupuku Island Sea Bird Sanctuary, Paoakalani Island Sea Bird Sanctuary, and Keaoi Island Sea Bird Sanctuary. Paʻalaea Island Sea Bird Sanctuary, formerly found off the Kohala coast, largely disappeared after an earthquake in 1975. The public can engage in wildlife observation and education at the islets (*http://www.hawaiioirc.org/OIRC-ISLETS.htm*).

Public wildlife observation and environmental interpretation opportunities are limited in the units of the Hakalau Forest NWR. Due to the presence of endangered species and suitable habitat, public access is regulated. In FY 2010, the Refuge had 1,692 visitors, of which most were nonresidents. At HFU, the Upper Maulua Tract was opened to public wildlife observation, birding, and photography in 1992. Use of this area is restricted to weekends and holidays, and reservations are required. Between 450-500 visitors use the Refuge for wildlife observation annually. Wildlife photography participants range between 10-22 each year. No visitor facilities or restrooms are available at these locations.

Additional visitor opportunities at the HFU are available during the annual open house. This event receives between 330-490 participants. In addition, volunteers at the HFU participate in natural history hikes. Table 5-2 provides additional information on FY 2010 Refuge wildlife observation and environmental education figures.

Currently the entire KFU, which remains unfenced and unmanaged in terms of ungulate control, remains closed to the public due to difficult access and the presence of highly sensitive species. The Three Mountain Alliance hopes to provide opportunities for the public to enjoy nature observation and education at the Unit after management efforts have begun (TMA 2007).

5.2.3 Camping

Camping is permitted within three State parks: Hāpuna State Recreation Area, Kalōpā State Recreation Area, and Manukā State Wayside. Permits may be obtained from the State Parks office and the maximum length of stay is limited to 5 consecutive nights. Hāpuna State Recreation Area has four-person A-frame shelters available for $20 per night. At the Kalōpā State Recreation Area, the State rents eight-person cabins for $55 per night. Facilities include beds, bedding, linen, restrooms, hot showers, and a fully equipped recreational dining hall. The Manukā State Wayside offers six-person cabins for $5 per night (Division of State Parks 2008).

Ten County of Hawai‘i facilities permit overnight camping. County of Hawai‘i camping permits are required in order to camp at all County parks. These permits can be obtained from the Department of Parks and Recreation main office or online. The maximum camping period is 1 week during the summer (June-August) and 2 weeks during the remainder of the year (County of Hawai‘i 2008).

County camping sites in the vicinity of HFU are the Laupāhoehoe Beach Park in North Hilo and Kolekole Beach Park in South Hilo. Amenities at these sites include pavilions, electrical outlets, restrooms, outdoor showers, and picnic areas. Fishing is also permitted at both of the campsites (County of Hawai‘i 2008).

Ho‘okena Beach Park, near the KFU, offers pavilions, restrooms, outdoor showers, picnic areas, and drinking water. Swimming and snorkeling, as well as fishing, are allowed under favorable conditions. Miloli‘i County Beach Park is located in South Kona at an ancient Hawaiian fishing village. This park allows fishing and has restrooms and picnic areas for visitors (County of Hawai‘i 2008).

5.2.4 Hiking

DOFAW’s Na Ala Hele Program maintains and provides access to hiking trails. Established in 1988, Na Ala Hele offers approximately 97 trails throughout the State (DLNR 2003). The purpose of the program is to “preserve and perpetuate the integrity, condition, naturalness and beauty of State trails and surrounding areas and to protect … environmental resources” (HRS Chapter 198D; HAR, Title 13, Chapter 130).

On the island, the system maintains 16 trails. Trails in the immediate vicinity of the HFU include Kaluakauka Trail (0.4 mi); Humu‘ula Trail (10.5 mi); Mauna Kea Access Road/Hunters Road (32 mi); Kaūmana Trail (3 mi); and Onomea Trail (0.5 mi). The only Na Ala Hele trail in South Kona, Keauhou Napo‘opo‘o Trail, is currently closed (*http://www.hawaiitrails.org/island.php?island=Hawaii*).

5.2.5 Hunting

Hunting is regulated by Hawai‘i Administrative Rules, Title 13, Chapter 122 and 123. Individuals engaging in hunting must possess a valid State of Hawai‘i hunting license. This license allows individuals to legally hunt only in designated public hunting areas. Private landowners also have their own hunting programs directed at the tourism market or at local hunters. Approximately 18,000 individuals hunted in the State of Hawai‘i in 2006, for a total of 420,000 days. Roughly 98 percent of the individuals were residents of the State. A total of 8,345 hunting licenses were issued throughout the State in 2006 (HDBEDT 2007). Four large game mammals and 14 species of game birds can be legally hunted on the island (*http://www.State.hi.us/dlnr/dcre/know.htm*).

5.2.6 Refuge Public Use Opportunities

Hakalau Forest Unit

In FY 2010, the total number of visitors to the Refuge was 1,692. Visitors to HFU are allowed access to the Maulua Tract through a call-in permit system. The Maulua Tract is approximately 2 hours from Hilo and requires a four-wheel drive vehicle. Visitors have access to a single track road that extends downslope from the gate for 2 mi with limited opportunities to turn vehicles around. Maulua Tract is accessible by reservation only on weekends and State holidays through an otherwise locked entrance called Maulua Gate. The area is available for wildlife-dependent activities such as bird-watching, nature photography, environmental education, and hiking. Reservations are made by calling the Hakalau Forest NWR office between 8:00 a.m. and 4:00 p.m. at least 1 week before the scheduled visit. Periodic closures do occur on the basis of fire danger from extreme dry conditions on the Refuge and surrounding lands. The Friends of Hakalau Forest are developing interpretive signs to complement certain site areas in Maulua Tract. Most visitors registering for permission to enter Maulua Tract are from the mainland U.S. Visitation over the years has gradually increased from a weekend average of four to currently an average of 10 people. No sanitation facilities are provided.

The remainder of the Refuge is not open to the public except through organized Refuge sponsored or permitted activities. The volunteer program provides wildlife photography and observation and environmental interpretation and education opportunities through a unique hands-on stewardship program. The volunteer program offers overnight experiences involving a full day of hands-on stewardship activity assisting with a combination of some of the following activities: koa outplanting, seed collection, plant nursery work, reseeding, and facility support maintenance. After spending the night in a Refuge cabin, the staff on the second day host groups on a forest bird interpretive walk, which requires someone skilled in how to locate, interpret, and observe the birds, and highlighting native forest ecosystem management and wildlife observation.

During 2007, 30 of the 52 possible weekends were scheduled and there is a 1-2 year waiting list for additional groups to participate. Currently these weekends are attended by groups such as the Sierra Club, Audubon Society, Boy and Girl Scouts, high school hiking clubs, teacher workshops, middle and high school-age participants in Youth Conservation Corps, and the Imi Pono no ka ‘Aina partnership environmental education program. The program has reached capacity, as the staff cannot fulfill the needed tasks for additional groups (e.g., scheduling, maintaining the overnight cabin, providing transportation, and other administrative and safety related responsibilities and logistics).

The Refuge is opened to the general public annually for the Refuge Week Open House, providing a 1-day opportunity for visitor programs tailored to the general public. The annual event, offered during National Wildlife Refuge Week in early October, has been growing in popularity over the years from 50 participants at the first open house day in 1992 to over 500 in 2007. The Open House is primarily attended by Hawai‘i Island residents. Reservations are required. Publicity is generally accomplished via articles in the Hawai‘i Tribune Herald, West Hawai‘i Today, the Big Island Weekly, and local radio stations.

The Open House is a labor-intensive event that requires participation by all of the staff for planning, preparation, and execution. Throughout the morning of the event attendees arrive at the Refuge and are guided to several open grass parking areas near the barn area in the Pua ʻĀkala Tract. Visitors are then provided the opportunity to visit the Pua ʻĀkala Cabin, the greenhouse, and/or participate in a guided hike. The Service, partner organizations, and agencies provide tour guides for the visiting public. Refuge, Friends of Hakalau Forest, and partners' exhibits are traditionally displayed at the Pua ʻĀkala barn site.

Due to its remote location (1.5 hours from Hilo) and 1-hour drive time on a bumpy road in a four-wheel drive vehicle, the number of visitors is limited. Public interest in the Refuge is substantial and a family-friendly approach with greater support from a growing Friends Group and other partners has improved attendance. This is consistent with the Refuge Connecting People with Nature priorities and the need to expand access to all visitors.

The Youth Conservation Corps and AmeriCorps are youth employment programs offering a strong environmental stewardship component that have been supported at Hakalau Forest NWR in the past and remain valuable program options for the Refuge pending available staff and funding.

Hakalau Forest NWR is associated with a comprehensive environmental education program called Imi Pono no ka ʻAina (seeking good for the land) currently administered by NPS, Hawaiʻi State Department of Education, and the U.S. Army Garrison of Hawaiʻi. The Service, along with these partners, developed and established this program in 1999. The program has been very successful and helps to instill a conservation ethic in local intermediate and high school students, who participate in educational service trips to the Refuge and other areas. The Service hopes to continue to host and provide support for Imi Pono no ka ʻAina as a model for other islands to conduct hands-on environmental education camps.

The Refuge issues a limited number of SUPs for tour groups to access the Refuge. The following stipulations apply to all of the permits: each permittee is limited to 100 visitor days, eight SUPs are issued per year, and all permittees are required to attend an all day orientation hosted by the Refuge staff. During 2007, 309 individuals visited the Refuge through these SUPs.

Commercial photography occurs through an SUP process allowing access into Hakalau Forest NWR under stringent conditions with a staff biologist escort for access to any closed areas. Only two permits were issued in 2007; on average no more than five permits are issued per year. Refuge staff generally conduct a 1-day orientation for new special use permit holders.

Off-Refuge outreach, environmental education, and interpretive activities are occasionally offered to community groups. The staff also participates as an exhibitor in the annual Earth Day festival in Hilo that attracts hundreds of students.

Kīpuka 21, an interpretive wayside exhibit and trail site on Saddle Road a few miles east of the access road to the Refuge, is managed by DOFAW. The State is still working on developing the site to provide easy access to Hawaiʻi's native forest birds. Once trail repairs are complete, individuals will be able to commonly see midstory and forest canopy viewing of ʻapapane, ʻiʻiwi, and ʻamakihi. The Refuge hopes to contribute to future interpretive efforts at the Kīpuka 21 site to provide basic information about resources common to both sites (the Saddle road area and HFU).

Table 5-2. FY 2010 Visitation at the Hakalau Forest Unit.

Activity	Number of individuals
Visitors On-Refuge	
Wildlife Observation	591
Environmental Education	153
Interpretation	578
Wildlife Photography	10
Volunteer Program	488
Maulua Tract Visitation	208
Commercial Ecotourism	309
Independent Visitors	22
Visitors Off-Refuge	
Refuge Office for Orientation	60
Interpretative Talks and Other Programs	578
Viewing Exhibits at Local Festivals, Fairs, and Events	2,000

In 2007, the Friends of Hakalau Forest NWR was formed from a small cadre of vested and interested volunteers. The group is now 140 members strong and is implementing small interpretive projects on and off the Refuge. The group also provides staff for a booth at the annual Open House where they encourage members to join. Throughout the year they help organize volunteers to assist in the greenhouse.

In 1992, HFU's Upper Maulua Tract was opened to the public for public hunting (no dogs) to assist with management of ungulates. Reservations were required and a maximum number of reservations established. Middle and Lower Maulua Tract became open for public hunting (dogs allowed) in 1993. No reservations were required and a bag limit for each hunter set at two pigs. With the successful fencing of the Upper Maulua Tract as well as the start of endangered species work, this area was closed to public hunting in 2000 due to the reduction of the number of pigs. For this tract, the levels of hunting use, based on 6 consecutive years of public hunting averaged 80 hunter days per year. No requests for public hunting at HFU have occurred since 2000. Through the CCP it was determined that public hunting was not a compatible use.

Kona Forest Unit

The KFU has never been opened to the public. The KFU is very difficult to access because of extreme road conditions into a 5,300 ac parcel of native forest in South Kona and until very recently, legal issues with access easements. Refuge staff may now access the area only after ascending an easement road running parallel to the Refuge boundary from the Māmalahoa Highway at roughly 900 ft in elevation to the 5,300 ft level.

From 1997-2005 and despite the difficult road conditions, organized community groups received occasional escorted access to the KFU. Of particular interest on the KFU are the lava tube skylights. Unstable ground and holes adjacent to the skylights make viewing them hazardous and would require viewing platforms to provide safe access.

Outreach/environmental education/interpretation activities offsite are performed on behalf of the Refuge as described under HFU and cover both units of Hakalau Forest NWR.

5.2.7 Recreational Trends and Demands

The State Comprehensive Outdoor Recreation Plan Update (SCORP 2009) built upon the SCORP (2003), which concluded that a general decrease in leisure time has influenced the demand for more recreational opportunities close to home. This decrease is due to a rise in single adults and working women, as well as an increase in the national median work week (DLNR 2003).

The top five priority issues for the 2009 update as determined from the agency and public meeting discussions and survey results are:

- Protection of natural and cultural resources;
- Management of recreation resources and facilities;
- Meeting the needs of recreation users;
- Access to recreation resources; and
- Funding.

In comparison to many other public land areas on Hawai‘i Island, Hakalau Forest NWR is not likely to provide significant recreational opportunities for the life of the CCP. Given the remote nature of the site and presence of endangered species, the Refuge will have a small role to play. However, the protection of the natural resources present here will help to address the number one priority issue from the SCORP Update. The Refuge will continue to offer limited recreational opportunities for very specialized recreation participants such as birdwatchers.

As a component of the National Wildlife Refuge System, Hakalau Forest NWR has a mandate to consider public uses such as hunting, fishing, wildlife observation and photography, and environmental education and interpretation. Those activities may be approved on a case-by-case basis and found compatible with the purposes and goals of the Refuge. Other public uses may be considered but must first be determined both appropriate and compatible (Appendix B identifies appropriate uses and compatible use determinations).

5.2.8 Impact of Illegal Uses

Incidence of theft, vandalism, and trespass on Refuge lands are factors that, owing to the remoteness of the Refuge, remain a concern in terms of staff and visitor safety, security, property damage or loss of government or partner assets, potential for impacts to threatened and endangered species, and potential contribution to accidental or deliberate wildfire. Service law enforcement coordinates with Refuge staff and other law enforcement agencies to monitor and investigate illegal activity. However, currently, there is only one law enforcement zone position for all 22 refuges in the Pacific and Hawaiian islands. Only Midway Atoll NWR, Guam NWR, and the Kaua‘i NWR Complex have their own law enforcement officer. It is anticipated that an increase in law enforcement presence would reduce the incidence of illegal activity.

5.2.9 Historic/Cultural Sites

Hakalau Forest Unit

National and State historic sites have the potential to be recreational areas for both local residents and tourists. There are 128 National and State historic sites within the County. Within the Hilo region, the

County General Plan (2006) identifies 19 sites that are listed on the Hawaiʻi Register of Historic Places and 10 sites listed on the National Register of Historic Places. These include burial areas, Kamehameha Hall, a courthouse, churches, theaters, residences, and other historic buildings (County of Hawaiʻi 2007). Keolonahihi State Historic Park and portions of the Kohala Historic Sites State Monument are not open to the public (DNLR 2003).

Compared to coastal, lower elevation regions, there is a low density and number of historic and cultural sites in upland areas (such as the Hakalau Forest NWR). As a result, most formal cultural or historic studies are restricted to these areas. In addition, a large number of historic sites have been either destroyed by agriculture, urban growth, and natural changes in landforms. (DNLR 2003).

In a traditional Native Hawaiian context, there is no division between nature and culture. The land, water, and sky were the foundation of life and the source of the spiritual relationship between people and their world. Native Hawaiian traditions express the attachment felt between the Native Hawaiian people and the Earth around them. "Native traditions describe the formation (literally the birth) of the Hawaiian Islands and the presence of life on and around them in the context of genealogical accounts. All forms of the natural environment – from the skies and mountain peaks, to the watered valleys and plains, to the shoreline and ocean depths – are the embodiments of Hawaiian gods and deities" (Maly 2001).

The ʻōhiʻa-koa zone was used by Native Hawaiians for specialized resources including bark for making fishing nets and māmaki to make kapa cloth. Native Hawaiians may have used the area for temporary camps while collecting natural resources or en route to a higher elevation adze quarry and associated surface work sites. Native Hawaiians had knowledge of shelter caves, overhangs, and water sources. In the dry māmane woodland, pili grass may have been collected as a special resource for thatching structures, as well as māmane wood for making adze handles, house posts, and hōlua sleds. Within or above the māmane zone, nēnē, ʻuʻau, and koloa maoli may have been used as a source of meat. Radiocarbon dating of bird bones from caves located in the saddle region between Mauna Loa and Mauna Kea indicate that Native Hawaiians were obtaining juvenile ʻuaʻu and collecting bird feathers between 1000-1450 A.D. (Dougherty and Moniz-Nakamura 2006).

The Refuge contains cultural/historic resource sites that have been inventoried in areas where management actions could have impacted these sites. This inventory will continue to ensure protection of these important resources. The Refuge allows cultural/historic resource investigations of sites by universities, researchers, students, and/or cultural practitioners.

Several cultural and archaeological sites do exist on the HFU. The Douglas Historic Monument, located north of the Refuge administrative site, is a monument to the famous naturalist David Douglas who traveled through the Hilo forest in 1834 (Stine 1985, Tomonari-Tuggle 1996) and died on the slopes of Mauna Kea. Two historical buildings also occur on the HFU. The Pua ʻĀkala Ranch is a complex of ranch structures built in the late 1800s; the Pua ʻĀkala cabin (or koa cabin) on the ranch has been nominated for the National Register of Historic Places. Nauhi Cabin was built at roughly 5,100 ft in the 1920s by the Hawaiʻi Sugar Planters Association. This cabin was part of the Nauhi Gulch Experiment Station (Tomonari-Tuggle 1996, Schuster et al. 2002).

Kona Forest Unit

Based on the historical documentation and archaeological investigations at similar elevations nearby, it can be expected that the most likely cultural resources within the KFU would be associated with the upper zone, ‘ama‘u, of the Kona Field System, a unique system of patterned networks of elongated rectangles bounded by earth and rock ridges used by Native Hawaiians for farming that extended from Kailua to the south of Honaunau. According to the idealized model of the Kona Field System, approximately the lower third of the KFU is within the ‘ama‘u. Today, this region is covered with forest, suggesting that it was not used for agriculture as intensively as were lower elevation areas. However, the presence of invasive species might be an indication that portions of the zone were cleared in earlier times.

It is worth noting that the idealized gradations for the zone of the Kona Field System are based on the full 32 mi expression of the system along the Kona region. In the southern portion of that region, where the KFU is located, the slopes of Mauna Loa are steeper, and consequently, the zones can be expected to be compressed into narrower bands. Indeed, detailed studies involving the field system in Ka‘ohe ahupua‘a demonstrate that the zones change more rapidly in this southern area, and that the upper reaches of the field system are at lower elevations than the normalized model suggests. Nevertheless, numerous agricultural features with associated temporary and even permanent habitation sites are present at elevations as high as 1,850 ft above sea level in nearby ahupua‘a. Those studies did not investigate elevations higher than that, so it is not known whether evidence of traditional Hawaiian agriculture extends to higher elevations. Based on the density and distribution of the agricultural features, it seems likely that the upper boundary of the system was not found and that the features do continue to some unknown higher elevation.

Caves have been identified in the KFU and more can be expected to be present. The inspection of four caves was focused on biological resources, so although no traditional cultural resources were reported other than observations of charcoal, it cannot be assumed that cultural resources do not exist. On the contrary, Boundary Commission testimony and archaeological investigations at similar elevations in the region indicate that caves were used for traditional activities.

People moved through the higher elevations to procure bird feathers and canoe wood. Camps for these kinds of activities may be present within the KFU. The known and named water holes in these higher elevations were likely valuable resources exploited for many centuries.

Although habitation was traditionally concentrated along the shoreline, historical references and archaeological work indicates that temporary shelters associated with agricultural pursuits were present throughout the Kona Field System. Temporary habitations of this kind may be present in the lower elevations of the KFU. Although rare, and not fully understood archaeologically or historically, a kind of habitation used by ali‘i to sequester royal youth could also be present in the lower portions of the KFU.

The village along the shoreline of Kalāhiki was an important place during traditional times and into the 1800s. Legends pertaining to this area emphasize the royal associations, and heiau in the uplands reflect the vitality of the sociopolitical activity throughout the lands here.

Based on the few cultural studies of the KFU, the most likely traditional Hawaiian cultural activities near the Unit were hunting birds for feathers, tree felling for canoes, and gathering of edible and medicinal plants. The most likely cultural resources on the Unit include roads, watering facilities, fences, paddocks, and logging sites (Raymond and Valentine 2007, USFWS 2008).

5.2.10 Special Designation Areas

The Pua ʻĀkala Cabin has been nominated for inclusion on the National Register of Historic Places. If the nomination is accepted, the cabin will continue to be maintained and managed by Refuge staff in accordance with guidelines provided by the National Register of Historic Places and the Secretary of the Interior's Standards for Historic Preservation.

5.3 Social and Economic Conditions

The purpose of this section is to address the local economy and social environment surrounding the two units of the Hakalau Forest NWR, including population estimates and economic indicators. Both of the Refuge units are located on the Island of Hawaiʻi within the County of Hawaiʻi. The Island of Hawaiʻi is divided into nine districts. The HFU is located in both the North Hilo District and the South Hilo District. The KFU is located in the South Kona District of Hawaiʻi County.

5.3.1 Population

The total resident population of the Hawaiian Islands in 2008 was 1,288,198. The Island of Hawaiʻi is home to 13.6 percent of this total, or 175,784 individuals (HDBEDT 2009). Within its 4,028.02 mi^2, the Island of Hawaiʻi has an average resident population density of 36.9 persons per mi^2. If tourists and visitors are included in the total island population, the average density increases to 41.5 persons per mi^2 (County of Hawaiʻi 2007). In comparison, the average density of the State during the same year was 189 persons per mi^2. The median age of the Hawaiʻi Island population in 2006 was 37.7 years (County of Hawaiʻi 2007).

The majority of the resident population on Hawaiʻi Island lives in the District of South Hilo. In 2000, approximately 47,386 residents lived in the 394.38 mi^2 district. The density of South Hilo is estimated to be 120.2 persons per mi^2. The North Hilo District had a much smaller population with 1,720 residents in 2000. The density of this area is about 4.6 persons per mi^2. The Hilo Community Development Plan (CDP) area is the most populated area on the island, with an estimated population of 40,759 individuals in 2000 (County of Hawaiʻi 2007).

Approximately 8,589 individuals resided in South Kona in 2000, a 12.2 percent increase from 1990. This district houses 25.6 persons per mi^2. Adjacent districts have also witnessed a dramatic increase in population. The resident population of Puna has increased noticeably, jumping from 11,751 individuals in 1980 to 31,335 in 2000. Kailua-Kona, located approximately 23 mi north of the Kona Forest Unit, is the largest town on the west side of the island. The CDPs located nearest the KFU are Captain Cook, Hōnaunau-Napoʻopoʻo, and Kealakekua. The average densities (persons per mi^2) of these areas in 2000 were 263.7, 63.5, and 218.2, respectively (County of Hawaiʻi 2007). Population figures for selected districts and CDPs are listed in Table 5-3.

The ethnic composition of the County of Hawaiʻi is diverse. In 2006, the County was comprised of 37 percent Caucasian, 24.3 percent Asian, 10.8 percent Native Hawaiian or other Pacific Islander, 0.7 percent Black or African American, and 0.7 percent American Indian and Alaska Native. Approximately 26.5 percent of the population identified themselves as having a mixed ethnic background of two or more races. Both the North and South Hilo Districts are largely comprised of people identifying themselves as Asian. The majority of the population within the South Kona District is Caucasian (County of Hawai‘i 2007).

The State of Hawai‘i also has a notable military population due to the presence of various military facilities. However, the military population has been decreasing throughout the islands since 1989 (DPP 2003). Less than 3.8 percent of the State population in 2008 was military personnel (HDBEDT 2009). Only 54 military personnel and their dependents lived on the Island of Hawai‘i in 2008 (HDBEDT 2009). The majority of the military personnel and dependents within the State reside on O‘ahu.

5.3.2 Housing

There were a total of 77,577 housing units on the Island of Hawai‘i in 2006. This number increased from 63,023 housing units in 2000 (HDBEDT 2007). On average, 2.75 persons inhabit each household on the island. The majority of the housing is in the South Hilo District, with 14,577 households in the Hilo CDP alone. The North Hilo District contains 597 households, with an average of 2.88 persons per household. In the South Kona District, there are 3,113 households. The majority of the houses in this district are located in the Captain Cook CDP (1,152 households), with an average of 2.76 persons per household in this area (County of Hawai‘i 2007).

5.3.3 Education

Forty-two public schools, 21 private schools, and 12 charter schools are within the County of Hawai‘i. Approximately 30,539 students were enrolled in these schools and the majority (almost 79.4 percent) were registered within the public school system. During the 2005-2006 school year, the average cost per student was $10,185 (County of Hawai‘i 2007).

Educational attainment on the Island of Hawai‘i is comparable to the State average. In 2000, approximately 84.6 percent of the Hawai‘i County population 25 years and over had received a high school diploma. Furthermore, approximately 22.1 percent have a Bachelor’s degree or higher. The State averages during the same year were 84.6 and 26.2 percent, respectively (HDBEDT 2007).

Table 5-3. Population Figures for Selected Areas.

Area	1980	% change	1990	% change	2000	% change	2008
State of Hawai‘i	964,691	14.9	1,108,229	9.3	1,211,537	6.3	1,288,198
Island of Hawai‘i	92,053	30.7	120,317	23.6	148,677	18.2	175,784
North Hilo District	1,679	-8.2	1,541	11.6	1,720	--	--
South Hilo District	42,278	5.6	44,639	6.2	47,386	--	--
South Kona District	5,914	29.5	7,658	12.2	8,589	--	--

Area	1980	% change	1990	% change	2000	% change	2008
Laupāhoehoe CDP	--	--	508	-6.9	473	--	--
Honomū CDP	--	--	532	1.7	541	--	--
Pāpa‘ikou CDP	--	--	1,634	-13.5	1,414	--	--
Paukaa CDP	--	--	495	0	495	--	--
Pepe‘ekeo CDP	--	--	1,813	-6.4	1,697	--	--
Wainaku CDP	--	--	1,243	-1.3	1,227	--	--
Hilo CDP	--	--	37,808	7.8	40,759	--	--
Captain Cook CDP	--	--	2,595	23.5	3,206	--	--
Hōnaunau-Napo‘opo‘o CDP	--	--	2,373	1.7	2,414	--	--
Kealakekua CDP	--	--	1,453	13.2	1,645	--	--

Source: County of Hawai‘i 2007, HDBEDT 2009.

The University of Hawai‘i system includes one community college and one university on the Island of Hawai‘i. During the 2008 school year, enrollment at the University of Hawai‘i at Hilo was 3,773; 522 students received Bachelor degrees and 28 received Master degrees during that year. During the 2008 school year, 2,884 students were enrolled at the Hawai‘i Community College (County of Hawai‘i 2007, HDBEDT 2009).

5.3.4 Employment and Income

In 2007, an estimated 68,944 people were employed in the County of Hawai‘i (HDBEDT 2009). The county unemployment rate is slightly higher than the State average. The leisure and hospitality industry employed the largest number of residents in 2006. The top five employers in the County of Hawai‘i in 2007 were (1) the State of Hawai‘i (7,696 employees); (2) the County of Hawai‘i (2,335 employees); (3) the U.S. Government (1,231 employees); (4) Hilton Waikoloa Village Resort (1,128 employees); and (5) KTA Superstores (885 employees) (County of Hawai‘i 2007).

The average per capita income for the State of Hawai‘i in 2009 was $42,009. This income is slightly higher than the U.S. average of $39,138. During the late 20th century, the per capita income of the State of Hawai‘i was higher than the national average, reaching a peak of 115.5 percent of the U.S. average in 1992. The median four person family income for the State in 2008 was $91,483, which is sixth highest in the Nation (HDBEDT 2009).

On the Island of Hawai‘i, the per capita income was lower at $26,591 (County of Hawai‘i 2007, HDBEDT 2007). The median household and family incomes for the County in 2000 were $39,805 and $46,480, respectively. The highest household incomes are in the South Kohala area, especially Kamuela (County of Hawai‘i 2007).

Table 5-4. Hawai‘i County Industry Job Counts and Average Annual Wages.

Industry	Hawai‘i County Job Counts (2009)	Average Annual Wage (2008)
Nat. resources, mining, construction	3,850	
Mining		$82,014
Construction		$62,056
Manufacturing	1,350	$38,800
Trade, transportation & utilities	13,100	
Wholesale trade	1,600	$48,001
Retail trade	8,850	$27,038
Information	650	$54,979
Financial activities	2,750	
Finance & insurance	1,150	$56,485
Real estate, rental, leasing	n/a	$40,562
Professional & business services	4,450	$61,909
Education & health services	7,600	
Education services	1,250	$34,047
Health care & social assistance	6,400	$43,753
Leisure & hospitality	12,550	
Government	12,850	$49,682
Agriculture	2,300	$30,538

Source: State of Hawai‘i Data Book 2009, HDBEDT.

5.3.5 Economy

The economy of the Island of Hawai‘i, and the State as a whole, is primarily driven by the visitor/tourist industry. The Hawai‘i DBEDT (2009) estimates 6,713,436 visitors traveled to the Hawaiian Islands in 2008. Of this total, 73 percent came from the continental United States and 27 percent from other countries. The largest percentage of domestic visitors (50.6 percent) came from the Pacific United States including Alaska, California, Oregon, and Washington. Of the passengers arriving from outside the United States, the largest number of visitors came from Japan (1,175,199), Canada (359,580), and Australia (137,812). Visitor related expenditures contributed $10.7 billion to the State in 2008 and 141,500 jobs (HDBEDT 2009).

The tourism industry became the primary economic generator for Hawai‘i County during the 1980s (County of Hawai‘i 2006). Although visitor arrivals have fluctuated over the years, it remains the key industry for the island. During 2008, 1,321,277 individuals visited the Island of Hawai‘i, of which 1,026,048 were domestic and 295,229 were international. In 2006, the average length of stay was 6.68 days (County of Hawai‘i 2007). The largest proportion of the Hawai‘i Island visitors were from the continental western U.S. (513,078), eastern U.S. (406,490), and Japan (214,066).

In the first half of 2007, total visitor spending was highest on the Island of Hawai‘i compared to other islands in the State. Estimated expenditures of total visitors in 2004 was $5,478.2 million (County of Hawai‘i 2007). Hotels on the island generate employment for 6,000 residents and have an annual payroll of over $163 million (Research Solutions, LLC and Gopalakrishnan 2002).

The success of the tourism industry on Hawaiʻi Island has been attributed to the diversity the island offers (First Hawaiian Bank 2007). Recreational opportunities include the following: SCUBA diving, fishing, snorkeling, swimming, sunbathing, shopping, wildlife observation, and viewing historical/cultural sites. More modern tourism opportunities such as ecotourism, health and wellness tourism, and educational tourism are also growing. The most popular tourist attraction is Hawaiʻi Volcanoes National Park; however, the principal visitor destination area on the Island of Hawaiʻi is the South Kohala-North Kona region in West Hawaiʻi (County of Hawaiʻi 2006).

Secondary components of the Hawaiʻi County economy are agriculture and research. Historically, agriculture has played a large role in the economy of the island, and the State as a whole. During the 19th and 20th centuries, the main industries were sugar cultivation and cattle ranching. The sugar industry gradually declined and finally ceased with the closure of the last sugar operation in Kaʻū in 1997 (County of Hawaiʻi 2007). Although this industry has declined in importance in other parts of the State, it remains a strong part of the Hawaiʻi County economy (First Hawaiian Bank 2007).

Current diversified agricultural activities include flowers and nursery products, coffee, macadamia nuts, tropical fruits, vegetable crops, orchards, aquaculture, and forestry (Research Solutions, LLC and Gopalakrishnan 2002, County of Hawaiʻi 2007). In 2008, the Island of Hawaiʻi had 4,650 farms employing approximately 2,350 people. Agricultural sales during 2007 totaled approximately $202 million. The State's livestock and aquaculture operations are centered on Hawaiʻi Island. Seventy percent of Hawaiʻi's livestock are raised on the island and nearly half of the aquaculture facilities are on Hawaiʻi Island. Sales of these two industries in 2000 were $14 million and $16 million, respectively (Research Solutions, LLC and Gopalakrishnan 2002).

The University of Hawaiʻi at Hilo is also a major component of the island's economy. It is estimated that the direct contribution of the University is $136 million per year. This is generated from research, construction, and foreign students. In addition, the University of Hawaiʻi at Hilo is the primary employer for the east side of the island (Research Solutions, LLC and Gopalakrishnan 2002, First Hawaiian Bank 2007).

The construction industry peaked in early 2006 on the Island of Hawaiʻi due to building within Puna and luxury condos on the west side; however, the construction and real estate sectors have recently slowed. This trend is evident in the decline in private construction permits (First Hawaiian Bank 2007).

The largest employers, after the government, were private entities (1) Hilton Waikoloa Village (employing 984 people), (2) Wal-Mart (employing 852 people), and (3) KTA Superstores (employing 800 people). (County of Hawaiʻi 2008).

Statewide, the U.S. Department of Defense plays an important part in the economy as the second major source of revenue behind tourism. Statewide defense expenditures were $5.6 billion in 2005. An estimated $742 million is being appropriated for military construction and defense related projects in Fiscal Year 2008. Annual per capita federal defense expenditures are $3,939. These expenditures are the highest on Oʻahu (Chamber of Commerce of Hawaiʻi 2008).

5.3.6 Refuge Contribution

Recreational spending near national wildlife refuges generates economic activity for local economies. These expenditures can include food, lodging, transportation, and other purchases from local businesses while engaging in refuge uses. Books, magazines, membership dues and contributions, land leasing or ownership, hunting and fishing licenses, and plantings, all for the purpose of wildlife-related recreation are also considered expenditures. In 2006, approximately 34.8 million people visited refuges around the contiguous United States, generating an estimated $1.7 billion in regional economies. Refuge employment contributed $542.8 million in income and recreational spending generated about $185.3 million in tax revenue at the local, State, and Federal level. Additional revenue is also derived from local taxes and employment income from the refuges.

Wildlife-related recreation in Hawaiʻi generated approximately $373,778,000 in 2006, with roughly $210,414,000 attributed to wildlife watching (USFWS 2007a). Although the units of the Hakalau Forest NWR are generally not available to the public, the Refuge does contribute to the local economy through recreational expenditures. Carver and Caudill (2007) found that the Hakalau Forest NWR had total annual recreational expenditure of $56,400 from 1,323 visitors. Roughly 90 percent of these total expenditures were from nonresidents. Birding and other wildlife observation were the main activities occurring at the HFU. In comparison, recreational expenditures at Kīlauea Point on Kauaʻi generated $10.7 million from 986,088 visitors.

In addition to recreational expenditures, the Refuge contributes money to the local economy through the Refuge Revenue Sharing Act of 1978 (16 U.S.C. 715s). This Act authorizes Federal payments to be transferred to the County of Hawaiʻi annually in lieu of discontinued taxation of private property. The amount compensated is approximately 0.75 percent of the fair market value of fee lands. In 2009, $66,557 was paid to Hawaiʻi County for Hakalau Forest NWR.

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Appendices

Above: Nēnē/John De Mello
Right: ‘I‘iwi/Jack Jeffrey Photography

Hakalau Forest Unit understory/Jack Jeffrey Photography

Appendix A. Species Lists for Hakalau Forest National Wildlife Refuge

Table A-1. Plant List (Both Native and Nonnative) for Hakalau Forest Unit.

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
Adiantaceae	*Adiantum capillus-veneris*	‘iwa‘iwa	I	f		
	Adiantum cuneatum	maidenhair fern	A	f		
Amarantaceae	*Charpentiera obovata*	pāpala	E	s,t		
Apocynaceae	*Alyxia olivaeformis*	maile	E	l	1987	
Aquifoliaceae	*Ilex anomala*	kāwa‘u	E	t	1987	
	Ilex aquifolium	English holly	A	s,t	1987	
Araceae	*Zantedeschia aethiopica*	calla lily	A	h	1987	
Araliaceae	*Cheirodendron trigynum*	‘ōlapa	E	t	1987	
	Tetraplasandra melandra	‘ohe	E	t		
Aspidiaceae	*Arachniodes carvifolia*		I	f	1987	
	Ctenitis rubiginosa		E	f	1987	
	Dryopteris fusco-atra		E	f	1987	
	Dryopteris glabra	kīlau	E	f	1987	
	Dryopteris hawaiiensis		E	f	1987	
	Dryopteris wallichiana	lau-kahi	I	f	1987	
	Dryopteris unidentata	‘akole	E	f	1987	
	Polystichum hillebrandii	papa‘oi	E	f		
Aspleniaceae	*Asplenium contiguum*		E	f	1987	
	Asplenium lobulatum	pi‘ipi‘i-lau	I	f	1987	
	Asplenium macraei		E	f	1987	
	Asplenium normale		I	f	1987	
	Asplenium polyodon		?	f	1987	
	Asplenium rhipidoneuron	iwa‘iwa-a-Kāne	I	f		
	Asplenium schizophyllum		SOC	f	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Asplenium unilaterale	pāmoho	I	f		
Asteraceae	*Cirsium vulgare*	bull thistle	A	s,t	1987	
Athyriaceae	*Athyrium microphyllum*	‘ākōlea	E	f	1987	
	Diplazium sandwichianum	hō‘i‘o	E	f	1987	
Blechnaceae	*Sadleria cyatheoides*	‘ama‘u, ‘ama‘uma‘u	E	f	1987	
	Sadleria pallida	‘ama‘u, ‘ama'uma‘u	E	f	1987	
	Sadleria souleyetiana	‘ama‘u, ama‘uma‘u	E	f	1987	
	Sadleria squarrosa	‘ama‘u	E	f		
Caprifoliaceae	*Lonicera japonica*	honeysuckle	A	l	1987	
Caryophyllaceae	*Cerastium vulgatum*	larger mouse ear, chickweed	A	h	1987	
	Drymaria cordata	drymaria	A	h	1987	
	Polycarpon tetraphyllum	allseed	A	h	1987	
	Stellaria media	common chickweed	A	h	1987	
Casuarinaceae	*Casuarina*	common ironwood	A	t	1987	
Celastraceae	*Perrottetia sandwicensis*	olomea	E	t	1987	
Commelinaceae	*Commelina diffusa*	day flower	A	h		
Compositae	*Ageratum conyzoides*	ageratum	A	h	1987	
	Ageratina riparia	spreading mist flower	A	h	1987	
	Bidens pilosa	Spanish needle	A	h	1987	
	Chrysanthemum leucanthemum	white daisy	A	h	1987	
	Crassocephalum crepidioides		A	h	1987	
	Dubautia scabra	na‘ena‘e	E	s,t	1987	
	Erechtites valerianaefolia	valerian-leaved fireweed	A	h	1987	
	Erigeron bonariensis	hairy horseweed	A	h	1987	
	Erigeron canadensis	Canada fleabane	A	h	1987	
	Gnaphalium japonicum	cudweed	A	h	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Hypochoeris radicata	hairy cat's-ear, gosmore	A	h	1987	
	Senecio sylvaticus	wood groundsel	A	h	1987	
	Senecio madagascariensis	fire weed	A	h	2004	
	Senecio mikanioides	German ivy	A	l	Pua ʻĀkala1990	
	Solanum tuberosum		A	h	1987	
	sonchus oleraceus	sow thistle	A	h	1987	
	Taraxacum officinale	dandelion	A	h	1987	
	Youngia japonica	oriental hawksbeard	A	h	1987	
Corynocarpaceae	*Corynocarpus laevigata*	karaka tree	A	t	1987	
Cruciferae	*Cardamine flexuosa*		A	h	1987	
	Nasturtium microphyllum	watercress	A	h	1987	
Cucurbitaceae	*Sicyos sp.*	kūpala	E	l		
Cupressaceae	*Chamaecyparis lawsoniana*	Port Orford cedar	A	t	1987	
Cyperaceae	*Carex alligata*		E	g	1987	
	Carex macloviana	St. Malo's sedge	I	g	1987	
	Carex wahuensis var. rubiginosa		E	g	1987	
	Cyperus brevifolius	kyllinga	A	g		
	Cyperus haspan		A	g	1987	
	Eleocharis obtusa	pīpī wai, kohekohe	I	g	1987	
	Eleocharis radicans		A	g	1987	
	Machaerina angustifolia	ʻuki	I	g	1987	
	Uncinia uncinata		I	g	1987	
Dennstaedtiaceae	*Microlepia strigosa*	palapalai, palai	I	f	1987	
Dicksoniaceae	*Cibotium chamissoi*	hāpuʻu ʻiʻi, ʻiʻi	E	f	1987	
	Cibotium glaucum	hāpuʻu pulu	E	f	1987	
	Cibotium hawaiense	meu	E	f		

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
Elaphoglossaceae	*Elaphoglossum alatum*	‘ēkaha	E	f	1987	
	Elaphoglossum crassifolium	‘ēkaha	E	f	1987	
	Elaphoglossum hirtum var. micans	‘ēkaha	E	f	1987	
	Elaphoglossum wawrae	‘ēkaha	E	f	1987	
Epacridaceae	*Styphelia tameiameiae*	pūkiawe	I	s	1987	
Ericaceae	*Rhododendrum x hybridium*	rhododendron	A	s	1987	
	Vaccinium calycinum	‘ōhelo-kau-lā‘au	E	s,t	1987	
	Vaccinium pahalae	‘ōhelo	E	s	1987	
	Vaccinium reticulatum	‘ōhelo	E	s	1987	
Fagaceae	*Castanea dentata*	American chestnut	A	t	1987	
Geraniaceae	*Erodium cicutarium*	Filaree	A	h	1987	
	Geranium carolinianum	Carolina crane’s	A	h	1987	
Gesneriaceae	*Cyrtandra lysiosepala*	kanawao-ke‘oke‘o	E	s	1987	
	Cyrtandra paludosa	kanawao-ke‘oke‘o	E	s	1987	
	Cyrtandra platyphylla	kanawao-ke‘oke‘o	E	s	1987	
	*Cyrtandra tintinnabula**	ha‘iwale	Endang		Maulua 1994	
	Hypericum mutilum	St. Johnswort	A	h	1987	
Gleicheniaceae	*Dicranopteris linearis*	uluhe	I	f	1987	
	Diplopterygium pinnata	uluhe-lau-nui	I	f	1987	
	Sticherus owhyhensis	uluhe	E	f	1987	
Gramineae	*Agrostis alba*	red top grass	A	g	1987	
	Agrostis avenacea		A	g	1987	
	Andropogon virginicus	broomsedge	A	g		
	Anthoxanthum odoratum	sweet vernal grass	A	g	1987	
	Avena fatua	wild oat	A	g	1987	
	Axonopus affinis	narrow-leaved carpet grass	A	g	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Dactylis glomerata	orchard grass	A	g	1987	
	Deschampsia australis		E	g	1987	
	Eragrostis brownei	Brown's lovegrass	A	g	1987	
	Festuca arundinacea		A	g	Hakalau Cabin 2005	
	Holcus lanatus	velvet grass	A	g	1987	
	Isachne distichophylla	‘ohe	E	g	‘Āwehi stream 4100ft 2002	
	Microlaena stipoides	meadow ricegrass	A	g	1987	
	Paspalum dilatatum	dallis grass	A	g	1987	
	Paspalum urvillei	vasey grass	A	g	1987	
	Pennisetum clandestinum	kikuyu grass	A	g	1987	
	Poa annua	annual bluegrass	A	g	1987	
	Poa pratensis	Kentucky bluegrass	A	g	1987	
	Sacciolepis indica	Glenwood grass	A	g	1987	
	Setaria geniculata	perennial foxtail	A	g	1987	
	Sporobolus africanus	African dropseed	A	g	1987	
Grammitidaceae	*Adenophorus hymenophylloides*	pai, palai-lā‘au	E	f	1987	
	Adenophorus pinnatifidus	kihi, kihe	E	f	1987	
	Adenophorus tamariscinus	wahine-noho-mauna	E	f	1987	
	Adenophorus tripinnatifidus	wahine-noho-mauna	E	f	1987	
	Grammitis hookeri	māku‘e-lau-li‘i	E	f	1987	
	Grammitis tenella	kolokolo	E	f	1987	
	Xiphopteris saffordii	mahine-lua	E	f	1987	
Guttiferae	*Hypericum degeneri*		A	h	1987	
Hemionitidaceae	*Coniogramme pilosa*	lo‘ulu	E	f	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
Hymenophyllaceae	*Mecodium recurvum*	‘ōhi‘a kū	E	f	1987	
	Sphaerocionium lanceolatum	palaihinahina	E	f	1987	
	Sphaerocionium obtusum	palai-lau-li‘i	E	f		
	Vandenboschia davallioides	kīlau, kālau, palahihi	E	f	1987	
Hypolepidaceae	*Hypolepis punctata*	‘olua	I	f	1987	
	Pteridium aquilinum var. decompositum	kīlau-a-pueo, brackenfern	E	f	1987	
Joinvilleaceae	*Joinvillea ascendens*	‘ohe	C	g		
Juncaceae	*Juncus effusus*	bog rush	A	g	1987	
	Juncus planifolius		A	g	1987	
	Juncus tenuis	slender rush	A	g	1987	
	Luzula hawaiiensis		E	g	1987	
Labiatae	*Mentha spicata*	spearmint	A	h	Nauhi cabin 1990	
	Phyllostegia floribunda		E	s		
	*Phyllostegia brevidens**		SOC		1991	
	*Phyllostegia racemosa**	kīponapona	Endang	h	1987	Portions of unit 1-2
	*Phyllostegia velutina**		Endang		1991	
	Phyllostegia vestita		SOC	l		
	Phyllostegia warshaueri		Endang			
	Prunella vulgaris	self-heal	A	h	1987	
	Stenogyne calaminthoides		E	l	1987	
	Stenogyne macrantha		E	l	1987	
	Stenogyne scrophularioides Benth. var. biflora	mōhihi	E	l	Maulua 1998	
	Stenogyne scrophularioides var. remvi	mōhihi	E	l		
Leguminosae	*Acacia koa*	koa	E	t	1987	
	Lotus angustissimus		A	h	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Lotus corniculatus	bird's foot trefoil	A	h	1987	
	Lotus uliginosus		A	h	1987	
	Medicago polymorpha	burr clover	A	h	1987	
	Sophora chrysophylla	māmane	E	t	1987	
	Trifolium repens	white clover	A	h	1987	
	Ulex europaeus	gorse	A	s	1987	
Liliaceae	*Astelia menziesiana*	pa'iniu	E	h	1987	
	Smilax sandwicensis	hoi-kuahiwi	E	l	1987	
Lindsaeceae	*Sphenomeris chinensis*	pala'ā	I	f	1987	
Lobeliaceae	*Clermontia lindseyana**		Endang	s	1987	Portions of unit 1-2
	Clermontia parviflor	'ōhāwai	E	s,t	Maulua 1992	
	Clermontia peleana peleana	'ōhāwai	Endang	s,t		Portions of unit 1, 3
	*Clermontia pyrularia**	'ōhāwai	Endang	s	Outplanted 1992	Portions of unit 1-2
	Clermontia sp.		E	s	1987	
	Cyanea fernaldii		E	s		
	Cyanea longipedunculata		E	s		
	Cyanea pilosa		E	s	1987	
	Cyanea platypylla	'aku'aku	Endang	s		
	*Cyanea shipmannii**	hāhā	Endang	s	1992	Portions of unit 1
	Cyanea tritomantha	'akū	E	s		
	Trematolobelia grandifolia	koli'i	E	s	Honohina 1992	
Loganiaceae	*Labordia hedyosmifolia var. gravana*	kamakahala	E	s	1987	
Loranthaceae	*Korthalsella complanata*	hulumoa	E	h	1987	
	Korthalsella cylindrica		E	h		
Lycopodiaceae	*Lycopodium cernum*	wāwae'iole	I	f	1987	
	Lycopodium erubescens		E	f		

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Lycopodium serratum		E	f		
Lythraceae	*Cuphea carthagenensis*	tarweed	A	h	1987	
	Lythrum maritimum		A	h,s	1987	
Magnoliaceae	*Magnolia grandiflora*	southern magnolia	A	t	1987	
Malvaceae	*Modiola caroliniana*	modiola	A	h	1987	
Marattiaceae	*Marattia douglasii*	pala	I	f	1987	
Myoporaceae	*Myoporum sandwicense*	naio	E	t	1987	
Myrsinaceae	*Embelia pacifica*	kilioe	E	l		
	Myrsine lessertiana	kōlea-lau-nui	E	t	1987	
	Myrsine sandwicensis.	kōlea-lau-li‘i	E	s,t	1987	
Myrtaceae	*Eucalyptus sp.*		A	t	1987	
	Eucalyptus robusta	swamp mahogany	A	t	1987	
	Metrosideros polymorpha	‘ōhi‘a lehua	E	s,t	1987	
	Psidium cattleianum	strawberry guava	A	t	2004	
Nephrolepidaceae	*Nephrolepis cordifolia*	ni‘ani‘au	I	f	1987	
Orchidaceae	*Arundina bambusaefolia*	bamboo orchid	A	h	1987	
	Liparis hawaiensis	‘awapuhi-a-kanaloa	E	h		
Oleaceae	*Fraxinus uhdei*	tropical ash	A	t	1987	
Onagraceae	*Epilobium cinereum*	willow herb	A	h	1987	
	Fuchsia magellanica	fucshia	A	s	1987	
	Ludwigia palustris	water purslane	A	h	1987	
Oxalidaceae	*Oxalis corniculata var. corniculata*	lady’s sorrel	A	h	1987	
Palmae	*Pritchardia lanigera*	lo‘ulu	E	t		
Pandanaceae	*Freycinetia arborea*	‘ie‘ie	E	l	1987	
Passifloraceae	*Passiflora mollissima*	banana poka	A	l	1987	
Phytolaccaceae	*Phytolacca sandwicensis*	pōpolo-kū-mai	SOC	s	1987	
Piperaceae	*Peperomia cookiana*	‘ala‘ala-wai-nui	E	h	1987	
	Peperomia expallescens	‘ala‘ala-wai-nui	E	h	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Peperomia hawaiensis	‘ala‘ala-wai-nui	E	h	1987	
	Peperomia hypoleuca	‘ala‘ala-wai-nui	E	h	1987	
	Peperomia leptostachya	‘ala‘ala-wai-nui	I	h	1987	
	Peperomia ligustrina	‘ala‘ala-wai-nui	E	h		
	Peperomia lilifolia	‘ala‘ala-wai-nui	E	h	1987	
	Peperomia macreana	‘ala‘ala-wai-nui	E	h		
	Peperomia tetraphylla	‘ala‘ala-wai-nui	I	h	1987	
Pittosporaceae	*Pittosporum undulatum*	victorian laurel	A	Ander-son & Crosby	1999	
Plantaginaceae	*Plantago australis*	plantain	A	h	1987	
	Plantago lanceolata	narrow-leaved plantain	A	h	1987	
	Plantago major	common plantain	A	h	1987	
Platanaceae	*Platanus sp.*	plane tree	A	t	1987	
Polygonaceae	*Polygonum punctatum*	water smartweed	A	h	1987	
	Rumex acetosella	sheep sorrel	A	h	1987	
	Rumex crispus	yellow dock	A	h	1987	
	Rumex giganteus	pāwale	E	s,l	1987	
Primulaceae	*Anagallis arvensis var. arvensis*	scarlet pimpernel	A	h	1987	
Polypodiaceae	*Pleopeltis thunbergiana*	‘ekaha-‘ākōle, pākahakaha	I	f	1987	
	Polypodium pellucidum var. pellucidum	‘ae	E	f	1987	
Psilotaceae	*Psilotum complanatum*	moa	I	f	1987	
	Psilotum nudum	moa	I	f	1987	
Pteridaceae	*Pteris cretica*	‘owāli‘i	I	f	1987	
	Pteris excelsa	waimaka-nui, iwa	E	f	1987	
	Pteris irregularis	mana	E	f		
Ranunculaceae	*Ranunculus hawaiensis*	makou	SOC			

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Ranunculus plebeius	common Australian buttercup	A	h	1987	
	Ranunculus repens	creeping buttercup	A	h	1987	
	Ranunculus mauiensis				Aug 1991	
Rosaceae	*Fragaria vesca f. alba*	European strawberry	A	h	1987	
	Prunus cerasus	sour cherry	A	t	1987	
	Prunus persica	peach	A	s,t	1987	
	Pyrus malus	apple	A	t		
	Rosa sp.	rose	A	s	1987	
	Photenia Davidiana	photenia - Nauhi area	A	s		
	Rubus hawaiiensis	ʻākala	E	s	1987	
	Rubus argutus	prickly Florida blackberry	A	s	1987	
	Rubus rosaefolius	thimbleberry	A	s	1987	
	Unknown Rubus		A	s	1987	
Rubiaceae	*Coprosma ochracea*	pilo	E	t	1987	
	Coprosma rhynchocarpa	pilo	E	s,t		
	Gouldia hillebrandii	manono	E	t	1987	
	Gouldia terminalis	manono	E	t	1987	
	Gouldia terminalis var. quadrangularis	manono	E	t		
	Nertera granadensis var. insularis Skottsb.	mākole	I	h	1987	
	Psychotria hawaiiensis var. hawaiienis	kōpiko	E	s,t	1987	
	Photenia Davidiana		A	s,t	1987	
Rutaceae	*Pelea clusiaefolia*	ʻalani	E	s,t	1987	
	Pelea grandifolia	ʻalani	E	t	1987	
	Pelea pseudoanisata	ʻalani	E	s,t	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Platydesma remyi	Remy's pilo-kea	C1R	t		
	Platydesma spathulata	pilo-kea	E	s,t		
Salaginellaceae	*Selaginella arbuscula*	lepelepe-a-moa	E	f	1987	
Sapindaceae	*Dodonaea viscosa*	‘a‘ali‘i	E	s	1987	
Saxifragaceae	*Broussaisia arguta Gaud.var. arguta forma ternata Forbes*	pū‘aha-nui, kanawao	E	s	1987	
	Hydrangea macrophylla	hydrangea	A	s	1987	
Scrophulariaceae	*Castilleja arvensis*	Indian paintbrush	A	h	1987	
	Veronica arvensis	corn speedwell	A	h	1987	
	Veronica plebeia	common speedwell	A	h	1987	
	Veronica serpyllifolia	thyme-leaved speedwell	A	h	1987	
Solanaceae	*Physalis peruviana*	cape gooseberry	A	h	1987	
	Solanum nigrum	pōpolo, black nightshade	I ?	s	1987	
	Solanum tuberosum	potato	A	h	1987	
	Nothocestrum longifolium	Aira	E	t	Maulua 12/90	
Taxodiaceae	*Cryptomeria japonica*	Tsugi or sugi pine	A	t	1987	
	Cunninghamia lanceolata	China fir	A	t	1987	
	Sequoia sempervirens	coast redwood	A	t	1987	
Theaceae	*Eurya sandwicensis**	ānini	SOC	t	Tr 2 Bottom 3/2007	
Thelypteridaceae	*Amauropelta globulifera*	palapalai-a-kama-pua‘a	E	f	1987	
	Christella cyatheoides	kikawaiō, pakikawaiō kupukupu-makali‘i	E	f		
	Pseudophegopteris keraudreniana	waimaka-nui	E	f	1987	
	Pneumatopteris sandwicensis	hō‘i‘o-kula	E	f	1987	
	Macrothelypteris torresiana		A	f	2001	
Thymelaeaceae	*Wikstroemia sp.*	‘ākia	E	s		
Umbelliferae	*Hydrocotyle sibthorpioides*	marsh pennywort	A	h	1987	

Family	Species (Scientific Name)	Common Name	Status	Life Form	Year First Observed	Critical Habitat
	Hydrocotyle verticillata	whorled marsh pennywort	A	h	1987	
Urticaceae	*Pilea peploides*		I	h	1987	
	Pipturus albidus	māmaki	E	s,t	1987	
	Touchardia latifolia	olonā	E	s		
	Urera sandvicensis	ōpūhe	E	t		
Verbenaceae	*Verbena litoralis*	weed verbena	A	h	1987	

Status
E = Endemic
I = Indigenous
P = Polynesian introduction

A = alien (nonnative)
SOC = species of concern, old C2
C1R = recommended for candidate1
C1P = candidate1 proposed for listing
Endang = endangered
? = Recorded during the Hawai‘i Forest Bird Survey, not seen since
* = Species in propagation at Hakalau Forest greenhouse

Life Form
f = fern
h = herb
g = grass or grass like (sedges, rushes and grasses)
s = shrub
t = tree
l = liana, vine

Table A-2. Plant List (Both Native and Nonnative) for Kona Forest Unit.

Genus	Species	Hawaiian/Common Name	3X3 CODE
Endemic			
Acacia	*koa*	koa	AcaKoa
Agrostis	*avenacea*	he‘u-pueo	AgrAve
Agrostis	*sandwicensis*	pili hale	AgrSan
Alyxia	*oliviformis*	maile	AlyOli
Antidesma	*platyphyllum*	hame	AntPlaPla
Astelia	*menziesiana*	pa‘iniu, kaluaha	AstMen
Broussaisia	*arguta*	pū‘aha-nui, kanawao	BroArg
Canavalia	*hawaiiensis*	‘āwikiwiki	CanHaw
Carex	*alligata*	no common name	CarAll
Carex	*macloviana*	no common name	CarMacSub
Carex	*wahuensis*	no common name	CarWah
Charpentiera	*obovata*	pāpala	ChaObo
Cheirodendron	*trigynum*	‘ōlapa	CheTri
Clermontia	*clermontioides ssp. clermontioides*	‘ōhāwai	CleCleCle
Clermontia	*clermontioides ssp. rockiana*	‘ōhāwai	CleCleRoc
E - *Clermontia*	*lindseyana*	‘ōhāwai	CleLin
Cocculus	*orbiculatus*	huehue	CocOrb
Coprosma	*ernodeoides*	kūkae-nēnē	CopErn
Coprosma	*montana*	pilo	CopMon
Coprosma	*rhynchocarpa*	pilo	CopRhy
C - *Cyanea*	*floribunda*	hāhā	CyaFlo
E (CH) - *Cyanea*	*hamatiflora*	hāhā	CyaHamCar
SOC - *Cyanea*	*marksii*	hāhā	CyaMar
Cyanea	*pilosa*	hāhā	CyaPilPil
E - *Cyanea*	*stictophylla*	hāhā	CyaSti
Cyperus	*polystachyos*	no common name	CypPol
Cyrtandra	*hawaiensis*	ha‘iwale	CyrHaw
Rare - *Cyrtandra*	*lysiosepala*	ha‘iwale	CyrLys
SOC - *Cyrtandra*	*menziesii*	ha‘iwale	CyrMen
Cyrtandra	*platyphylla*	‘ilihia	CyrPla

Genus	Species	Hawaiian/Common Name	3X3 CODE
Deschampsia	*nubigena*	hairgrass	DesNub
Dianella	*sandwicensis*	‘uki ‘uki	DiaSan
Dodonaea	*viscosa*	‘a‘ali‘i	DodVis
Dubautia	*scabra*	na‘en‘ae	DubSca
Embelia	*pacifica*	kilioe	EmbPac
Exocarpos	*menziesii*	heau	ExoMen
Fimbristylis	*dichotoma*	tall fringe rush	FimDic
SOC - *Fragaria*	*Chiloensis ssp. sandwicensis*	‘ōhelo papa	FraChiSan
Freycinetia	*arborea*	‘ie‘ie	FreArb
Geranium	*cuneatum*	nohoanu	GerCun
Hedyotis	*centranthoides*	no common name	HedCen
Hedyotis	*hillebrandii*	manono	HedHil
Hedyotis	*terminalis*	manono	HedTer
Ilex	*anomala*	kāwa‘u	IleAno
Ipomoea	*indica*	morning glory, koali‘awa	IpoInd
Korthalsella	*latissima*	Hawaiian mistletoe, hulumoa, kaumahana	KorLat
Labordia	*hedyosmifolia*	kāmakahala	LabHed
Luzula	*hawaiiensis*	wood rush	LuzHaw
Machaerina	*angustifolia*	‘uki	MacAng
Melicope	*clusiifolia*	kolokolo mokihana, kūkaemoa	MelClu
Melicope	*radiata*	alani	MelRad
Melicope	*volcanica*	alani	MelVol
Metrosideros	*polymorpha*	‘ōhi‘a, ‘ōhi‘a lehua, lehua	MetPol
Metrosideros	*polymorpha*	‘ōhi‘a, ‘ōhi‘a lehua, lehua	MetPolGla
Metrosideros	*polymorpha*	‘ōhi‘a, ‘ōhi‘a lehua, lehua	MetPolInc
Metrosideros	*polymorpha*	‘ōhi‘a, ‘ōhi‘a lehua, lehua	MetPolMac
Metrosideros	*polymorpha*	‘ōhi‘a, ‘ōhi‘a lehua, lehua	MetPolPol
Morelotia	*gahniiformis*	no common name	MorGah
Myoporum	*sandwicense*	naio, bastard sandalwood	MyoSan
Myrsine	*lanaiensis*	kōlea	MyrLan
Myrsine	*lessertiana*	kōlea lau nui	MyrLes
Myrsine	*sandwicensis*	kōlea lau li‘i	MyrSan
E - *Nothocestrum*	*breviflorum*	‘aiea	NotBre

Genus	Species	Hawaiian/Common Name	3X3 CODE
Nothocestrum	*longifolium*	‘aiea	NotLon
Panicum	*tenuifolium*	mountain pili, konakona	PanTen
Paspalum	*scrobiculatum*	ricegrass	PasScr
Peperomia	*cookiana*	‘ala‘ala wai nui	PepCoo
Peperomia	*hypoleuca*	‘ala‘ala wai nui	PepHyp
Peperomia	*macraeana*	‘ala‘ala-wai-nui	PepMac
Perrottetia	*sandwicensis*	olomea	PerSan
Phyllostegia	*ambigua*	no common name	PhyAmb
C - *Phyllostegia*	*floribunda*	no common name	PhyFlo
SOC - *Phyllostegia*	*stachyoides*	no common name	PhySta
E - *Phyllostegia*	*velutina*	no common name	PhyVel
SOC - *Phyllostegia*	*vestita*	no common name	PhyVes
Rare - *Phytolacca*	*sandwicensis*	pōpolo kū mai	PhySan
Pilea	*peploides*	no common name	PilPep
Pipturus	*albidus*	māmaki	PipAlb
Pisonia	*sandwicensis*	āulu, kaulu	PisSan
Pittosporum	*hosmeri*	hō‘awa	PitHos
Pittosporum	*terminalioides*	hō‘awa	PitTer
Platydesma	*spathulata*	pilo kea	PlaSpa
E - *Portulaca*	*sclerocarpa*	po‘e	PorScl
Pseudognaphalium	*sandwicensium*	‘ena‘ena	PseSanSan
Psychotria	*hawaiiensis*	kōpiko ‘ula, ‘ōpiko	PsyHaw
Rubus	*hawaiensis*	‘ākala	RubHaw
SOC - *Rubus*	*macraei*	‘ākala	RubMac
Rumex	*giganteus*	pāwale, uhauhakō	RumGig
Rumex	*skottsbergii*	pāwale	RumSko
SOC - *Sanicula*	*sandwicensis*	no common name	SanSan
Santalum	*paniculatum*	‘iliahi, sandalwood	SanPanPan
Schoenoplectus	*juncoides*	kaluhā	SchJun
Sicyos	*lasiocephalus*	‘ānunu	SicLas
C - *Sicyos*	*macrophyllus*	‘ānunu	SicMac
T - *Silene*	*hawaiiensis*	no common name	SilHaw
SOC - *Sisyrinchium*	*acre*	mau‘u hō‘ula ‘ili	SisAcr

Genus	Species	Hawaiian/Common Name	3X3 CODE
Smilax	*melastomifolia*	hoi-kuahiwi, ʻakaʻawa	SmiMel
Sophora	*chrysophylla*	māmane	SopChr
Stenogyne	*calycosa*	no common name	SteCal
SOC - *Stenogyne*	*macrantha*	no common name	SteMac
Stenogyne	*rugosa*	maʻohiʻohi	SteRug
SOC - *Stenogyne*	*scrophularioides*	mōhihi	SteScr
Stenogyne	*sessilis*	no common name	SteSes
Styphelia	*tameiameiae*	pūkiawe	StyTam
Tetramolopium	*humile*	no common name	TetHum
Tetraplasandra	*hawaiensis*	ʻohe	TetHaw
Tetraplasandra	*oahuensis*	ʻohe mauka	TetOah
Touchardia	*latifolia*	olonā	TouLat
Trisetum	*glomeratum*	Heʻu-pueo, mountain pili	TriGlo
Uncinia	*uncinata*	no common name	UncUnc
Urera	*glabra*	ōpūhe	UreGla
Vaccinium	*calycinum*	ʻōhelo kau lāʻau	VacCal
Vaccinium	*reticulatum*	ʻōhelo	VacRet
Wikstroemia	*phillyreifolia*	ʻākia	WikPhi
Wollastonia	*subcordata*	nehe	WolSub
Xylosma	*hawaiiense*	maua	XylHaw
Ferns			
Adenophorus	*hymenophylloides*	pai	AdeHym
Adenophorus	*tamariscinus*	wahine noho mauna	AdeTam
Adenophorus	*tripinnatifidus*	wahine noho mauna	AdeTri
Adiantum	*hispidulum*	no Hawaiian name	AdiHis
Adiantum	*raddianum*	no Hawaiian name	AdiRad
Amauropelta	*globulifera*	palapalai a Kamapuaʻa	AmaGlo
Asplenium	*acuminatum*	lola	AspAcu
Asplenium	*adiantum-nigrum*	ʻiwaʻiwa, manawahua	AspAdi
Asplenium	*contiguum*	no Hawaiian name	AspCon
Asplenium	*insiticium*	ʻāpaliʻi	AspIns
Asplenium	*lobulatum*	piʻi piʻi lau manamana, ʻanaliʻi	AspLob
Asplenium	*macraei*	ʻiwaʻiwa lau liʻi, ʻiwa lau liʻi	AspMac

Genus	Species	Hawaiian/Common Name	3X3 CODE
Asplenium	*monanthes*	no Hawaiian name	AspMon
Asplenium	*nidus*	‘ēkaha,‘ekaha kuahiwi, ‘ākaha, ‘ekahakaha	AspNid
E - *Asplenium*	*peruvianum var. insulare*	no Hawaiian name	AspPerIns
Asplenium	*polyodon*	‘iwa, ‘alae	AspPol
Asplenium	*sphenotomum*	no Hawaiian name	AspSph
Asplenium	*trichomanes*	‘owāli‘i	AspTriDen
Asplenium	*unilaterale*	pāmoho	AspUni
Athyrium	*microphyllum*	‘ākōlea	AthMic
Blechnum	*appendiculatum*	no Hawaiian name	BleApp
Callistopteris	*baueriana*	no Hawaiian name	CalBau
Christella	*parasitica*	no Hawaiian name	ChrPar
Cibotium	*chamissoi*	hāpu‘u, hāpu‘u ‘i‘i	CibCha
Cibotium	*glaucum*	hāpu‘u	CibGla
Cibotium	*menziesii*	hāpu‘u	CibMen
Coniogramme	*pilosa*	lo‘ulu	ConPil
Cyrtomium	*falcatum*	no Hawaiian name	CyrFal
SOC - *Cystopteris*	*douglasii*	no Hawaiian name	CysDou
Deparia	*petersenii*	no Hawaiian name	DepPet
Dicranopteris	*linearis*	uluhe	DicLin
Diplazium	*arnottii*	hō‘i‘o, pohole	DipArn
Diplazium	*sandwichianum*	hō‘i‘o	DipSan
Dryopteris	*fusco-atra*	‘olua, ‘opeha	DryFus
Dryopteris	*glabra*	hohiu, kīlau	DryGla
Dryopteris	*hawaiiensis*	no Hawaiian name	DryHaw
Dryopteris	*unidentata*	‘akole	DryUni
Dryopteris	*wallichiana*	lau kahi, ‘i‘o nui	DryWal
Elaphoglossum	*alatum*	‘‘opeha	ElaAla
Elaphoglossum	*crassifolium*	laukahi	ElaCra
Elaphoglossum	*paleaceum*	‘ēkaha	ElaPal
Elaphoglossum	*parvisquameum*	‘ēkaha	ElaPar
Elaphoglossum	*wawrae*	māku‘e	ElaWaw
Grammitis	*hookeri*	māku‘e lau li‘i	GraHoo
Grammitis	*tenella*	kolokolo	GraTen

Genus	Species	Hawaiian/Common Name	3X3 CODE
Huperzia	*erosa*	wawaeʻiole	HupEro
Huperzia	*serrata*	wawaeʻiole	HupSer
Hypolepis	*hawaiiensis*	ʻolua	HypHaw
Lellingeria	*saffordii*	kihi	LelSaf
Lepisorus	*thunbergianus*	ʻēkaha ʻākōlea	LepThu
Lycopodium	*venustulum*	wawaeʻiole	LycVen
Macrothelypteris	*torresiana*	no Hawaiian name	MacTor
Rare - *Marattia*	*douglasii*	pala, kapuaʻi lio	MarDou
Mecodium	*recurvum*	ʻōhiʻa kū	MecRec
Microlepia	*strigosa*	palapalai	MicStr
Nephrolepis	*cordifolia*	ʻakupukupu	NepCor
Nephrolepis	*exaltata*	ʻōkupukupu	NepExaHaw
Nephrolepis	*multiflora*	no Hawaiian name	NepMul
Nothoperanema	*rubiginosa*	mākuʻe, pauoa	NotRub
Odontosoria	*chinensis*	palaʻā	OdoChi
Oligadenus	*pinnatifidus*	kihi	OliPin
Oligadenus	*pinnatifidus*	kihi	OliPin
Ophioderma	*pendula*	lau kahi	OphPen
Palhinhaea	*cernua*	wawaeʻiole	PalCer
Pellaea	*ternifolia*	kalamoho, kalamoho lau liʻi	PelTer
Phlebodium	*aureum*	lauaʻe haole	PhlAur
Phlegmariurus	*filiformis*	wawaeʻiole	PhlFil
Phlegmariurus	*phyllanthus*	wawaeʻiole	PhlPhy
Pityrogramma	*austroamericana*	no Hawaiian name	PitAus
Pneumatopteris	*sandwicensis*	hōʻiʻo kula	PneSan
Polypodium	*pellucidum*	ʻae	PolPel
Polystichum	*haleakalense*	kāʻapeʻape	PolHal
Polystichum	*hillebrandii*	papaʻoi, kaʻupu	PolHil
Pseudophegopteris	*keraudreniana*	ʻiikolea, waimakanui, alaʻalai	PseKer
Psilotum	*complanatum*	moa, moa nahele, pipi	PsiCom
Psilotum	*nudum*	moa	PsiNud
Pteridium	*aquilinum*	kīlau, paiʻā	PteAquDec
Pteris	*cretica*	ʻowali	PteCre

Genus	Species	Hawaiian/Common Name	3X3 CODE
Pteris	*excelsa*	waimaka nui	PteExc
Pteris	*hillebrandii*	no Hawaiian name	PteHil
Pteris	*irregularis*	‘iwa puakea (Maui), mana, ‘āhewa (O‘ahu)	PteIrr
Sadleria	*cyatheoides*	‘ama‘u, ama‘uma‘u	SadCya
Sadleria	*pallida*	‘ama‘u ‘i‘i	SadPal
Sadleria	*souleyetiana*	‘ama‘uma‘u	SadSou
Selaginella	*arbuscula*	lepelepe a moa	SelArb
Sphaerocionium	*lanceolatum*	palai hinahina	SphLan
Sphenonmeris	*chinensis*	pala‘ā	SphChi
Vandenboschia	*davallioides*	kīlau	VanDav
Nonnative (weeds)			
Adiantum	*hispidulum*	Australian maidenhair	AdiHis
Adiantum	*raddianum*	maiden hair fern	AdiRad
Ageratina	*riparia*	spreading mist flower; hamakua pāmakani	AgeRip
Ageratum	*conyzoides*	maile-hohono	AgeCon
Agrostis	*stolonifera*	redtop, creeping bentgrass	AgrSto
Aleurites	*moluccana*	kukui, candlenut	AleMol
Andropogon	*virginicus*	broomsedge	AndVir
Anthoxanthum	*odoratum*	sweet vernalgrass	AntOdo
Asplenium	*nidus*	‘ēkaha, bird’s-nest fern	AspNid
Arthrostema	*ciliatum*	no common name	ArtCil
Axonopus	*fissifolius*	narrow-leaved carpetgrass	AxoFis
Begonia	*hirtella*	begonia	BegHir
Begonia	*reniformis*	grape-leaf begonia	BegRen
Blechnum	*occidentale*	occidental blechnum	BleOcc
Briza	*minor*	little quaking grass	BriMin
Buddleia	*asiatica*	butterfly bush, dog tail	BudAsi
Cardamine	*flexuosa*	bittercress	CarFle
Carex	*longii*	no common name	CarLon
Carica	*papaya*	papaya	CarPap
Castilleja	*arvensis*	field Indian paintbrush	CasArv
Centaurium	*erythraea*	bitter herb, European centaury	CenEryEry

Genus	Species	Hawaiian/Common Name	3X3 CODE
Centella	*asiatica*	Asiatic pennywort, pohe kula	CenAsi
Cerastium	*fontanum*	chickweed, hehine-hauli	CerFonTri
Cirsium	*vulgare*	bull-thistle	CirVul
Genus	*Species*	Common Name	3X3 CODE
Clidemia	*hirta*	Koster's curse	CliHirHir
Conyza	*bonariensis*	hairy horseweed	ConBon
Conyza	*canadensis*	Canada fleabane, lani wela	ConCanPus
Crassocephalum	*crepidioides*	no common name	CraCre
Cunninghamia	*lanceolata*	China fir, Chinese fir	CunLan
Cuphea	*carthagenensis*	tarweed	CupCar
Cupressus	*lanceolata*	cypress	CupLan
Cyclosorus	*parasiticus*	no common name	CycPar
Cyperus	*difformis*	sedge	CypDif
Cyperus	*haspan*	sedge	CypHas
Cyperus	*sanguinolentus*	no common name	CypSan
Cyrtomium	*falcatum*	holly fern	CyrFal
Delairea	*odorata*	German ivy	DelOdo
Desmodium	*incanum*	Spanish clover	DesInc
Desmodium	*sandwicense*	Spanish or chili clover	DesSan
Digitaria	*ciliaris*	Henry's crabgrass	DigCil
Digitaria	*eriantha*	pangola grass	DigEri
Dissotis	*rotundifolia*	no common name	DisRot
Drymaria	*cordata*	pipili	DryCorPac
Ehrharta	*stipoides*	meadow ricegrass	EhrSti
Epidendrum	*x obrienianum*	butterfly orchid	EpiXob
Epilobium	*billardierianum*	no common name	EpiBilCin
Eragrostis	*brownii*	sheepgrass	EraBro
Erechtites	*valerianifolia*	fireweed	EreVal
Euchiton	*sphaericus*	Japanese cudweed	EucSph
Euphorbia	*peplus*	petty spurge	EupPep
Falcataria	*moluccana*	no common name	FalMol
Flindersia	*brayleyana*	Queensland maple, silkwood	FliBra

Genus	Species	Hawaiian/Common Name	3X3 CODE
Fragaria	*vesca*	European, woodland, or sowteat strawberry	FraVes
Gamochaeta	*purpurea*	purple cudweed	GamPur
Geranium	*homeanum*	crane's bill	GerHom
Grevillea	*robusta*	silky oak	GreRob
Hedychium	*coronarium*	white ginger	HedCor
Hippobroma	*longiflora*	Star-of-Bethlehem	HipLon
Holcus	*lanatus*	velvetgrass, yorkshire fog	HolLan
Hydrocotyle	*bowlesioides*	marsh pennywort	HydBow
Hypericum	*mutilum*	St. John's wort	HypMutMut
Hypericum	*parvulum*	St. John's wort	HypPar
Hypnum	*plumiformis*	moss	HypPlu
Hypochoeris	*radicata*	gosmore, hairy cat's ear	HypRad
Hyptis	*pectinata*	comb hyptis	HypPec
Juncus	*effusus*	Japanese mat rush	JunEff
Juncus	*ensifolius*	rush	JunEns
Juncus	*planifolius*	rush	JunPla
Juncus	*tenuis*	path rush	JunTen
Kalanchoe	*pinnata*	air plant	KalPin
Kyllinga	*brevifolia*	kili'o'opu	KylBre
Kyllinga	*nemoralis*	kyllinga, kili'o'opu	KylNem
Lantana	*camara*	lantana, lākana	LanCam
Lepidium	*virginicum*	wild peppergrass	LepVir
Lotus	*subbiflorus*	no common name	LotSub
Lotus	*uliginosus*	no common name	LotUli
Ludwigia	*octovalvis*	primrose willow	LudOct
Ludwigia	*palustris*	marsh purslane	LudPal
Macroptilium	*atropurpureum*	no common name	MacAtr
Macrothelypteris	*torresiana*	no common name	MacTor
Malvastrum	*coromandelianum*	false mallow	MalCorCor
Mentha	*spicata*	spearmint	MenSpi
Mimosa	*pudica*	sensitive plant, sleeping grass	MimPudUni
Momordica	*charantia*	balsam pear	MomCha

Genus	Species	Hawaiian/Common Name	3X3 CODE
Nephrolepis	*multiflora*	scaly swordfern	NepMul
Oplismenus	*hirtellus*	basketgrass, honohono	OplHir
Oxalis	*corniculata*	yellow wood sorrel	OxaCor
Oxalis	*debilis*	pink wood sorrel	OxaDeb
Panicum	*maximum*	Guinea grass	PanMax
Paspalum	*conjugatum*	Hilo grass, mau‘u-hilo	PasCon
Paspalum	*dilatatum*	dallis grass	PasDil
Paspalum	*fimbriatum*	Panama or fimbriate paspalum, Columbia grass	PasFim
Paspalum	*urvillei*	Vasey grass	PasUrv
Passiflora	*edulis*	liliko‘i, passion fruit	PasEdu
Passiflora	*foetida*	love-in-a-mist, pohāpohā	PasFoe
Passiflora	*ligularis*	sweet granadilla	PasLig
Passiflora	*mollissima*	banana poka	PasMol
Pennisetum	*clandestinum*	kikuyu grass	PenCla
Persicaria	*capitata*	knotweed, smartweed	PerCap
Persicaria	*punctata*	water smartweed	PerPun
Phaius	*tankarvilleae*	Chinese ground orchid	PhaTan
Phlebodium	*aureum*	laua‘e haole	PhlAur
Physalis	*peruviana*	pohā, cape gooseberry	PhyPer
Pinus	*radiata*	monterey pine	PinRad
Pinus	*taeda*	loblolly pine	PinTae
Pityrogramma	*austroamericana*	gold fern	PitAus
Plantago	*australis*	dwarf plantain	PlaAusHir
Plantago	*major*	broad-leaved plantain	PlaMaj
Pluchea	*carolinensis*	sour bush	PluCar
Poa	*annua*	annual bluegrass	PoaAnn
Poa	*pratensis*	Kentucky bluegrass	PoaPra
Polygala	*paniculata*	milkwort	PolPan
Prunella	*vulgaris*	selfheal, heal-all	PruVul
Psidium	*cattleianum*	strawberry guava, waiwai	PsiCat
Psidium	*guajava*	guava, common guava, kuawa	PsiGua

Genus	Species	Hawaiian/Common Name	3X3 CODE
Ranunculus	*parviflorus*	buttercup	RanPar
Ranunculus	*plebeius*	common Australian buttercup	RanPle
Ranunculus	*repens*	creeping buttercup, butter daisy	RanRep
Ricinus	*communis*	castor bean	RicCom
Rubus	*argutus*	blackberry	RubArg
Rubus	*rosifolius*	thimbleberry	RubRos
Rumex	*acetosella*	sheep sorrel	RumAce
Rumex	*brownei*	slender dock	RumBro
Sacciolepis	*indica*	Glenwood grass	SacInd
Schinus	*terebinthifolius*	Christmas berry	SchTer
Schizachyrium	*condensatum*	beardgrass	SchCon
Senecio	*sylvaticus*	wood groundsel	SenSyl
Senna	*occidentalis*	coffee senna	SenOcc
Senna	*pendula*	kolomona, kalamona	SenPenAdv
Senna	*surattensis*	kolomona, kalamona	SenSur
Setaria	*palmifolia*	palmgrass	SetPal
Setaria	*parviflora*	perennial foxtail	SetPar
Sherardia	*arvensis*	spurwort	SheArv
Sida	*rhombifolia*	cuba jute	SidRho
Sisymbrium	*irio*	London rocket	SisIri
Sisyrinchium	*exile*	blue-eyed grass	SisExi
Solanum	*americanum*	glossy nightshade	SolAme
Sonchus	*oleraceus*	sow thistle	SonOle
Spathodea	*campanulata*	African tulip tree	SpaCam
Spermacoce	*assurgens*	buttonweed	SpeAss
Sporobolus	*africanus*	African dropseed	SpoAfr
Sporobolus	*indicus*	West Indian dropseed	SpoInd
Stachytarpheta	*australis*	oī, ōwī	StaAus
Stenotaphrum	*secundatum*	St. Augustine grass, buffalo grass	SteSec
Syzygium	*jambos*	rose apple	SyzJam
Tibouchina	*herbacea*	glorybush	TibHer
Toona	*ciliata*	Australian red cedar	TooCil

Genus	Species	Hawaiian/Common Name	3X3 CODE
Trifolium	*repens*	white clover	TriRepRep
Verbascum	*thapsus*	common mullein	VerTha
Veronica	*arvensis*	corn speedwell	VerArv
Veronica	*plebeia*	trailing or common speedwell	VerPle
Veronica	*serpyllifolia*	thyme-leaved speedwell	VerSer
Vulpia	*bromoides*	brome fescue	VulBro
Wahlenbergia	*gracilis*	no common name	WahGra
Youngia	*japonica*	oriental hawksbeard	YouJap
Zingiber	*zerumbet*	shampoo ginger, ‘awapuhi-kua hiwi	ZinZer

C = Candidate

E = Endangered

CH = Critical Habitat (at KFU)

SOC = Species of Concern

T = Threatened

Table A-3. Native Species for Repatriation at Kona Forest Unit.

3x3 Code	Genus	Species	Syn	Status	Intro	Repatriation	Augment	Not Recorded
AspFraIns	*Asplenium*	*fragile*		*E*			x	
BidCam	*Bidens*	*campylotheca*		*MIXD*				
CarWah	*Carex*	*wahuensis*		*MIXD*				
ChaOlo	*Chamaesyce*	*olowaluana*		*SOC*	*x*			
CleLin	*Clermontia*	*lindseyana*		*E*				
ClePyr	*Clermontia*	*pyrularia*		*E*				
CyaHamCar	*Cyanea*	*hamatiflora*		*E*				
CyaMar	*Cyanea*	*marksii*		*SOC*			x?	
CyaPla	*Cyanea*	*platyphylla*		*E*				
CyaSti	*Cyanea*	*stictophylla*		*E*			x?	
CyrMen	*Cyrtandra*	*menziesii*		*SOC*			x	
CysDou	*Cystopteris*	*douglasii*		*SOC*			x	
DieEre	*Diellia*	*erecta*		*E*		o?		
FluNeo	*Flueggea*	*neowawraea*		*E*		x, o?		
FraChiSan	*Fragaria*	*chiloensis*		*SOC*		x?		
HupMan	*Huperzia*	*mannii*	*Phlegmarius mannii*	*E*				o
MelHaw	*Melicope*	*hawaiensis*		*NS*		x, o		
NerOva	*Neraudia*	*ovata*		*E*		x, o		
NotBre	*Nothocestrum*	*breviflorum*		*E*		x, o		
PhyFlo	*Phyllostegia*	*floribunda*		*C*		o?		
PhySta	*Phyllostegia*	*stachyoides*		*SOC*		o		
PhyVel	*Phyllostegia*	*velutina*		*E*		o, x		
PhyVes	*Phyllostegia*	*vestita*		*R*				o
PhySan	*Phytolacca*	*sandwicensis*		*R*		o	x	
PleHaw	*Pleomele*	*hawaiiensis*		*NS*		x		o
PorScl	*Portulaca*	*sclerocarpa*		*E*				x
PriAff	*Pritchardia*	*affinis*		*E*				o
PriSch	*Pritchardia*	*schattaueri*		*E*		x, o		
RanHaw	*Ranunculus*	*hawaiensis*		*C*		o		

3x3 Code	Genus	Species	Syn	Status	Intro	Repatriation	Augment	Not Recorded
RanMau	*Ranunculus*	*mauiensis*		*C*		o		
RubMac	*Rubus*	*macraei*		*SOC*			x, o	
SanSan	*Sanicula*	*sandwicensis*		*SOC*		x	o?	
SicCuc	*Sicyos*	*cucumerinus*		*NS*				o?, x
SicMac	*Sicyos*	*macrophyllus*		*C*			x, o	
SilHaw	*Silene*	*hawaiiensis*		*T*				x
SisAcr	*Sisyrinchium*	*acre*		*SOC*			x	
SteMac	*Stenogyne*	*macrantha*		*SOC*			x, o?	
SteScr	*Stenogyne*	*scrophularioides*		*SOC*			o?	
StrPen	*Streblus*	*pendulinus*		*R*		o		
TreGra	*Trematolobelia*	*grandifolia*		*SOC*		o		
ZanDipDip	*Zanthoxylum*	*dipetalum*		*SOC*		x		

Legend

X = Keali‘i Bio, PEP Hawai‘i Island
O=Linda Pratt, USGS
Y = Jim Jacobi, USGS

C= Candidate E = Endangered T = Threatened
SOC = Species of Concern R = Rare NS = No Status

Table A-4. Hakalau and Kona Forest Unit NWR Priority Alien (Nonnative) Plants/Weeds.

The priority target species were selected on the basis of invasiveness at Hakalau Forest NWR and/or similar habitats in other parts of the State. Additional species are likely to be added to this list in the future.

Highest Priority

Rubus argutus (prickly Florida blackberry)*
Tibouchina herbacea (cane tibouchina)* +
Passiflora mollissima (banana poka)* +
Ulex europaeus (gorse)*
Ilex aquifolium (English holly)*
*Photenia davidiana**
Pennisetum clandestinum (kikuyu grass)* +
Miconia calvescens (velvet tree, bush currant)
Rubus ellipticus (Himalayan raspberry)
Myrica faya (firetree)
Pennisetum setaceum (fountain grass)

Intermediate Priority

Ehrharta stipoides (meadow ricegrass)* +
Psidium cattleianum (strawberry guava)* +
Psidium guajava (guava)+
Delairea odorata (German ivy)+ *
Clidemia hirta (Koster's curse)+
Juncus effuses (soft rush)*
Tibouchina urvilleana (glory-bush)
Schinus terebinthifolius (Christmas berry)+
Setaria palmifolia (palm grass)
Heychium gardenerianum (kahili ginger)
Spathodea campanulata (African tulip)
Cryptomeria japonica (sugi pine)*

Lower Priority

Verbascum thapsus (mullein)* +
Cirsium vulgare (bull thistle)*
Passiflora ligularis (sweet granadilla, grenadia)+
Andropogon virginicus (broom sedge)*

Below 2,000 ft abutting Kona Forest Unit - Invasive Species of concern

Albizia spp.
Syzygium jambos (rose apple)
Grevilla robusta (silky oak)

Legend
+ species known to occur on Kona Forest Unit
* species known to occur on Hakalau Forest Unit or within Piha State GMA

Table A-5. Animals (Both Native and Nonnative) Found at Hakalau Forest NWR.

Species	Common Name	Category	Found at Hakalau Forest Unit	Found at Kona Forest Unit
BIRDS				
Hemignathus munroi	ʻakiapōlāʻau	E	Y	Y
Loxops c. coccineus	Hawaiʻi ʻākepa	E	Y	Y
Oreomystis mana	Hawaiʻi creeper	E	Y	Y
Psittirostra psittacea	ʻōʻū	E	?	N
Hemignathus v. virens	Hawaiʻi ʻamakihi	En	Y	Y
Himatione sanguinea	ʻapapane	En	Y	Y
Vestiaria coccinea	ʻiʻiwi	En	Y	Y
Chasiempis sandwichensis	Hawaiʻi ʻelepaio	En	Y	Y
Myadestes obscurus	ʻōmaʻo	En	Y	N
Corvus hawaiiensis	ʻalalā	E	N	Y
Asio flammeus sandwichensis	pueo	En	Y	Y
Buteo solitarius	Hawaiian hawk, ʻio	E	Y	Y
Anas wyvilliana	Hawaiian duck, koloa maoli	E	Y	N
Branta sandvicensis	Hawaiian goose, nēnē	E	Y	N
Fulica alai	Hawaiian coot, ʻalae keʻokeʻo	E	Y	N
Carpodacus mexicanus	house finch	X	Y	Y
Lonchura punctulata	nutmeg mannikin	X	Y	Y
Passer domesticus	house sparrow	X	Y	Y
Padda oryzivora	Java sparrow			Y
Leiothrix lutea	red-billed leiothrix	X	Y	Y
Garrulax canorus	melodius laughing thrush	X	Y	Y
Acridotheres tristis	common myna	X	Y	Y
Zosterops japonicus	Japanese white-eye	X	Y	Y
Cettia diphone	Japanese bush-warbler	X	Y	Y
Cardinalis cardinalis	northern cardinal	X	Y	Y
Mimus polyglottos	northern mocking bird	X		Y
Lonchura malabarica	African silverbill	X	Y	?
Sicalis flabeola	saffron finch	X		Y
Alauda arvensis	skylark	X	Y	?
Meleagris gallopavo	turkey	X	Y	Y
Francolinus erckelii	Erckel's francolin	X	Y	Y
Callipepla californica	California quail	X	Y	?
Phasianus colchicus	ring-necked pheasant	X	Y	?

Species	Common Name	Category	Found at Hakalau Forest Unit	Found at Kona Forest Unit
Lophura leucomelana	kalij pheasant	X	Y	Y
Alectoris chukar	Chukar	X	Y	
Columba livia	rock dove	X	Y	
Geopelia striata	spotted dove	X	Y	Y
Strepteopelia chinensis	zebra dove	X		Y
Pluvialis squatarola	black-bellied plover	I		
Coturnix japonica	Japanese quail	X	Y	?
Serinus mozambicus	yellow fronted canary	X	Y	?
Pluvialis fulva	Pacific golden plover, kōlea	I	Y	?
Arenaria interpres	ruddy turnstone, ‘akekeke	I	Y	N
Calidris alba	sanderling, huna kai	I		
Gallinago stenura	pin-tailed snipe	I		
Tyto alba	barn owl	X	Y	Y
MAMMALS				
Lasiurus cinereus semotus	Hawaiian hoary bat, ‘ōpe‘ape‘a	E	Y	Y
Herpestes auropuntatus	Indian mongoose	X	Y	Y
Sus scrofa	pig	X	Y	Y
Bos taurus	cattle	X	Y	Y
Canis familiaris	dog	X	Y	Y
Felis catus	cat	X	Y	Y
Mus domesticus	house mouse	X	Y	Y
Rattus rattus	black rat	X	Y	Y
Rattus norvegicus	Norwegian rat	X	Y	Y
Rattus exulans	Polynesian rat	X	Y	Y
Ovis aries	sheep	X	N	Y
Ovis musimon	mouflon	X	N	Y
Capra hircus	goat	X	N	?
Equus caballus	horse	X	N	Y
Equus asinus	donkey	X	N	Y
INVERTEBRATES				
Table 4-5 in Chapter 4 also has a table listing additional arthropods occurring at both units				
Drosophila	picture-wing flies	E		Y (CH)
Coleotichus blackburniae	koa bug	En	Y	
Succinea cf. cepulla	mollusk	En	Y	
Tornatellides sp.	mollusk	En	Y	
Culex quinquefasciatus	southern house mosquito	X	Y	Y

Species	Common Name	Category	Found at Hakalau Forest Unit	Found at Kona Forest Unit
Vespula pensylvanica	western yellowjacket wasp	X	Y	Y
Sophonia rufofascia	two-spotted leafhopper	X		Y
Cardiocondyla wroughtoni	ant	X		Y
Paratrechina bourbonica	ant	X		Y
Solenopsis papuana	ant	X		Y
Tetramorium bicarinathum	ant	X		Y

Legend

En = Endemic
E = Endangered
X = Exotic (nonnative)
I = Indigenous

CH = Critical Habitat

Appendix B. Appropriate Uses and Compatibility Determinations

Appropriate Use Findings

Under the Appropriate Refuge Uses Policy, 603 FW 1 (2006), refuge managers are directed to determine if a new or existing public use is an appropriate refuge use. If an existing use is not appropriate, the refuge manager is directed to modify the use to make it appropriate or terminate it, as expeditiously as practicable. If a new use is not appropriate, the refuge manager will deny the use without determining compatibility. If a use is determined to be appropriate, then a compatibility determination should be developed to determine whether the use can be allowed. For purposes of this CCP an “appropriate use” must meet at least one of the following three conditions:

- The use is one of six wildlife-dependent recreational uses identified in the Improvement Act;
- The use involves the take of fish and wildlife under State/Territorial regulations; and
- The use has been found to be appropriate as specified in section 1.11 of the policy and documented on Service Form 3-2319.

During the CCP process the Refuge manager evaluated all existing and proposed nonpriority wildlife-dependent refuge uses at Hakalau Forest NWR using the following guidelines and criteria as outlined in the policy:

- Do we have jurisdiction over the use?
- Does the use comply with applicable laws and regulations (Federal, State, and local)?
- Is the use consistent with applicable Executive orders and Department and Service policies?
- Is the use consistent with public safety?
- Is the use consistent with goals and objectives in an approved management plan or other document?
- Has an earlier documented analysis not denied the use, or is this the first time the use has been proposed?
- Is the use manageable within available budget and staff?
- Will this be manageable in the future within existing resources?
- Does the use contribute to the public’s understanding and appreciation of the Refuge’s natural or cultural resources, or is the use beneficial to the Refuge’s natural or cultural resources?
- Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality, compatible, wildlife-dependent recreation into the future?

Using this process and these criteria, and as documented on the following pages, the Refuge manager determined the following refuge uses were appropriate, and directed that compatibility determinations be completed for each use.

Refuge Use – Hakalau Forest NWR	Appropriate
Commercial Photography, Video, Filming or Audio Recording	yes
Commercial Tour Operation/Conservation and Education Group Visits	yes
Research, Scientific Collecting, and Surveys	yes
University of Hawai‘i Field Station	yes

FINDING OF APPROPRIATENESS OF A REFUGE USE

Refuge Name: Hakalau Forest NWR

Use: Commercial Photography, Video, Filming or Audio Recording

This form is not required for wildlife-dependent recreational uses, take regulated by the State, or uses already described in a refuge CCP or step-down management plan approved after October 9, 1997.

Decision Criteria:	YES	NO
(a) Do we have jurisdiction over the use?	✓	
(b) Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?	✓	
(c) Is the use consistent with applicable Executive orders and Department and Service policies?	✓	
(d) Is the use consistent with public safety?	✓	
(e) Is the use consistent with goals and objectives in an approved management plan or other document?	✓	
(f) Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?	✓	
(g) Is the use manageable within available budget and staff?	✓	
(h) Will this be manageable in the future within existing resources?	✓	
(i) Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?	✓	
(j) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?	✓	

Where we do not have jurisdiction over the use ("no" to (a)), there is no need to evaluate it further as we cannot control the use. Uses that are illegal, inconsistent with existing policy, or unsafe ("no" to (b), (c), or (d)) may not be found appropriate. If the answer is "no" to any of the other questions above, we will **generally** not allow the use.

If indicated, the refuge manager has consulted with State fish and wildlife agencies. Yes ✓ No ___

When the refuge manager finds the use appropriate based on sound professional judgment, the refuge manager must justify the use in writing on an attached sheet and obtain the refuge supervisor's concurrence.

Based on an overall assessment of these factors, my summary conclusion is that the proposed use is:

Not Appropriate_____ **Appropriate** ✓

Refuge Manager: [signature] Date: 9/21/10

If found to be **Not Appropriate**, the refuge supervisor does not need to sign concurrence if the use is a new use.

If an existing use is found **Not Appropriate** outside the CCP process, the refuge supervisor must sign concurrence.

If found to be **Appropriate**, the refuge supervisor must sign concurrence.

Refuge Supervisor: [signature] Date: 9/21/10

A compatibility determination is required before the use may be allowed.

**FWS Form 3-2319
02/06**

Appropriate Uses Justification, Attachment 1

Date: September 21, 2010

Refuge: Hakalau Forest National Wildlife Refuge (NWR)

Project: Commercial Photography, Videography, Filming, or Audio Recording

Summary: The Refuge allows a small number of commercial photographers and videographers, on a case-by-case basis, access to Hakalau Forest NWR to obtain still images and video or film to support environmental education for the general public. Commercial photographers and videographers are regulated through Special Use Permitting and permit conditions that are strict and protective of resident wildlife and habitats. The benefit to the Refuge comes with the increased exposure to the public of images and film that may result in an increased appreciation for the rare species found on the Refuge. Credit must be given to the Service as the source for access to Hakalau Forest NWR as a permit condition, and further requirements for sharing images and digital film media obtained for Service educational purposes are included as permit conditions.

The State of Hawai‘i DLNR was invited on two occasions to participate on core planning teams, but declined due to insufficient staffing. However, as this Appropriate Use Justification does not propose a significant deviation from the status quo, and no comments on this topic were received from the State during the comment period, we believe additional coordination was not necessary.

For each of the findings listed on FWS Form 3-2319, a justification has been provided below:

a. Do we have jurisdiction over the use?

The permitted activities take place within Refuge boundaries in clearly specified limited areas. The Refuge has jurisdiction over those visits that are sited within Refuge boundaries.

b. Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?

All permitted activities comply with applicable laws and regulations and any restrictions or qualifications that are required to comply with law and regulations are specified in the SUP.

c. Is the use consistent with applicable Executive orders and Department and Service policies?

Through Refuge staff review and monitoring of the proposed activity, review of permittee proposals and letters of request on corporate letterheads, and a case-by-case review process, a limited capacity for commercial usage is maintained. The Refuge ensures that all visits are consistent with applicable policies through SUP conditions. No fees beyond permit application fees are presently charged.

d. Is the use consistent with public safety?

Through individual permit review, the Refuge will ensure that each permittee’s activities are consistent with public safety. If necessary, additional stipulations to ensure public safety will be included in the permittee’s SUP. Permittees will be provided clear information on Refuge boundaries to further ensure their safety and protect the property rights of neighboring landowners.

e. Is the use consistent with goals and objectives in an approved management plan or other document?

Requests to film or photograph in the Refuge are approved in instances where the expected products may contribute to public appreciation and support for Refuge resources and appreciation of natural resources in support of the Refuge System mission. Special Use Permit special conditions have been crafted to assure minimal to no impacts to Refuge resources.

f. Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?

This use has been requested and approved in the past and a documented analysis was conducted during the Compatibility Determination process.

g. Is the use manageable within available budget and staff?

The Refuge permits only a few visits per year for this activity and it is currently manageable with available budget and staff.

h. Will this be manageable in the future within existing resources?

The proposed activity at current threshold levels for use would be manageable in the future with existing staff resources (see above).

i. Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?

The proposed use is beneficial to the Refuge's natural and cultural resources because exposure of the general public to professionally produced images and film footage depicting resident wildlife and plant life in their natural protected environment should result in greater appreciation for Refuge purposes and our agency mission. Because most of the Refuge has not been opened to the public, dissemination of information by professional photographers and videographers is a positive outcome for the Refuge, and an acceptable trade off for limited access to a small number of commercial entities.

j. Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality, compatible, wildlife-dependent recreation into the future?

The Refuge will ensure that the commercial filming and photography activities will not impair existing or future wildlife-dependent recreational use of the Refuge through proper monitoring and oversight of permittees and review of their products.

FINDING OF APPROPRIATENESS OF A REFUGE USE

Refuge Name: Hakalau Forest NWR

Use: Commercial Tour Operation/Conservation and Education Group Visits

This form is not required for wildlife-dependent recreational uses, take regulated by the State, or uses already described in a refuge CCP or step-down management plan approved after October 9, 1997.

Decision Criteria:	YES	NO
(a) Do we have jurisdiction over the use?	✓	
(b) Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?	✓	
(c) Is the use consistent with applicable Executive orders and Department and Service policies?	✓	
(d) Is the use consistent with public safety?	✓	
(e) Is the use consistent with goals and objectives in an approved management plan or other document?	✓	
(f) Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?	✓	
(g) Is the use manageable within available budget and staff?	✓	
(h) Will this be manageable in the future within existing resources?	✓	
(i) Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?	✓	
(j) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?	✓	

Where we do not have jurisdiction over the use ("no" to (a)), there is no need to evaluate it further as we cannot control the use. Uses that are illegal, inconsistent with existing policy, or unsafe ("no" to (b), (c), or (d)) may not be found appropriate. If the answer is "no" to any of the other questions above, we will **generally** not allow the use.

If indicated, the refuge manager has consulted with State fish and wildlife agencies. Yes ✓ No ___

When the refuge manager finds the use appropriate based on sound professional judgment, the refuge manager must justify the use in writing on an attached sheet and obtain the refuge supervisor's concurrence.

Based on an overall assessment of these factors, my summary conclusion is that the proposed use is:

Not Appropriate_____ **Appropriate** ✓

Refuge Manager: [signature] Date: 9/21/10

If found to be **Not Appropriate**, the refuge supervisor does not need to sign concurrence if the use is a new use.

If an existing use is found **Not Appropriate** outside the CCP process, the refuge supervisor must sign concurrence.

If found to be **Appropriate**, the refuge supervisor must sign concurrence.

Refuge Supervisor: [signature] Date: 9/21/10

A compatibility determination is required before the use may be allowed.

FWS Form 3-2319
02/06

Appropriate Uses Justification, Attachment 1

Date: September 21, 2010

Refuge: Hakalau Forest National Wildlife Refuge (NWR)

Project: Commercial Tour Operation/Conservation and Education Group Visits

Summary: The Refuge operates in partnership with a small number of commercial tour operators to provide limited access and environmental education to the general public through guided tours on Refuge lands. Tour operators are regulated through Special Use Permitting and permit conditions protective of resident wildlife and habitats. The benefit to the Refuge comes with the access and educational experience made possible through collaboration with these operators. Refuge staffing levels are not sufficient to provide ongoing public education experiences with rare exceptions. Currently no fees are charged for this access.

The State of Hawai‘i DLNR was invited on two occasions to participate on core planning teams, but declined due to insufficient staffing. However, as this Appropriate Use Justification does not propose a significant deviation from the status quo, and no comments on this topic were received from the State during the comment period, we believe additional coordination was not necessary.

For each of the findings listed on FWS Form 3-2319, a justification has been provided below:

a. Do we have jurisdiction over the use?

The proposed activities would take place within Refuge boundaries in clearly specified limited areas. The Refuge has jurisdiction over those visits that are sited within Refuge boundaries.

b. Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?

All permitted activities comply with applicable laws and regulations and any restrictions or qualifications that are required to comply with law and regulations are specified in the SUP.

c. Is the use consistent with applicable Executive orders and Department and Service policies?

Through staff monitoring of the proposed program, review of permittee reports, and a predetermined annual carrying capacity for visitors, the Refuge would ensure that they are consistent with applicable policies.

d. Is the use consistent with public safety?

Through individual permit review, the Refuge will ensure that each guide’s activities are consistent with public safety. If necessary, additional stipulations to ensure public safety will be included in the permitte’s SUP. Permittees will be provided clear information on Refuge boundaries to further ensure their safety and protect the property rights of neighboring landowners.

e. Is the use consistent with goals and objectives in an approved management plan or other document?

Public use activities are approved in instances where they can provide meaningful experiences that contribute to public support for Refuge management and public appreciation of natural resources. This activity will help the Refuge meet its objectives in goal seven. Special Use Permit special conditions have been crafted to assure minimal to no impacts to Refuge resources.

f. Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?

This use has been requested and approved in the past and a documented analysis was conducted during the Compatibility Determination process.

g. Is the use manageable within available budget and staff?

The Refuge permits a maximum of 12 SUPs at 100 visitors per year for this activity and it is currently manageable with available budget and staff.

h. Will this be manageable in the future within existing resources?

The proposed activity at current threshold levels for use would be manageable in the future with existing staff resources (see above).

i. Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?

The proposed use is beneficial to the Refuge's natural and cultural resources because enhanced exposure with trained, experienced guides results in greater appreciation for Refuge purposes and our agency mission by contributing to public understanding and appreciation of natural and/or cultural resources.

j. Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?

The Refuge will ensure that the guided commercial activities will not impair existing or future wildlife-dependent recreational use of the Refuge during ongoing annual permit reviews, prior to issuing a SUP for subsequent years.

FINDING OF APPROPRIATENESS OF A REFUGE USE

Refuge Name: Hakalau Forest NWR

Use: Research, Scientific Collecting, and Surveys

This form is not required for wildlife-dependent recreational uses, take regulated by the State, or uses already described in a refuge CCP or step-down management plan approved after October 9, 1997.

Decision Criteria:	YES	NO
(a) Do we have jurisdiction over the use?	✓	
(b) Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?	✓	
(c) Is the use consistent with applicable Executive orders and Department and Service policies?	✓	
(d) Is the use consistent with public safety?	✓	
(e) Is the use consistent with goals and objectives in an approved management plan or other document?	✓	
(f) Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?	✓	
(g) Is the use manageable within available budget and staff?	✓	
(h) Will this be manageable in the future within existing resources?	✓	
(i) Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?	✓	
(j) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?	✓	

Where we do not have jurisdiction over the use ("no" to (a)), there is no need to evaluate it further as we cannot control the use. Uses that are illegal, inconsistent with existing policy, or unsafe ("no" to (b), (c), or (d)) may not be found appropriate. If the answer is "no" to any of the other questions above, we will **generally** not allow the use.

If indicated, the refuge manager has consulted with State fish and wildlife agencies. Yes ✓ No ___

When the refuge manager finds the use appropriate based on sound professional judgment, the refuge manager must justify the use in writing on an attached sheet and obtain the refuge supervisor's concurrence.

Based on an overall assessment of these factors, my summary conclusion is that the proposed use is:

Not Appropriate_____ **Appropriate** ✓

Refuge Manager: [signature] Date: 9/21/10

If found to be **Not Appropriate**, the refuge supervisor does not need to sign concurrence if the use is a new use.

If an existing use is found **Not Appropriate** outside the CCP process, the refuge supervisor must sign concurrence.

If found to be **Appropriate**, the refuge supervisor must sign concurrence.

Refuge Supervisor: [signature] Date: 9/21/10

A compatibility determination is required before the use may be allowed.

**FWS Form 3-2319
02/06**

Appropriate Uses Justification, Attachment 1

Date: September 21, 2010

Refuge: Hakalau Forest National Wildlife Refuge (NWR)

Project: Research, Scientific Collecting, and Surveys[1]

Summary: The Service defines these uses as:
- Research: Planned, organized, and systematic investigation of a scientific nature;
- Scientific collecting: Gathering of refuge natural resources or cultural artifacts for scientific purposes; and
- Surveys: Scientific inventory or monitoring.

The types of research vary greatly but could revolve around birds, bats, plants, insects/pollinators, invasive species, habitat classification, restoration techniques, and cultural and historic resources. The State of Hawai‘i DLNR was invited on two occasions to participate on core planning teams, but declined due to insufficient staffing. However, as this Appropriate Use Justification does not propose a significant deviation from the status quo, and no comments on this topic were received from the State during the comment period, we believe additional coordination was not necessary.

For each of the findings listed on FWS Form 3-2319, a justification has been provided below:

a. Do we have jurisdiction over the use?

The proposed activities would take place within Refuge boundaries in clearly specified limited areas. The Refuge has jurisdiction over those visits that are sited within Refuge boundaries.

b. Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?

All permitted activities comply with applicable laws and regulations and any restrictions or qualifications that are required to comply with law and regulations are specified in the SUP.

c. Is the use consistent with applicable Executive orders and Department and Service policies?

Through staff monitoring of the proposed program and review of permittee reports, the Refuge would ensure that they are consistent with applicable policies.

d. Is the use consistent with public safety?

Through individual permit review, the Refuge will ensure that each researcher’s activities are consistent with public safety. If necessary, additional stipulations to ensure public safety will be included in the permitte’s SUP. Permittees will be provided clear information on Refuge boundaries to further ensure their safety and protect the property rights of neighboring landowners.

[1] This does not apply to Refuge management activities conducted by the Refuge System, including the surveys identified in this CCP’s strategies.

e. Is the use consistent with goals and objectives in an approved management plan or other document?

The primary goals of the Refuge are to (a) support recovery and perpetuation of federally listed endangered and threatened plants and animals and prevent the listing of additional species, (b) restore and protect high-quality habitat for native plants and animals occurring on the slopes of Mauna Kea and Mauna Loa, (c) control nonnative pests and predators including ungulates and noxious weeds, (d) provide wildlife-dependent cultural, educational and recreational opportunities for the public, and (e) in partnership with public and private organizations, increase awareness of and appreciation for the Refuge and the Hawaiian ecosystem. The Refuge believes that appropriate, compatible research activities will contribute to, and are essential to accomplishing, the enhancement, protection, conservation, and management of native wildlife populations and their habitats on the Refuge.

f. Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?

This use has been requested and approved in the past and a documented analysis was conducted during the Compatibility Determination process.

g. Is the use manageable within available budget and staff?

The Refuge permits an average of 10 SUPs for this activity (research) each year and this level is currently manageable with available budget and staff.

h. Will this be manageable in the future within existing resources?

The proposed activity at current threshold levels for use would be manageable in the future with existing staff resources (see above).

i. Does the use contribute to the public's understanding and appreciation of the Refuge's natural or cultural resources, or is the use beneficial to the Refuge's natural or cultural resources?

The Service believes that wildlife and habitat conservation and management on the Refuge should be based upon statistically viable scientific research combined with long-term monitoring. The information gained through appropriate, compatible research on Refuge lands will be beneficial to the Refuge's natural resources through application of this information into adaptive management strategies. The Refuge will also distribute any information gained to the public, which will allow them to better understand and appreciate the Refuge resources and the need for protecting them.

j. Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?

The Refuge will ensure that the research activities will not impair existing or future wildlife-dependent recreational use of the Refuge during ongoing annual permit reviews, prior to issuing a SUP for subsequent years.

FINDING OF APPROPRIATENESS OF A REFUGE USE

Refuge Name: Hakalau Forest NWR

Use: University of Hawai`i Field Station

This form is not required for wildlife-dependent recreational uses, take regulated by the State, or uses already described in a refuge CCP or step-down management plan approved after October 9, 1997.

Decision Criteria:	**YES**	**NO**
(a) Do we have jurisdiction over the use?	✓	
(b) Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?	✓	
(c) Is the use consistent with applicable Executive orders and Department and Service policies?	✓	
(d) Is the use consistent with public safety?	✓	
(e) Is the use consistent with goals and objectives in an approved management plan or other document?	✓	
(f) Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?	✓	
(g) Is the use manageable within available budget and staff?	✓	
(h) Will this be manageable in the future within existing resources?	✓	
(i) Does the use contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or is the use beneficial to the refuge's natural or cultural resources?	✓	
(j) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?	✓	

Where we do not have jurisdiction over the use ("no" to (a)), there is no need to evaluate it further as we cannot control the use. Uses that are illegal, inconsistent with existing policy, or unsafe ("no" to (b), (c), or (d)) may not be found appropriate. If the answer is "no" to any of the other questions above, we will **generally** not allow the use.

If indicated, the refuge manager has consulted with State fish and wildlife agencies. Yes ✓ No ___

When the refuge manager finds the use appropriate based on sound professional judgment, the refuge manager must justify the use in writing on an attached sheet and obtain the refuge supervisor's concurrence.

Based on an overall assessment of these factors, my summary conclusion is that the proposed use is:

Not Appropriate_____ **Appropriate** ✓

Refuge Manager: James O. Watts Date: 9/21/10

If found to be **Not Appropriate**, the refuge supervisor does not need to sign concurrence if the use is a new use.

If an existing use is found **Not Appropriate** outside the CCP process, the refuge supervisor must sign concurrence.

If found to be **Appropriate**, the refuge supervisor must sign concurrence.

Refuge Supervisor: Barry W. Stieglitz Date: 9/21/10

A compatibility determination is required before the use may be allowed.

**FWS Form 3-2319
02/06**

Appropriate Uses Justification, Attachment 1

Date: September 21, 2010

Refuge: Hakalau Forest National Wildlife Refuge (NWR)

Project: University of Hawaiʻi Field Station

Summary: The UH operates a biological field station located on the Hakalau Forest NWR Administrative Site. Operation of the field station is described in a Memorandum of Agreement (MOA), dated October 29, 1985 (Contract No. 14-48-0001-95500) between the Service and UH. The field station is used to house and support UH faculty, students, and visiting scientists conducting research supporting the conservation and restoration of native species and habitats at Hakalau Forest NWR.

The State of Hawaiʻi DLNR was invited on two occasions to participate on core planning teams, but declined due to insufficient staffing. However, as this Appropriate Use Justification does not propose a significant deviation from the status quo, and no comments on this topic were received from the State during the comment period, we believe additional coordination was not necessary.

For each of the findings listed on FWS Form 3-2319, a justification has been provided below:

a. Do we have jurisdiction over the use?

The proposed activities would take place within Refuge boundaries in clearly specified limited areas. The Refuge has jurisdiction over those visits that are sited within Refuge boundaries.

b. Does the use comply with applicable laws and regulations (Federal, State, tribal, and local)?

All permitted activities comply with applicable laws and regulations and any restrictions or qualifications that are required to comply with law and regulations are specified in the SUP.

c. Is the use consistent with applicable Executive orders and Department and Service policies?

Through staff monitoring of the proposed program and review of permittee reports, the Refuge would ensure that they are consistent with applicable policies.

d. Is the use consistent with public safety?

Through individual permit review, the Refuge will ensure that activities are consistent with public safety. If necessary, additional stipulations to ensure public safety will be included in the permittee’s SUP. Permittees will be provided clear information on Refuge boundaries to further ensure their safety and protect the property rights of neighboring landowners.

e. Is the use consistent with goals and objectives in an approved management plan or other document?

The primary goals of the Refuge are to (a) support recovery and perpetuation of federally listed endangered and threatened plants and animals; and prevent the listing of additional species, (b) restore and protect high quality habitat for native plants and animals occurring on the slopes of Mauna Kea and Mauna Loa, (c) control nonnative pests and predators including ungulates and noxious weeds, (d) provide wildlife-dependent cultural, educational, and recreational opportunities for the public, and (e) in partnership with public and private organizations, increase awareness of and appreciation for the Refuge and the Hawaiian ecosystem. The Refuge believes that the University of Hawaiʻi Field Station is appropriate and compatible with the Refuge goals. The research activities will contribute to and are essential to accomplishing the enhancement, protection, conservation, and management of native wildlife populations and their habitats on the Refuge.

f. Has an earlier documented analysis not denied the use or is this the first time the use has been proposed?

This use has been requested and approved in the past and a documented analysis was conducted during the Compatibility Determination process.

g. Is the use manageable within available budget and staff?

The use is currently manageable with available budget and staff.

h. Will this be manageable in the future within existing resources?

The proposed activity at current threshold levels for use would be manageable in the future with existing staff resources.

i. Does the use contribute to the public's understanding and appreciation of the Refuge's natural or cultural resources, or is the use beneficial to the Refuge's natural or cultural resources?

The Service believes that wildlife and habitat conservation and management on the Refuge should be based upon statistically viable scientific research combined with long-term monitoring. The information gained through appropriate, compatible research on Refuge lands will be beneficial to the Refuge's natural resources through application of this information into adaptive management strategies. The University of Hawaiʻi Field Station provides a suitable base to conduct research that will contribute to the public's understanding and appreciation of the Refuge's natural or cultural resources. The Refuge will also distribute any information gained to the public, which will allow them to better understand and appreciate the Refuge resources and the need for protecting them.

j. Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D, 603 FW 1, for description), compatible, wildlife-dependent recreation into the future?

The Refuge will ensure that the research activities conducted from the Research Station will not impair existing or future wildlife-dependent recreational use of the Refuge during ongoing annual Memorandum of Agreement (MOA) reviews, prior to issuing a SUP for research activities.

Compatibility Determinations

The Compatibility Determinations (CDs) developed during the CCP planning process evaluate uses as projected to occur under the CCP for Hakalau Forest NWR. The evaluation of funds needed for management and implementation of each use also assumes implementation as described in the CCP.

A. Uses Evaluated at this Time

The following section includes full CDs for all Refuge uses that are required to be evaluated at this time. According to Service policy, CDs will be completed for all uses proposed under a CCP. Existing wildlife-dependent recreational uses must also be re-evaluated and new CDs prepared during development of a CCP. According to the Service's compatibility policy, uses other than wildlife-dependent recreational uses are not explicitly required to be re-evaluated in concert with preparation of a CCP, unless conditions of the use have changed or unless significant new information relative to the use and its effects have become available or the existing CDs are more than 10 years old. However, the Service planning policy recommends preparing CDs for all individual uses, specific use programs, or groups of related uses associated with the proposed action. Accordingly, the following CDs are included in this document:

Refuge Use	Compatible	Year Due for Re-evaluation
Public Recreational Hunting	no	N/A
Wildlife Observation and Photography	yes	2025
Commercial Photography, Videography, Filming or Audio Recording	yes	2020
Commercial Tour Operation/Conservation and Education Group Visits	yes	2020
Research, Scientific Collecting, and Surveys	yes	2020
University of Hawai‘i Field Station	yes	2020

B. Compatibility - Legal and Historical Context

Compatibility is a tool refuge managers use to ensure that recreational and other uses do not interfere with wildlife conservation, the primary focus of refuges. Compatibility is not new to the Refuge System and dates back to 1918 as a concept. As policy, it has been used since 1962. The Refuge Recreation Act of 1962 directed the Secretary of the Interior to allow only those public uses of refuge lands that were "compatible with the primary purposes for which the area was established."

Legally, refuges are closed to all public uses until officially opened through a CD. Regulations require that adequate funds be available for administration and protection of refuges before opening them to any public uses. However, wildlife-dependent recreational uses (hunting, fishing, wildlife observation and photography, and environmental education and interpretation) are to receive enhanced consideration and cannot be rejected simply for lack of funding resources unless the refuge has made a concerted effort to seek out funds from all potential partners. Once found compatible, wildlife-dependent recreational uses are deemed the priority public uses at the refuge. If a proposed use is found not compatible, the refuge manager is legally precluded from approving it. Economic uses that are conducted by or authorized by the refuge also require CDs.

Under compatibility policy, uses are defined as recreational, economic/commercial, or management use of a refuge by the public or a non-Refuge System entity. Uses generally providing an economic return (even if conducted for the purposes of habitat management) are also subject to CDs. The Service does not prepare CDs for uses when the Service does not have jurisdiction. For example, the Service may have limited jurisdiction over refuge areas where property rights are vested by others, where legally binding agreements exist, or where there are treaty rights held by tribes. In addition, aircraft overflights, emergency actions, some activities on navigable waters, and activities by other Federal agencies on "overlay refuges" are exempt from the compatibility review process.

New compatibility regulations, required by the Improvement Act, were adopted by the Service in October 2000 (*http://Refuges.fws.gov/policymakers/nwrpolicies.html*). The regulations require that a use must be compatible with both the Refuge System mission and the purpose(s) of the individual refuge. This standard helps to ensure consistency in application across the Refuge System. The Act also requires that CDs be in writing and that the public have an opportunity to comment on most use evaluations.

The Refuge System mission emphasizes that the needs of fish, wildlife, and plants must be of primary consideration. The Improvement Act defined a compatible use as one that ". . .in the sound professional judgment of the Director, will not materially interfere with or detract from the fulfillment of the mission of the System or the purposes of the Refuge." Sound professional judgment is defined under the Improvement Act as ". . .a finding, determination, or decision, that is consistent with principles of sound fish and wildlife management and administration, available science and resources. . ." Compatibility for priority wildlife-dependent uses may depend on the level or extent of a use.

Court interpretations of the compatibility standard have found that compatibility is a biological standard and cannot be used to balance or weigh economic, political, or recreational interests against the primary purpose(s) of the refuge.

The Service recognizes that CDs are complex. For this reason, refuge managers are required to consider "principles of sound fish and wildlife management" and "best available science" in making these determinations. Evaluations of the existing uses at Hakalau Forest NWR are based on the professional judgment of refuge and planning personnel including observations of refuge uses and reviews of appropriate scientific literature.

Use: Public Recreational Hunting

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (the Service) to manage each refuge to fulfill the Refuge System mission, to maintain and, where appropriate, restore the refuge’s ecological integrity, and achieve the specific purpose(s) for which the refuge was established.

Hakalau Forest Unit

The purpose of Hakalau Forest NWR is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA).

Kona Forest Unit

The purpose of Kona Forest Unit is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA). More specifically, the unit was established to provide habitat for the ‘alalā and to assist the ‘Alalā Recovery Program’s repatriation efforts.

National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

Hakalau Forest NWR reviewed and evaluated the compatibility of the public recreational hunting program. The Maulua tract of Hakalau Forest NWR was opened to the public for pig hunting under a Sport Hunting Plan approved February 14, 1991. The 2,000 acre Maulua Tract of Hakalau Forest NWR was opened to the public on February 1, 1992. Hunters were allowed to take pigs on State holidays and during the first three weekends of each month. For safety reasons, the maximum number of reservations accepted for any hunt day was 12. State game mammal hunting regulations applied, with the exception that there was no limit on the number of pigs that could be taken. Dogs were not permitted in Maulua Tract. Access for hunting was provided by reservation only through gates along Keanokolu Road.

On July 1, 1993, the Sport Hunting Plan, was modified to allow pig hunters to access the lower portion of the Lower Maulua Tract. Hunters could access the lower Maulua Tract through either the Pīhā State Game Management Area (Hilo Forest Reserve) or the Laupāhoehoe State Natural Area Reserve. Dogs could be used and the bag limit for each hunter was two pigs. No reservations were required.

On November 18, 1995, with the completion of a fence around the 2,000 acre Upper Maulua Tract of Hakalau Forest NWR, the Service allowed pig hunters to use dogs.

The Upper Maulua Tract was closed to public hunting in 2000 as the pig population was reduced to low numbers that did not provide an acceptable public hunting experience.

Hunting was previously considered useful as an initial means to begin reduction of ungulate numbers. This was seen as a step toward the ultimate goal of ungulate eradication and habitat restoration. The levels of hunting use, based on 6 consecutive years of public hunting in the upper Maulua Unit, averaged 80 hunter days per year. Access to Middle and Lower Maulua units for public hunting was permitted through State lands (east boundary) on June 17, 1993, with no administrative controls (reservations, law enforcement patrols, etc.) required; therefore, no data is available.

Over time, the desired management effect was achieved on eight ungulate management units. Portions of the Refuge, including areas where populations of rare birds and plants are highest, are closed to the public. No requests for approval to hunt on Hakalau Forest NWR have occurred since 2000.

Public recreational hunting for games birds was never allowed at the Refuge since the flight path of the endangered nēnē and wild turkey (game bird) overlap.

The Kona Forest Unit has never been opened to the public.

Availability of Resources:

Current staffing levels do not allow for administration and oversight of a public hunting program at the Refuge. Management of a quality public recreation hunt program at Hakalau Forest NWR would require full-time law enforcement staff oversight, with regular law enforcement presence on the Refuge to ensure a safe, quality program that does not adversely impact sensitive plant and animal species and to prevent user conflicts. In addition, the purpose of the Refuge is in direct conflict with keeping ungulate numbers at a level that would provide a quality public recreation hunt program.

Anticipated Impacts of the Use(s):

Recreational public pig hunting would likely have significant adverse effects on endangered, threatened, and rare species and their habitats. Hakalau Forest NWR contains habitat for 25 plant species that are either federally endangered, species of concern, or rare. Endangered plants were first outplanted in the Upper Maulua Tract of Hakalau Forest NWR in 2005, and the effort continues. To date, totals of each species planted are:

- Endangered lobeliads:
  - *Cyanea shipmanii* – 543;
  - *Clermontia pyrularia* – 1,931;
  - *Clermontia lindseyana* – 350;
- Endangered mints:
  - *Phyllostegia racemosa* – 878;
  - *Phyllostegia velutina* – 60; and
  - *Phyllostegia brevidens* – 74.

The grand total of all endangered plants outplanted in the Upper Maulua Tract is 3,836.

Subsequent use of the Upper Maulua Tract for outplanting of endangered plants and nonconsumptive public uses such as wildlife photography and observation have increased over time. The Refuge is home to eight federally endangered bird species, one endangered mammal species, and 16 threatened and endangered plant species. Due to the removal of cattle and pigs from the Upper Maulua Tract, the forest bird habitat has recovered with the reestablishment of the forest understory. Recent forest bird surveys have indicated a population increase of common and endangered forest birds. The Refuge and the State also reintroduced nēnē to Hakalau Forest NWR in January 1995 with the construction of a predator-proof enclosure fence and the release of five breeding pairs. The nēnē have expanded to approximately 60 adults and juvenile birds that utilize the upper areas of the Refuge including the Upper Maulua Tract.

Unlike other public use opportunities, such as wildlife photography and bird watching which occur on identified roads and on a path to keep people from negatively impacting Refuge resources, hunting is not an activity that has similar infrastructure in place to protect resources and guide the user. Hunting is a pursuit of a wild animal that can go anywhere and the hunter follows. This unguided pathway through Refuge habitats could inadvertently impact native vegetation and restoration efforts as well as disturb habitat for native species.

Additional concerns about impact to Refuge resources are the inadvertent spread of nonnative weed species through Refuge habitats. Given the many other hunting opportunities on the rest of the island, it is unknown what invasive plant species seeds or other reproductive plant mediums may be attached to clothing or equipment. Since the Refuge is adjacent to a state game management area, hunters and their dogs pass through low elevation forest areas that contain high density nonnative plant populations. The potential for dispersal of invasive weeds and their subsequent spread and establishment within remote sites is a concern. The cost of controlling invasive weeds in remote areas is high. It is easier to prevent the establishment of nonnative plants than control them after the fact. Enforcement of endangered plant protection, hunting regulations, and Refuge integrated pest management (IPM) weed prevention programs is not possible without Refuge law enforcement personnel.

In addition to the impacts identified, recreational public hunting will not meet the needs of the Refuge's ungulate control program in reducing and eradicating ungulates as ungulate numbers decrease. Pigs are one of the major threats to listed species as well as native habitats. The Refuge goal is total eradication of pigs in fenced units where pigs are controlled. This goal does not support pig populations at levels that would provide recreational public hunting.

The Refuge determined that criteria used in previous compatibility statements and in the 1991 Sport Hunting Decision Document were not enforceable, and circumstances on the ground have changed.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. Comments were received related to public hunting and were addressed in Appendix K.

Determination:

__X_ Use is Not Compatible

_____ Use is Compatible

Stipulations Necessary to Ensure Compatibility: Not applicable.

Justification:

The Service proposes to re-close the Refuge to public recreational hunting because it is not compatible with the purposes and goals of the Refuge. Public recreational hunting will not meet the goals of the Refuge's ungulate control program. Reduction and ultimately eradication of ungulates is necessary to achieve the required level of protection and eliminate disturbance to native species. The highest priority Refuge goal of protecting endangered species and their habitats is being realized as habitat improvements are made and native species diversity is gradually restored. Recreational hunting is unlikely to achieve the desired goal of reducing pig populations in managed units by >70% annually, in order to assure control objectives are achieved where more efficient methods are available (Hess et al.2006). Failure to maintain the highest level of pressure on pig populations and selective removal of larger pigs could result in population increases through ingress by additional pigs that use smaller territories and reproductive response in the pig population.

The Middle and Lower Maulua Tracts are remote and have no established routes of access from off-refuge areas. The boundaries remain unmarked and unfenced. Levels of use by hunters, proper access, invasive plant introduction and dispersal, and the impacts of recreational public hunting within the remote areas of the Refuge would be difficult to monitor or regulate. Enforcement of endangered plant protection, hunting regulations, and Refuge IPM weed prevention programs would not occur within remote areas of the Refuge.

Mandatory 10- or 15-year Reevaluation Date:

___________ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

___________ Mandatory 10-year reevaluation date (for non wildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X_ Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

References Cited:

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U.S. Fish and Wildlife Service, 1996, Hakalau Forest NWR, Feral Ungulate Management Plan.

Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

James G. Kraus 9/24/10
(Signature) (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

Barry W. Stieglitz 9/24/10
(Signature) (Date)

Regional Chief
National Wildlife Refuge System

Carolyn A. Bohan 9/28/10
(Signature) (Date)

Use: Wildlife Observation and Photography

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (Service) to manage each refuge to fulfill the Refuge System mission, to maintain and, where appropriate, restore the refuge's ecological integrity, and achieve the specific purpose(s) for which the refuge was established.

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National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

The Improvement Act defined wildlife observation and photography as wildlife-dependent public uses. In that Act, Congress directed that such uses shall be given special consideration in planning for and management of the Refuge System when compatible. When determined compatible on a refuge-specific basis, these uses are priority general public uses of that national wildlife refuge.

Self-guided wildlife observation and photography activities by the general public take place only in the Upper Maulua Unit of the Refuge. The forested habitat in this area consists of an open and closed koa/‘ōhi‘a tree canopy with native subcanopy and a ground cover of scattered native shrubs, ferns, and nonnative grasses. Limited numbers of endangered birds and plants inhabit this tract compared to other Refuge tracts, although outplantings of several hundred endangered plants in the past several years provide unique opportunities to view these plants. Impacts to rare plants will be minimal in comparison to the disturbance caused to the understory and ground cover by more than 150 years of cattle grazing and pig rooting. The relatively small number of endangered birds found in this area have likely become somewhat acclimated to the presence of humans since the Upper Maulua Unit has been open to public use for 23 years.

Reservations are required for public wildlife observation/photography on the Upper Maulua Unit in order to coordinate such visits with Refuge management activities. A brochure describing the Refuge and listing permitted and prohibited activities, along with a map of the Upper Maulua Unit, is distributed via e-mail or mail to reservation holders prior to their visit. This brochure is also available at the Refuge Office in Hilo. Access to the Upper Maulua Unit is permitted on Saturdays, Sundays, and holidays between sunrise and sunset. The main gate must be closed and locked after entry and exit. Visitors are required to provide their telephone number, the number of people in their group, license plate number, and vehicle description.

Visitation to the Upper Maulua Unit varies from year to year with total visitors ranging from 200-500 people. Drought conditions periodically require closure of the area, and depending on the severity and duration of dry weather, may greatly influence cumulative visitation numbers.

Visitors to other Refuge tracts such as Pua ʻĀkala will continue to be guided and managed through the SUP process in order to minimize disturbance to sensitive wildlife and their habitats. A limit of 1,200 visitors per year, visiting for a few hours of bird watching under SUPs for guided tours, has long been established for this area and has not been reached to date.

Wildlife viewing and observation is the primary visitor activity at Hakalau Forest NWR. This use, if compatible, becomes a priority general public use, and, therefore, receives consideration in Refuge planning and management.

Quality wildlife observation is defined by the following elements: (1) opportunities exist to view wildlife in their habitat and in a natural setting; (2) observation opportunities promote public understanding of Hakalau Forest NWR resources and its role in managing and protecting those resources; (3) observations occur in places with the least amount of disturbance to wildlife; (4) facilities are safe, fully accessible, and available to a broad spectrum of the public; (5) viewing opportunities are tied to interpretive and educational opportunities; and (6) observers have minimal conflict with other visitors or Refuge operations (*http://www.fws.gov/policy/605fw4.html*).

Information about conservation of natural resources and habitat restoration will be shared with the visitors to educate and reduce the impact visitors have on the Refuge. The assistance of the Friends of Hakalau Forest NWR, a nonprofit support organization for the Refuge, is expected to increase over time with special emphasis on public use and environmental education and interpretation issues.

Opportunities for enhanced wildlife observation and photography are limited at the Upper Maulua Unit, but will increase through the development and maintenance of trails and parking area. Wildlife viewing opportunities may be provided for more members of the general public in the future. The 1.2 million tourists who visit Hawaiʻi Island annually generally visit far more easily accessible places. The Kona Forest Unit has never been opened to the public.

Availability of Resources:

The Refuge has sufficient staff time and other resources to allow this use at the current levels. Currently the Refuge has a Deputy Refuge Manager to administer and monitor the activities, and a Maintenance Supervisor and crew of two maintenance workers to maintain public facilities and access points.

Category and Itemization	One-time ($)	Annual ($/yr)
Administration and Management	No fees charged	$7,600

The above annual cost reflects the cost to manage the program and prevent impacts to natural resources. Estimated costs were calculated using 2 percent of the base cost of a GS-12 Deputy Refuge Manager, 1 percent of the GS-13 Refuge Manager, 2 percent of the GS-12 Wildlife Biologist, 2 percent of the GS-9 Administrative, and 2 percent of the WS-4 Maintenance Supervisor's staff time, the "portion of the year" each position would use to administer and coordinate wildlife observation and photography activities on the Refuge.

Anticipated Impacts of the Use(s):

The Refuge wildlife-dependent uses being evaluated (wildlife observation and photography) will impose minimal negative impacts on specific physical resources such as trails and on natural resources such as wildlife and vegetation.

Wildlife Observation:

Physical and habitat alteration: The impact of these activities depends upon the size of the group (typically a single car or SUV at one time in Upper Maulua), the season of use, the location within the Upper Maulua Unit and the duration of the activity. The construction and maintenance of visitor use facilities (i.e., trail, parking lot) would have some effect on soils, vegetation, and possibly hydrology in specific areas. This could potentially increase erosion and cause localized soil compaction (Liddle 1975), reduced seed emergence (Cole and Landres1995), alteration of vegetative structure and composition, and sediment loading (Cole and Marion 1988).

Human disturbance - general: The presence of people observing or photographing wildlife will also cause some impact to wildlife. Numerous studies have confirmed that people on foot can cause a variety of disturbance reactions in wildlife, including flushing or displacement (Erwin 1989; Fraser et al. 1985; Freddy 1986), heart rate increases (MacArthur et al. 1982), altered foraging patterns (Burger and Gochfeld, 1991), and even, in some cases, diminished reproductive success (Boyle and Samson 1985). These studies and others have shown that the severity of the effects depends upon the distance to the disturbance and its duration, frequency, predictability, and visibility to wildlife (Knight and Cole 1991). The variables found to have the greatest influence on wildlife behavior are (a) the distance from the animal to the disturbance and (b) the duration of the disturbance. Animals show greater flight response to humans moving unpredictably than to humans following a distinct path (Gabrielsen and Smith 1995). Short-term and immediate responses to disturbance are fairly simple to document. A question that has received less research attention is whether these short-term responses, which generally require increased energetic expenditures on the part of the individual, ultimately diminish an individual or population's capacity to survive and breed successfully (fitness).

Energetic demands of responding to disturbance events were measured by Belanger and Bedard. In Quebec, they found that if disturbance was severe enough to cause geese to fly and not resume feeding upon alighting, hourly energy expenditure increased by 3.4 percent; and hourly metabolized energy intake decreased by 2.9 - 19.4 percent. A 32 percent increase in nighttime feeding was required to restore the energy losses incurred.

Effect of disturbance intensity: Some researchers have attempted to correlate disturbance events in wildlife to the intensity, proximity, or loudness of human disturbance. Burger, studying shorebirds on an eastern coastal refuge, found that the level of disturbance in the shorebirds increased (fewer remained, more flew) as the total number of disturbances and the number of children, joggers, people walking, dogs, aircraft, and boats increased, and the duration of the disturbance and distance from the disturbance decreased.

Effect of human proximity: Other researchers have looked at the question of proximity. At what distance do humans on foot elicit a disturbance response? From an examination of the available studies, it appears that the distance varies dramatically from species to species. Burger and Gochfeld (1991) found that sanderlings foraged less during the day and more during the night as the number of people within 109 yards increased. Elk in Yellowstone National Park were disturbed when people were at average distances of 626 yards (Cassirer, 1990). These elk temporarily left the drainage and their home range core areas and moved to higher elevations, steeper slopes, and closer to forested areas. Average return time to the drainage was 2 days. Erwin studied colonial wading and seabirds in Virginia and North Carolina. Mixed colonies of common terns-black skimmers responded at the greatest distances, with respective means of 155 and 142 yards; mixed wading bird species were more reluctant to flush (33-55 yards average). There were few statistically significant relationships between flushing distance and colony size. Similarly, there were few differences between responses during incubation compared to post-hatching periods.

An analysis of over 4,000 human activity events near bald eagle nests in Central Arizona (Grubb and King 1991) found distance to disturbance to be the most important classifier of bald eagle response, followed in decreasing order of discriminatory value by duration of disturbance, visibility, number of units per event, position relative to affected eagle, and sound.

Breeding bald eagles in north-central Minnesota (Fraser et al. 1985) flushed at an average distance of 520 yards at the approach of a pedestrian. A multiple regression model including number of previous disturbances and date and time of day explained 82 percent of the variability in flush distance and predicted a maximum flush distance at the first disturbance of 550 yards (SE=131). Skagen (1980), also studying bald eagles in northwest Washington, found a statistically significant decrease in the proportion of eagles feeding when human activity was present within 200 yards of the feeding area in the previous 30 minutes. A statistically significant between-season variation occurred in the use of feeding areas relative to human presence, which correlated with food availability. Eagles appeared more tolerant of human activity in the season of low food availability.

In a review of several studies of the reaction of waterfowl and other wetland birds to people on foot, distances greater than 109 yards in general did not result in a behavioral response (DeLong 2002).

Wildlife Photography:

Wildlife photography is likely more disturbing, per instance, than wildlife observation. Klein (1993) observed at Ding Darling NWR, that of all the nonconsumptive uses, photographers were the most likely to attempt close contact with birds, and that even slow approach by photographers disrupted waterbirds.

Dwyer and Tanner (1992) noted that wildlife habituate best to disturbance that is somewhat predictable or "background." Investigating 111 nests of sandhill cranes in Florida, Dwyer and Tanner found that nesting cranes seemed to habituate to certain forms of human disturbance and nested within 436 yards of highways, railroads, and mines; cranes also were tolerant of helicopter flyovers. Even so, investigator visits to nests and development-induced alterations of surface water drainage were implicated in 24 percent of the nest failures.

Minor impacts to wildlife, plants, and habitat would occur on the Refuge in the form of disturbance. Movement and behavior patterns could be altered by the presence of visitors. Some trampling of vegetation could occur as visitors stray to the edges of trails and access roads.

Use of the Hakalau Forest NWR increases the potential for introductions of nonnative species and interactions (some negative) by visitors with sensitive endangered bird and/or plant habitats. Accidental introduction of a nonnative plant species could be detrimental to the rainforest environment.

A number of nonnative plant and wildlife species occur on Hakalau Forest NWR in general, and many of those (e.g., pigs, mongooses, rats, numerous invasive plants and insects) have become established on the Refuge. Refuge personnel strive to eliminate or reduce pest species. It is possible that invasive plants and animals could be transported onto the Refuge in vehicles or from seeds that are trapped in clothing or vehicle wheels. Protocols for prevention of introducing invasive weeds are supplied to all SUP holders and to visitors requesting access to Maulua.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. Comments were received related to opportunities for wildlife observation and photography and addressed in Appendix K.

Determination:

___ Use is Not Compatible

_X_ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

Wildlife observation and photography may only occur in the Upper Maulua Unit area that has been opened to the public. The two Refuge Managers, the Refuge Wildlife Biologist, and the Refuge Maintenance Crew Leader and maintenance staff administer and monitor the activities of visiting public.

User stipulations:

- Visitors will be required to access Upper Maulua Unit only at designated access points/areas, thus reducing potential for wildlife disturbance and establishment of illegal trails;
- Visitors will be required to stay on legally established trails thus limiting the amount of area on the Refuge where impacts may take place;
- Use is restricted to daylight hours; and
- Visitors will be required to follow protocols in order to avoid introductions of nonnative species (e.g., cleaning mud and seeds from boots, gear, and vehicles before entering the Upper Maulua Unit).

Administrative stipulations:

- Directional, informational, and interpretive signs will be posted and maintained to help keep visitors on trails and help educate the public on minimizing wildlife and habitat disturbance;
- Monitoring by Refuge staff, volunteers, and partners. Refuge staff will monitor impacts to wildlife, vegetation, and soil and employ adaptive management when needed. Management responses may include such actions as developing additional instructional guidance in brochures or signs, designating parking areas, passing lanes on roads, limiting vehicle access to the upper road by gating, etc.;
- Promote the "Leave No Trace" philosophy. At least 95 percent of the Refuge will be managed as wildlife sanctuary, free from routine disturbance.

Additionally, the following activities are prohibited:

- Hunting;
- Use or possession of domestic animals;
- Use or possession of alcoholic beverages or illegal drugs;
- Operation of all terrain vehicles, dirt bikes, and mountain bikes, etc.;
- Removal or damage to any plant or plant material;
- Harassment of forest birds or other wildlife;
- Littering or dumping trash;
- Removal or damage to numbered tags, colored flagging tape, mist nets, and other equipment or materials used for biological research;
- Disposal of lighted smoking materials;
- Open fires;
- Overnight parking and camping; and
- Damage to fences, signs, or other structures.

Justification:

Individuals and groups are able to spend time outdoors and provide the Service an opportunity to expose the general population to the Refuge System, habitat management, and the impacts of invasive species on the native ecosystem. Hakalau Forest NWR provides a unique opportunity in this regard because of the limited amount of high-elevation native forest and endangered bird habitats remaining in the Hawaiian Islands. Public support for the Refuge could be improved through grassroots outreach to the public. Offering opportunities for wildlife observation and photography presents a wildlife conservation message to members of the public who are not likely to be reached by other means. In addition, allowing these activities supports the "connecting people with nature" initiative within the Service. When determined compatible on a refuge-specific basis, wildlife observation and photography are priority public uses of that national wildlife refuge. As endangered species recovery activities increase, it may be necessary to limit this activity and/or reevaluate for compatibility.

The combination of limiting visiting days/hours, properly maintaining visitor access points, allowing visitors to access only certain areas of the Refuge, and monitoring visitor use and behavior allows the Refuge to minimize any adverse effects associated with Refuge visitation. Given the scale of the activity, the stipulations outlined above, as well as the best management practices identified above, potential impacts relative to wildlife/human interactions are expected to be minimal.

By applying the stipulations described above, it is anticipated that wildlife populations will find sufficient food resources, nesting, and resting refugia such that their abundance and use of the Refuge will not be measurably decreased by wildlife observation and photography activities. The relatively limited number of individuals expected to be adversely affected due to wildlife observation and photography will not cause wildlife populations to materially decline; the physiological condition and production of native bird, plant, and bat species will not be impaired; their behavior and normal activity patterns will not be altered dramatically; and their overall welfare will not be negatively impacted. The opportunity to engage in several priority public uses provided would outweigh any anticipated negative impacts associated with implementation of the program. Thus, allowing wildlife observation and photography to occur with stipulations will not materially detract or interfere with the purposes for which the Refuge was established or the Refuge System mission. The stipulations included herein would allow such uses to occur in a compatible manner.

Mandatory 10- or 15-year Reevaluation Date:

_____X_____ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

____________ Mandatory 10-year reevaluation date (for non-wildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X_Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

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Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

(Signature) 9/24/10 (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

(Signature) 9/24/10 (Date)

Regional Chief
National Wildlife Refuge System

(Signature) 9/28/10 (Date)

Use: Commercial Photography, Videography, Filming, or Audio Recording

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (Service) to manage each refuge to fulfill the Refuge System mission, to maintain and, where appropriate, restore the refuge’s ecological integrity, and achieve the specific purpose(s) for which the refuge was established.

Hakalau Forest Unit

The purpose of Hakalau Forest NWR is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA).

Kona Forest Unit

The purpose of Kona Forest Unit is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA). More specifically, the unit was established to provide habitat for the ‘alalā and to assist the ‘Alalā Recovery Program’s repatriation efforts.

National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

Commercial photography, video, filming, and audio recording (“recording”) are considered in this compatibility determination. This use has occurred at Hakalau Forest NWR for almost 20 years, and future requests are expected to increase. Commercial recording activities not related to natural, historic, or cultural subjects are not covered under this compatibility determination. The Refuge has averaged 2-4 permits for this use annually during the last 5 years. The use typically involves creating a documentary film, taking still photographs, or recording wildlife sounds for commercial purposes. For example, the permittee may wish to take photographs of endangered forest birds or rare plants most easily seen at the Refuge. Afterwards, the permittee would attempt to sell the photos to a publication. Commercial photographers, journalists, and film crews may wish to visit Hakalau Forest NWR to take stills or movies for use in a wide variety of publications, documentaries, newscasts, exhibitions, or other presentations. Some of the products will be available to the Refuge for use in brochures, PowerPoint presentations, orientation movies, and other interpretive and educational purposes. Special use permits will be issued to cover these types of activities.

Much of the Refuge, including areas with the highest populations of rare birds and plants, is not open to the public. The photos, films, artwork, narratives, and recordings resulting from permitted activities will enable the general public to vicariously view and experience Hakalau Forest NWR's rare and imperiled wildlife and plant resources and learn about research and management activities. These products will also serve as tools for environmental education and cultivate support for Refuge programs and conservation actions.

Photography, video, filming, or audio recording of a noncommercial nature are addressed under a separate compatibility determination (wildlife observation and photography). This compatibility determination does not apply to bona fide news media activities.

Commercial photography, video, filming, or audio recording may be conducted only on lands within our jurisdiction. Although applications for this activity may be for any time of year, time restrictions may be required to limit disturbance. This may include such specifications as time of day and seasonal restrictions. Specific conditions have been developed by the Refuge to minimize or avoid impacts to Refuge resources and are listed in "Stipulations Necessary to Ensure Compatibility" in this document.

In order to ensure there are no negative impacts to Refuge resources, the applicant will be required to obtain a Special Use Permit from the Refuge, which is reviewed and signed by the Refuge Manager. Additionally, when conducting actual onsite operations, the applicant could be accompanied or contacted by Refuge personnel to ensure compliance with the permit conditions and prevent any unforeseen negative impacts to Refuge resources.

Availability of Resources:

At present, Hakalau Forest NWR can only accommodate one or two commercial video, filming, or audio recording operations per month. If the number of applicants begins to increase, additional staffing would be required. The Refuge requires the permittee to offset any cost incurred by the Refuge by payment of a one-time permit fee of $150.00.

Category and Itemization	**One-time ($)**	**Annual ($/yr)**
Administration and Management	$150/permittee	$4,000

The above annual cost reflects the cost to manage the program and prevent impacts to natural resources. Estimated costs were calculated using 1 percent of the base cost of a GS-12 Deputy Refuge Manager, 1 percent of the GS-13 Refuge Manager, 1 percent of the GS-12 Wildlife Biologist, and 1 percent of the GS-9 Administrative staff, the estimated portion of the year that this activity would require to administer this use. The one-time administration and monitoring cost reflects the approximate cost per commercial photography, video, filming, or audio recording operation incurred by the Refuge, and the offsetting cost reflects the reimbursement provided by the permittee. The user fees are designed to be equal to the Refuge-incurred cost (costs to administer the use, including any costs associated with facilities, equipment, supplies) and would come to the Refuge in the form of monies paid by the commercial photographers.

Anticipated Impacts of the Use(s):

The area in which most photojournalistic and/or filming activities will occur at Hakalau Forest NWR is forested and characterized by moderately closed canopy stands of ‘ōhi‘a and koa trees with a subcanopy of native trees and bushes. Ground cover consists of nonnative grasses and some native shrubs and ferns. Much of the understory and ground cover has been disturbed by more than 100 years of cattle grazing and pig rooting.

To the extent possible, permittees will confine their activities to existing roads, natural clearings, and trails. Foot traffic will compact or crush a small amount of native vegetation, but the impact will be minimal when compared to the damage done by pigs or cattle. Birds being photographed are unlikely to be negatively impacted if the conditions of the permit are followed; however, even with the proper management and execution of a well-planned project, certain behavioral responses in avifauna may occur that are not easily recognized by the casual observer. Stress reactions (elevated heart rate, elevated corticosterone levels, and behavioral responses) have been documented in several species of birds as a result of human activities in nesting areas. However, studies have not been conducted to document long-term cumulative effects of human-caused disturbances. Limited duration disturbance, however, has only minor, short-term effects. It is important to note that even wildlife photography by professionals can cause disturbance, depending upon the manner in which it is pursued.

Although a single commercial filming, photography, video, or audio recording visit for 1 day may cause few, if any, negative resource impacts, it may in fact cause cumulative impacts over a longer span of time when considered additively with all activity on the Refuge. Therefore, it is critical for the Refuge Manager to examine all permit proposals with a multiyear timeframe in mind and consider all activities that are planned concurrently on the Refuge before approval is granted. It may be appropriate to set a limit to the number of commercial photography, filming, video, or recording visits occurring in a particular habitat or relative to a single species or species group, even if personnel are available to coordinate the projects. Some proposed activities will require further analysis and compliance by the Refuge as more detailed information becomes available. These requirements may include additional analysis in accordance with NEPA and consultation under ESA.

A number of nonnative plant and wildlife species occur on Hakalau Forest NWR in general, and many of those (e.g., pigs, mongooses, rats, numerous invasive plants and insects) have become established on the Refuge. Refuge personnel strive to eliminate or reduce pest species. It is possible that invasive plants and animals could be transported onto the Refuge in vehicles or from seeds that are trapped in clothing or vehicle wheels. Adhering to appropriate protocols should reduce the risk of introducing nonnative species.

Overall, however, allowing well-designed and properly reviewed commercial filming, photography, video, or audio recording visits is likely to have very little impact on Refuge wildlife populations. If the visit is conducted with professionalism and integrity, potential adverse impacts are likely to be outweighed by the knowledge gained about an entire species, habitat, or public use.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. No public comment was received on this compatibility determination.

Determination:

___ Use is Not Compatible

_X_ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

Special Use Permits (SUP) will be issued for all photography, filming, video, or audio recording activities conducted by non-Service personnel. The SUP will list the conditions that the Refuge Manager determines to be necessary to ensure compatibility. Any permit may be terminated at any time for noncompliance with the SUP conditions, or modified, redesigned, relocated or terminated, upon a determination by the Refuge Manager that the activity is causing unanticipated adverse impacts to wildlife, wildlife habitat, approved priority public uses, or other Refuge management activities. Care will be taken to minimize the impacts of permitted photography, filming, video, or audio recording activities on native birds, plants, and habitat to ensure compatibility. One of the special conditions attached to each permit will state that activities may not be conducted in a manner that modifies the natural behavior of the birds being filmed or photographed. Activities will cease immediately if the subject shows signs of disturbance and/or stress, and the permittee must vacate the vicinity. Special conditions to protect the habitat will also be incorporated. These include taking precautions to prevent the introduction of nonnative plants and insects to the Refuge. Vehicles, boots, clothing, and equipment must be cleaned and inspected for seeds, eggs, and larvae prior to entry to the Refuge. Cutting or clearing vegetation is not permitted. Temporary blinds must be approved by the Refuge Manager and removed after use. Refuge gates must be secured at all times to prevent ungulate entry. Other conditions prohibit fires, require the removal of all trash, and restrict activities to existing roads, trails, and natural clearings to minimize adverse impacts to native vegetation.

Permittees will be required to provide the Refuge with at least one free copy of all commercial products generated on the Refuge for noncommercial use promoting the Hakalau Forest NWR and the Refuge System.

All commercial films, books, and other recordings of images and sounds collected on the Refuge are required to reference the fact they were collected at Hakalau Forest NWR under the administration of the U.S. Fish and Wildlife Service.

Justification:

Allowing commercial photography, video, filming, or audio recording as an economic use would contribute to the achievement of the Refuge purpose and the Refuge System mission. The products may reach groups of people who would not normally know about the Refuge. The services provided by commercial filmmakers and photographers are beneficial to expand public appreciation for and understanding of unique wildlife, diverse native habitats, management programs, and the mission of the Refuge System.

Because each SUP will contain specific conditions for minimizing adverse effects to Refuge resources while the commercial activity is being conducted, it is anticipated that wildlife populations will find sufficient food resources and resting places such that their abundance and use of the Refuge will not be measurably lessened from these activities. The relatively limited number of individuals expected to be adversely affected from these activities will not cause wildlife populations to materially decline, the physiological condition and production of native wildlife species will not be impaired, their behavior and normal activity patterns will not be altered dramatically, and their overall welfare will not be negatively impacted. In light of the benefits these uses are expected to have in expanding public appreciation for and understanding of Hakalau Forest NWR's unique wildlife, diverse native habitats, management programs, and the mission of the Refuge System, allowing commercial photography, filming, video, or audio recording activities to occur with stipulations will contribute to the purposes for which the Refuge was established and the Refuge System mission.

Mandatory 10- or 15-year Reevaluation Date:

_____________Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

____X_ _____ Mandatory 10-year reevaluation date (for nonwildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X_ Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

References Cited:

U.S. Fish and Wildlife Service. 1985. Refuge Manual. Washington, D.C.: U.S. Government Printing Office.

U.S. Fish and Wildlife Service. 2009. Compatibility determination for commercial photography, videography, filming, or audio recording, Hawaiian Islands National Wildlife Refuge.

Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

(Signature) 9/24/10 (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

(Signature) 9/24/10 (Date)

Regional Chief
National Wildlife Refuge System

(Signature) 9/28/10 (Date)

Use: Commercial Tour Operation/Conservation and Education Group Visits

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (Service) to manage each refuge to fulfill the Refuge System mission, to maintain and where appropriate, restore the refuge’s ecological integrity; and achieve the specific purpose(s) for which the refuge was established.

Hakalau Forest Unit

The purpose of Hakalau Forest NWR is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA).

Kona Forest Unit

The purpose of Kona Forest Unit is “... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ...” 16 U.S.C. Sec. 1534 (ESA). More specifically, the unit was established to provide habitat for the ‘alalā and to assist the ‘Alalā Recovery Program’s repatriation efforts.

National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

Entry requests from the general public are increasing as more people learn about the Refuge and the resources it protects. Due to staffing and funding limitations, the risk of adverse impacts to endangered species and their habitats prevents the Refuge from offering unlimited access to everyone. Visitor safety and the potential for visitor interference with management programs and research projects must also be considered. The entry of a limited number of small groups, led by competent and conscientious people familiar with Refuge objectives and programs, will minimize the risk of adverse impacts. Guided visits will provide significant environmental education for participants as well as further knowledge of and appreciation for the Refuge System.

A maximum of 12 SUPs allowing 100 individual person visits will be issued during a calendar year to commercial tour operators and conservation and education groups to permit entry to the upper Pua ʻĀkala and Hakalau Forest Unit tracts to observe common and endangered native forest birds, plants, and rainforest habitats. A maximum of six visits may occur under any one permit. The maximum group size will be 25 individuals. Specific conditions would be developed by the Refuge to minimize or avoid impacts to Refuge resources and are listed in "Stipulations Necessary to Ensure Compatibility" in this document.

The permittee is required to provide a list of the number of visits and individuals when requesting permission to access the Refuge. The permittee will submit a monthly written report with the total number of visits and individuals.

Visitors associated with volunteer activities, the annual Open House, Refuge inspections, and other official visits will continue to enter the Refuge without requiring issuance of a SUP. The Refuge Manager will limit these visits to minimize the risk of adverse impacts on wildlife and habitat.

The proposed action will provide limited access to portions of the Refuge (Pua ʻĀkala and HFU tracts) which are not open to the general public and have relatively high populations of endangered birds, specifically ʻakiapōlāʻau, Hawaiʻi ʻākepa, and Hawaiʻi creeper. These endangered birds are seldom seen within the Upper Maulua Tract, which is open to the public every weekend.

The Kona Forest Unit has never been opened to the public.

Availability of Resources:

At present, Hakalau Forest NWR can only accommodate 12 tour group permits per year. If the number of applicants begins to increase, additional staffing would be required. The Refuge requires the permittee to offset any cost incurred by the Refuge by payment of a one-time permit fee of $150.00.

Category and Itemization	One-time ($)	Annual ($/yr)
Administration and Management	$150/permit issued	$9,200

The above annual cost reflects the cost to manage the program and prevent impacts to natural resources. Estimated costs were calculated using 3 percent of the base cost of a GS-12 Deputy Refuge Manager, 2 percent of the GS-13 Refuge Manager, 2 percent of the GS-12 Wildlife Biologist, 3 percent of the GS-9 Administrative, and 1 percent of the Maintenance Supervisor's staff time, based on the assumption that this activity would use that portion of their year to administer and coordinate commercial tour, conservation, and education group tours.

The one-time administration and monitoring cost reflects the approximate cost per tour group operation incurred by the Refuge and the offsetting cost reflects the reimbursement provided by the permittee. The user fees are designed to be equal to the Refuge-incurred cost (costs to administer the use, including any costs associated with facilities, equipment, supplies) and would come to the Refuge in the form of monies paid by the commercial photographers.

Anticipated Impacts of the Use(s):

The area in which most commercial guided tours and noncommercial education group activities will occur at Hakalau Forest NWR is forested, and characterized by moderately closed to closed-canopy stands of ‘ōhi‘a and koa trees, with a subcanopy of native trees and bushes. Ground cover consists of nonnative grasses and some native shrubs and ferns. Much of the understory and ground cover has been disturbed by more than 100 years of cattle grazing and pig rooting.

To the extent possible, permittees will confine their activities to existing roads, natural clearings, and trails. Foot traffic will compact or crush a small amount of native vegetation, but the impact will be minimal when compared to the damage done by pigs or cattle. Birds being observed by tour groups are unlikely to be negatively impacted if the conditions of the permit are followed; however, even with the proper management and execution of a well-planned project, certain behavioral responses in avifauna may occur that are not easily recognized by the casual observer. Stress reactions (elevated heart rate, elevated corticosterone levels, and behavioral responses) have been documented in several species of birds as a result of human activities in nesting areas. However, studies have not been conducted to document long-term cumulative effects of human-caused disturbances. Limited duration disturbance, however, has only minor, short-term effects. It is important to note that even wildlife observation conducted by professionals can cause disturbance, depending upon the manner in which it is pursued.

Although a single commercial or noncommercial conservation group visit for 1 day may cause few, if any, negative resource impacts, it may cause cumulative impacts over a longer span of time when considered additively with all activity on the Refuge. Therefore, it is critical for the Refuge Manager to examine all permit proposals with a multiyear timeframe in mind and consider all activities that are planned concurrently on the Refuge before approval is granted. It may be appropriate to periodically reevaluate the number of visits occurring in a particular habitat or relative to a single species or species group, even if personnel are available to coordinate and monitor the tours. Specialized proposed activities will require further analysis and compliance by the Refuge as more detailed information becomes available. These requirements may include additional analysis in accordance with NEPA and consultation under ESA.

A number of nonnative plant and wildlife species occur on Hakalau Forest NWR in general, and many of those (e.g., pigs, mongooses, rats, numerous invasive plants and insects) have become established on the Refuge. Refuge personnel strive to eliminate or reduce pest species. It is possible that invasive plants and animals could be transported onto the Refuge in vehicles or from seeds that are trapped in clothing or vehicle wheels. Adhering to appropriate protocols should reduce the risk of introducing nonnative species.

Overall, however, allowing well-designed and properly reviewed commercial tours and noncommercial conservation/education group visits is unlikely to have significant impacts on Refuge wildlife populations. If visits are conducted with professionalism and integrity, potential adverse impacts are likely to be outweighed by the knowledge gained about the Refuge’s programs, protected species, and habitats.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. Comments were received related to commercial tour operations, and conservation and education group visits, and are addressed in Appendix K.

Determination:

___ Use is Not Compatible

_X_ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

Special Use Permits (SUP) will be issued for all commercial and noncommercial conservation and education group tour activities conducted by non-Service personnel. The SUP will list the conditions that the Refuge Manager determines to be necessary to ensure compatibility. Any permit may be terminated at any time for noncompliance with the SUP conditions, or modified, redesigned, relocated or terminated upon a determination by the Refuge Manager that the activity is causing unanticipated adverse impacts to wildlife, wildlife habitat, approved priority public uses, or other Refuge management activities.

Care will be taken to minimize the impacts of permitted commercial and noncommercial tour activities on native birds, plants, and habitat to ensure compatibility. Tour group leaders will provide a 5-10 minute environmental education talk to each tour group. The talk will include information relative to establishment and management of the Refuge, endangered forest birds, and protection and management of the native plants and animals. One of the special conditions attached to each permit states that activities may not be conducted in a manner that modifies the natural behavior of the birds being viewed. Activities will cease immediately if the subject shows signs of disturbance and/or stress, and the permittee must vacate the vicinity. The handling or harassment of birds or their nests is strictly prohibited. Special conditions to protect the habitat are incorporated. These include taking precautions to prevent the introduction of nonnative plants and insects to the refuge. Vehicles, boots, clothing, and equipment must be cleaned and inspected for seeds, eggs, and larvae prior to entry to the Refuge. Cutting or clearing vegetation is not permitted. Other conditions prohibit fires and require the removal of all trash and refuse resulting from his/her activities.

Justification:

Hakalau Forest NWR provides unique educational opportunities to highlight the conservation and management of Hawaiian forest birds and their habitats unmatched elsewhere. Compatible tours promote environmental education and interpretation, which are priority public uses of the Refuge System as identified in the Improvement Act.

Allowing limited numbers of closely monitored guided tours for educational purposes should have indirect positive impacts on Refuge resources. Supporting environmental education services and programs that strive to convey an understanding and appreciation of wildlife resources, the issues affecting them, and the techniques and programs pursued to restore them supports the goals of Hakalau Forest NWR. The services provided by commercial tour guides are beneficial to expand public appreciation for and understanding of unique wildlife, diverse native habitats, management programs, and the mission of the Refuge System.

Because each SUP will contain specific permit conditions for minimizing adverse effects to Refuge resources while the commercial activity is being conducted, it is anticipated that wildlife populations will find sufficient food resources and resting places such that their abundance and use of the Refuge will not be measurably lessened from these activities. The relatively limited number of individuals expected to be adversely affected from these activities will not cause wildlife populations to materially decline, the physiological condition and production of native wildlife species will not be impaired, their behavior and normal activity patterns will not be altered dramatically, and their overall welfare will not be negatively impacted. In light of the benefits the use is expected to having in expanding public appreciation for and understanding of Hakalau Forest NWR's unique wildlife, diverse native habitats, management programs, and the mission of the Refuge System, allowing commercial tours and noncommercial conservation and education group visits to occur with stipulations will contribute to the purpose(s) for which the Refuge was established or the Refuge System mission.

Mandatory 10- or 15-year Reevaluation Date:

___________ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

_____X_____ Mandatory 10-year reevaluation date (for nonwildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

References Cited:

U.S. Fish and Wildlife Service. 1985. Refuge Manual. Washington, D.C.: U.S. Government Printing Office.

U.S. Fish and Wildlife Service. 2009. Compatibility determination for commercial photography, videography, filming, or audio recording, Hawaiian Islands National Wildlife Refuge.

U.S. Fish and Wildlife Service. 2003. Addendum No. 1, Compatibility Determination No: COMPAT-03-94, Special Use Permit, Commercial Tour Operations, Conservation and Education Groups.

Boyle, S.A. and Samson, F.B. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildl. Soc. Bull. 13: 110-116.

Cole, D. N. and P. B. Landres. 1995. Indirect effects of recreation on wildlife. Pages 183-201 in R.L. Knight and K. J. Gutzwiller, ed. Wildlife and Recreationists: coexistence through management and research Island Press, Washington, D.C. 372pp.

Knight, R. L. and D. N. Cole. 1991. Effects of recreational activity on wildlife in wildlands, In Transactions of the North American Wildlife and Natural Resources Conference. 56:238-247.

Liddle, M.J. 1975. A selective review of the ecological effects on human trampling on natural ecosystems. Biol. Conserv. 7:17-36.

Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

(Signature) 9/24/10 (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

(Signature) 9/24/10 (Date)

Regional Chief
National Wildlife Refuge System

(Signature) 9/28/10 (Date)

Use: Research, Scientific Collecting, and Surveys

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (Service) to manage each refuge to fulfill the Refuge System mission, to maintain and where appropriate, restore the refuge's ecological integrity; and achieve the specific purpose(s) for which the refuge was established.

Hakalau Forest Unit

The purpose of Hakalau Forest NWR is "... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ..." 16 U.S.C. Sec. 1534 (ESA).

Kona Forest Unit

The purpose of Kona Forest Unit is "... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ..." 16 U.S.C. Sec. 1534 (ESA). More specifically, the unit was established to provide habitat for the ‘alalā and to assist the ‘Alalā Recovery Program's repatriation efforts.

National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

When determined appropriate and compatible on a refuge-specific basis, research, scientific collecting, and surveys (research) are allowable uses and are conducted on Refuge lands and waters by independent researchers, partnering agencies, and educational groups.

The Service defines these uses as:
- Research: Planned, organized, and systematic investigation of a scientific nature;
- Scientific collecting: Gathering of refuge natural resources or cultural artifacts for scientific purposes; and

- Surveys: Scientific inventory or monitoring.

The types of research vary greatly but could revolve around birds, bats, plants, insects/pollinators, invasive species, habitat classification, restoration techniques, and cultural and historic resources.

Research proposals may be for any time of the year and on any of the habitat types within Hakalau Forest NWR. However, the Refuge may limit the time and location of research projects to ensure that negative impacts to Refuge resources are avoided or limited. Additionally, the Refuge may impose limits on the duration and/or number of animals trapped for research purposes, specifically, mist-netting capture of birds and/or bats and handling techniques.

Each research, scientific collection, or survey project on the Hakalau or Kona Forest Units would undoubtedly have different protocols and methodologies; therefore, each study necessitates its own scientific review. Each research project would be carefully reviewed to prevent any significant short-term, long-term or cumulative impacts. New research requests would be evaluated by Refuge staff by comparing them to ongoing or recently completed research on the Refuge to determine if the species studied, methodologies used, or habitat type and locations used may lead to undesirable cumulative impacts. All projects would be subject to the Refuge permitting process. This review would help ensure all levels and types of impacts are carefully considered before any permit for research is issued. Within the Hakalau and Kona Forest Unit's SUP, conditions will be clearly defined so as to protect and conserve the existing natural, cultural, and historic resources found on the Refuge. Standard and specific conditions are included in this Compatibility Determination under "Stipulations Necessary to Ensure Compatibility."

Research is a specialized use (603 FW1) and, therefore, it is not considered a priority public use by Refuge System policy. Refuge plans and actions based on research and monitoring provide an informed approach to habitat, wildlife, and public use management programs. Forest bird conservation and management at the Refuge are based upon best available scientific information from research combined with long-term monitoring. Some research is used to address specific wildlife conservation questions, such as understanding the causes of reduced or declining forest bird populations and development of tools and techniques to aid recovery of threatened or endangered species. Other research has broader applicability, such as using a suite of forest birds as indicators of native forest health conditions, and to document change in the larger island environment and associated impacts related to climate change and global warming.

The Service will encourage and support research and management studies on Hakalau and Kona Forest Units that improve and strengthen natural resource management decisions. The Hakalau Forest NWR Refuge manager will encourage and seek research relative to approved Refuge objectives that clearly improve land management approaches and promote adaptive management. Information that enables better management of the Nation's biological resources and is generally considered important to agencies of the Department of the Interior, including the Service, the Refuge System, conservation and State agencies, and/or that addresses important management issues or demonstrate techniques for management of species and/or habitats, will be the priority.

The Service's Appropriate Refuge Uses policies (603 FW1.10D (4)) indicate priority research that contributes to the enhancement, protection, use, preservation, and management of native wildlife populations and their habitat as well as their natural diversity. Projects that contribute to refuge-specific and/or wilderness management, where applicable, would be given a higher priority over other requests. Research applicants must submit a detailed proposal that would outline:

1) Objectives of the study;
2) Justification for the study;
3) Detailed methodology and schedule;
4) Potential impacts on Refuge wildlife or habitat, including disturbance (short and long term), injury and/or mortality. This includes a description of measures the researcher will take to reduce disturbance or impacts;
5) Personnel required;
6) Costs to the Refuge, if any, including staff time and equipment;
7) Expected outcomes or results; and
8) A time line for submitting progress reports and final products (e.g., reports, theses, dissertations, publications).

Research proposed to be conducted on the Refuge would be reviewed by Refuge staff and others as appropriate, to weigh the anticipated impacts versus the benefits of the research activity to refuge management and understanding of natural systems. This would form the basis for allowing the project to proceed or be denied. If the proposal is approved, the Refuge Manager would issue a SUP(s) that would set the terms and conditions of the study to avoid and/or minimize the impacts on Refuge resources, public use activities, and Refuge field operations. All research projects would be assessed during implementation to ensure that impacts remain within acceptable levels.

Research would not be allowed on Refuge lands if one or more of the following criteria apply to a project proposal:

- Research that conflicts with other ongoing research, monitoring, or management programs will not be granted;
- Highly intrusive or manipulative research is generally not permitted in order to protect native birds and other wildlife populations and wilderness values;
- Research projects that can be accomplished off the Refuge are less likely to be approved;
- Research that causes undue disturbance or is more than minimally intrusive is not likely to be granted;
- The level and type of disturbance will be carefully evaluated when considering a request. Strategies to minimize disturbance through study design, including location, timing, scope, number of permittees, study methods, number of study sites, etc., will be required;
- If staffing or logistics make it impossible for Refuge staff to monitor the researcher, the permit is likely to be denied; and
- If the activity is in a sensitive area, the research request may be denied, depending on the specific circumstances.

Hakalau Forest NWR may also consider research for purposes not directly associated to Refuge-specific objectives; such research could potentially contribute to the broader enhancement, protection, use, preservation, and management of wildlife and plant populations and their natural diversity within the Hawaiian Islands. These proposals must comply with the Service's compatibility policy.

Hakalau Forest NWR has developed a preliminary list of research needs that will be provided to prospective researchers or organizations at the Refuge Manager's discretion. Refuge support of research directly related to Refuge objectives may take the form of funding, in-kind services such as housing or use of other facilities, direct staff assistance with the project in the form of data collection, provision of historical records, conducting of management treatments, or other assistance as appropriate.

Availability of Resources:

The bulk of the cost for research is incurred in staff time to review research proposals, coordinate with researchers, write SUPs, attend meetings, and review the research results. The amount of resource required is highly variable depending on the nature of the work involved. In some cases, a research project may only require 1 day of staff time to write a SUP. In other cases, a research project may require a week or more of staff time.

The Refuge requires the permittee to offset any cost incurred by the Refuge by payment of a one-time permit fee of $150.00.

Category and Itemization	One-time ($)	Annual ($/yr)
Administration and Management	$150/permittee	$13,500

The above annual cost reflects the cost to manage the program and prevent impacts to natural resources. Estimated costs were calculated using 3 percent of the base cost of a GS-12 Deputy Refuge Manager, 3 percent of the GS-13 Refuge Manager, 7 percent of the GS-12 Wildlife Biologist, 1 percent of the GS-9 Administrative, and 2 percent of the Maintenance Supervisor's staff time, based on the assumption that this activity would use that portion of the year to administer and coordinate outside research.

Anticipated Impacts of the Use(s):

Use of Hakalau Forest NWR to conduct research, scientific collection, and surveys will generally benefit plant populations, wildlife, and habitats. The impacts of research activities would be project- and site-specific, and would vary depending on the scope and type of research conducted. Scientific findings gained through these projects provide important information regarding life-history needs of species and species groups as well as identify or refine management actions to achieve resource management objectives in refuge management plans (especially CCPs). Reducing uncertainty regarding wildlife and habitat responses to refuge management actions in order to achieve desired outcomes reflected in resource management objectives is essential for adaptive management in accordance with 522 DM 1.

If a project's methods impact or conflict with Refuge resources, other public-uses, other high-priority research, and Refuge management programs, then it must be clearly demonstrated that its scientific findings will be essential to resource management and that the project cannot be conducted off-refuge lands for the project to be compatible. The investigator(s) must identify methods/strategies in advance required to minimize or eliminate the potential impact(s) and conflict(s). If unacceptable impacts cannot be avoided, then the project will not be compatible and will not be approved. Projects that represent public or private economic use of the natural resources of any national wildlife refuge (e.g., bioprospecting), in accordance with 16 U.S.C. 715s, must contribute to the achievement of the national wildlife refuge purposes or the Refuge System mission to be compatible (50 C.F.R. 29.1).

Impacts would be project- and site-specific, where they will vary depending upon nature and scope of the field work. Data collection techniques will generally have negligible animal mortality or disturbance, habitat destruction, no introduction of contaminants, and no introduction of nonindigenous species. In contrast, projects involving the collection of biotic samples (plants or animals) or requiring intensive ground-based data or sample collection will have short-term impacts. To reduce impacts, the minimum number of samples (e.g., water, soils, vegetative litter, plants, macroinvertebrates, vertebrates) will be collected for identification and/or experimentation and statistical analysis. Where possible, researchers would coordinate and share collections to reduce sampling needed for multiple projects.

Although a single research project for a single year may cause few, if any, negative resource impacts, it may in fact cause cumulative impacts over multiple years or when considered additively with all activity on the Refuge. Therefore, it is critical that the Refuge Wildlife Biologist and Refuge Manager examine all projects with a multi-year timeframe in mind and consider all activities that are planned concurrently on the Refuge before approval is granted. It may be appropriate to set a limit to the number of research projects occurring in a particular habitat or relative to a single species or species group, even if personnel are available to coordinate the projects.

Disturbance to wildlife and vegetation by researchers could occur through observation, a variety of wildlife capture techniques, banding, and accessing the area by foot or vehicle. It is possible that direct or indirect mortality could result as a byproduct of research activities. Mist-netting or other wildlife capture techniques, for example, can cause mortality directly through the capture method or in trap predation, and indirectly through capture injury or stress caused to the organism. Some level of disturbance is expected with all research activities, since most researchers will be entering areas that are normally closed to the public and, depending on specific research activities, may also be collecting samples or handling wildlife. However, minimal impact to Refuge wildlife and habitats will be expected with research studies because SUPs will include conditions to ensure that impacts to wildlife and habitats are kept to a minimum (see discussion above).

Direct damage or alteration to the habitat from researchers would be minor due to the research proposal evaluation process and stipulations imposed through the SUP. However, some increase in invasive plants is possible from ground disturbance and/or transportation of source seed on research equipment and personnel, and rodents and disease organisms could potentially be transferred from boats and trapping equipment. Likewise, localized and temporary effects could result from direct impacts of vegetation trampling, collecting soil and plant samples, or trapping and handling wildlife. Other potential, but localized and temporary, effects would include wildlife disturbance, which is expected with some research activities. Researcher disturbance could result in altering wildlife behavior. However, only research with reasonably certain short-term effects from disturbance would be permitted. Only the minimum of samples (e.g., water, soils, vegetative litter, plants, macroinvertebrates, tissue etc.) required for identification and/or experimentation and statistical analysis would be permitted.

State and Federal collecting permits will also ensure minimal impacts to fish, wildlife, plants, and their habitats. A Section 7 consultation under the ESA will be required for activities that may affect a federally listed species and/or critical habitat.

At least 6 months before initiation of field work (unless an exception is made by prior approval of the Refuge Manager), project investigator(s) must submit a detailed proposal using the format provided in Attachment 1. Project proposals will be reviewed by Refuge staff and others, as needed, to assess the potential impacts (short-term, long-term, and cumulative) relative to benefits of the investigation to Refuge management issues and understanding of natural systems. This assessment will form the primary basis for allowing or denying a specific project. Projects which result in unacceptable Refuge impacts will not be found compatible and will not be approved.

If the proposal is approved, then the Refuge Manager will issue a SUP(s) with required stipulations (terms and conditions) of the project to avoid and/or minimize potential impacts to Refuge resources as well as conflicts with other public-use activities and Refuge field management operations.

The combination of stipulations identified above and conditions included in any SUP(s) will ensure that proposed projects contribute to the enhancement, protection, conservation, and management of native wildlife populations and their habitats on the Refuge. As a result, these projects will help fulfill Refuge purposes; contribute to the Refuge System mission; and maintain the biological integrity, diversity, and environmental health of the Refuge.

Spread of invasive plants and/or pathogens is possible from ground disturbance and/or transportation of project equipment and personnel, but it will be minimized or eliminated by requiring proper cleaning of investigator equipment and clothing as well as quarantine methods, where necessary. If after all practical measures are taken, an unacceptable spread of invasive species is anticipated to occur, the project will be found not compatible without a restoration or mitigation plan.

Localized and temporary effects may occur from vegetation trampling, collecting soil and plant samples, or trapping and handling wildlife. Impacts may also occur from infrastructure necessary to support projects (e.g., permanent transects or plot markers, exclosure devices, monitoring equipment, solar panels to power unattended monitoring equipment). Some level of disturbance is expected with these projects, especially if investigator(s) enter areas closed to the public and collect samples or handle wildlife. However, wildlife disturbance (including altered behavior) will be localized and temporary in nature. Where long-term or cumulative unacceptable effects cannot be avoidable, the project will not be found compatible. Project proposals will be reviewed by Refuge staff and others, as needed, to assess the potential impacts (short-term, long-term, and cumulative) relative to benefits of the investigation to Refuge management issues and understanding of natural systems. This assessment will form the primary basis for allowing or denying a specific project.

Overall, however, allowing well designed and properly reviewed research to be conducted by non-Service personnel is likely to have very little impact on Refuge wildlife populations. If the research project is conducted with professionalism and integrity, potential adverse impacts are likely to be outweighed by the knowledge gained about an entire species, habitat or public use.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. Comments were received related to research activities on the refuge and addressed in Appendix K.

Determination:

___ Use is Not Compatible

_X_ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

The SUP will be issued for all research conducted by non-Service personnel. The SUP will list the conditions that the Refuge Manager determines to be necessary to ensure compatibility. The SUPs will also identify a schedule for progress reports and the submittal of a final report or scientific paper.

Regional Refuge biologists, U.S. Geological Survey Biological Resources Discipline staff scientists, other Service programs, State agencies, or nongovernmental organizations and biologists may be asked to provide additional review and comment on any research proposal at the discretion of the Refuge Wildlife Biologist and/or Refuge Manager.

All researchers are required to obtain appropriate State and Federal permits.

If the proposed research methods would impact or potentially impact Refuge resources (habitat or wildlife), it must be demonstrated that the research is essential (i.e., critical to the survival of a species; Refuge provides only or critical habitat for a species; contributes significantly to understanding of impacts from climate change; or assessment and/or restoration after cataclysmic events), and the researcher must identify the issues in advance of the impact. Highly intrusive or manipulative research is generally not permitted in order to protect native bird populations.

All SUPs will have a definite termination date. Renewals will be subject to Refuge Manager review and approval based on timely submission of and content in progress reports, compliance with SUP stipulations, and required permits. Other stipulations and provisions would include the following:

- Potential researchers must submit a written, detailed research proposal to the Refuge Manager at least 6 months prior to start of field work. The required proposal format would be provided to researchers (see Attachment 1);
- Researchers are responsible for acquiring and/or renewing any necessary State and Federal permits prior to beginning or continuing their project;
- A Section 7 consultation under the ESA would be required for research activities that may affect a federally threatened, endangered, or proposed species;
- Research that does not involve birds generally will only be allowed outside of the breeding season of avian species, unless it can be demonstrated that there likely will be no impact to those breeding species. If a research project can only be conducted during the breeding season, such studies will only be permitted where there are specific protocols to minimize disturbance;
- Research will adhere to scientifically defensible protocols for data collection, where available and feasible;
- Approved research projects will be conducted under a Refuge-issued SUP that will have additional project-specific stipulations;

- Annual or other short-term SUPs are preferred; however, some permits will be for a longer period, if needed, to facilitate the research. All SUPs will have a definite termination date. Renewals will be subject to Refuge Manager review of research data, status reports, compliance with compatibility determination and permit stipulations, and other permits;
- If unacceptable impacts or issues arise or be noted by the Refuge staff, then the Refuge Manager can suspend/modify conditions/terminate on Refuge research that is already permitted and in progress;
- Research progress reports are required at least annually, and final reports are due within 1 year of the completion of the project, unless negotiated otherwise. The minimum required elements for a progress report will be provided to investigator(s);
- The Refuge staff will be given the opportunity to review draft manuscript(s) from the project before being submitted to a scientific journal(s) for consideration of publication;
- The Refuge staff will be provided with copies of raw data (preferably electronic database format) at the conclusion of the project;
- The Refuge staff will be provided with copies of all publications developed from Refuge research projects;
- The Service and the Refuge will be appropriately cited and acknowledged in all written and oral presentations resulting from the research on the Refuge;
- Where appropriate, the Refuge staff reserves the right to be coauthor(s) on any reports or publications resulting from the study conducted on the Refuge. Authorship is appropriate where justifiably based upon participation in the project over the course of implementation occurs (e.g., field work, data analyses, summary of findings);
- Upon completion of the project or annually, research sites must be cleaned up to the Refuge Manager’s satisfaction and all physical markers removed. For long-term projects, conditions for clean up and removal of equipment and physical markers would be stipulated in the SUP;
- All samples collected on Refuge lands are the property of the Service even while in the possession of the investigator(s). Any future work with previously collected samples not clearly identified in the project proposal will require submission of a subsequent proposal for review and approval. In addition, a new SUP will be required for additional project work;
- Investigator(s) and support staff will follow all Refuge-specific regulations that specify access and travel on the Refuge;
- At any time, Refuge staff may accompany the researchers;
- Only projects that have no effect or will result in not likely to adversely affect determinations will be considered compatible;
- After approval, all projects also will be assessed during implementation to ensure impacts and conflicts remain within acceptable levels; and
- Projects that are not covered by the CCP or subsequent step-down plans may require additional NEPA documentation.

All research related SUPs contain a statement regarding the Service’s policy regarding disposition of biotic specimen. The current Service policy language in this regard is:

> *“You may use specimens collected under this permit, any components of any specimens (including natural organisms, enzymes, genetic material or seeds), and research results derived from collected specimens for scientific or educational purposes only, and not for commercial purposes unless you have entered into a Cooperative Research and Development Agreement (CRADA) with us. We prohibit the sale of collected research specimens or other*

transfers to third parties. Breach of any of the terms of this permit will be grounds for revocation of this permit and denial of future permits. Furthermore, if you sell or otherwise transfer collected specimens, any components thereof, or any products or any research results developed from such specimens or their components without a CRADA, you will pay us a royalty rate of 20 percent of gross revenue from such sales. In addition to such royalty, we may seek other damages and injunctive relief against you."

Any research project may be terminated at any time for noncompliance with the SUP conditions, or modified, redesigned, relocated or terminated, upon a determination by the Refuge manager that the project is causing unanticipated adverse impacts to wildlife, wildlife habitat, approved priority public uses, or other Refuge management activities.

Justification:

Research on the Hakalau Forest NWR is inherently valuable to the Service, since it is intended to expand the knowledge base of those who are given the responsibility of managing the resources found within the Refuge. This is particularly true for Hakalau Forest NWR, where many of the resources remain in pristine condition and detailed information is lacking for a portion of these species. In many cases, if it were not for the Refuge providing access to the lands and waters along with some support, the research would never take place and less scientific information would be available to the Service to aid in managing and conserving the Refuge resources.

Because each SUP will contain specific conditions for minimizing adverse effects to Refuge resources while the research project is being conducted, it is anticipated that wildlife populations will find sufficient food resources and resting places such that their abundance and use of the Refuge will not be measurably lessened from research activities. The relatively limited number of individuals expected to be adversely affected due to research will not cause wildlife populations to materially decline, the physiological condition and production of native wildlife and plant species will not be impaired, their behavior and normal activity patterns will not be altered dramatically, and their overall welfare will not be negatively impacted. Thus, allowing research to occur with the stipulations described above will not materially detract or interfere with the purposes for which Hakalau Forest NWR was established or the Refuge System mission.

Mandatory 10- or 15-year Reevaluation Date:

____________ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

_____X______ Mandatory 10-year reevaluation date (for nonwildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X_ Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

References Cited:

U.S. Fish and Wildlife Service. 1999. Director's Order No. 109: Use of Specimens Collected on Fish and Wildlife Lands. March 30, 1999.

Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

(Signature) 9/24/10 (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

(Signature) 9/24/10 (Date)

Regional Chief
National Wildlife Refuge System

(Signature) 9/28/10 (Date)

Attachment 1

FORMAT FOR PROPOSALS TO CONDUCT RESEARCH OR LONG-TERM ECOLOGICAL STUDY

Title

Principal Investigator(s) and background

Provide the name(s) and affiliation(s) of all principal investigator(s) that will be responsible for implementation of the research and/or long-term monitoring described in the proposal. In addition, provide a brief description of expertise for principal investigator(s) germane to work described in the proposal.

Background and justification

In a narrative format, describe the following as applicable:

- The conservation issue (e.g., decline in *Pisonia* rainforest) and/or knowledge gap regarding ecological function that currently exists with any available background information;
- Benefit of research/study findings (e.g., management implications) to resources associated with refuge purpose(s); and
- Potential consequences if the conservation issue and/or knowledge gap regarding ecological function is not addressed.

Objectives

Provide detailed objective(s) to be evaluated by the proposed research or study.

Methods and Material

Provide a detailed description of the methods and materials associated with field work to be conducted for the research and/or ecological study. Methods should include the following:

- Study area(s);
- Number of samples;
- Sampling dates and locations;
- Sampling techniques; and
- Data analyses including statistical tests and significance levels.

Previously published methods should be cited without explanation; whereas, new or modified techniques should be described in detail. Include number of personnel as well as all facilities and equipment (e.g., vehicles, structures, markers) required to collect samples/data. Provide a clear description of the relationships among study objectives, field methods, and statistical analyses.

Permits

Identify all State and Federal permits required if applicable. If appropriate, assess the impact on the species population if animals or eggs are to be sacrificed or collected. Note any official status of the species involved (e.g., threatened or endangered).

Compatibility and Section 7 assessments

In order for a research and/or long-term ecological monitoring project to be compatible, it must not materially interfere with or detract from refuge purpose(s) or the Refuge System mission. Describe potential impacts to threatened or endangered species as well as other refuge plants, wildlife, and fish species that could result from the implementation of project activities on the refuge if applicable. Consider the cumulative impacts associated with this project in relationship to other on-going or proposed research and/or long-term monitoring.

Animal welfare Plan

If appropriate, attach a copy of animal welfare plans that are required by the supporting research affiliate.

Partnerships and funding sources

List other participating institutions, agencies, organizations, or individuals as well as the nature and magnitude of their cooperative involvement (e.g., funding, equipment, personnel).

Project schedule

Provide estimated initiation and completion dates for field sampling, laboratory work, data analyses, and report/manuscript preparation. If the study is divided into phases to be accomplished separately, provide initiation and completion dates for each phase.

Reports and raw data

Establish a schedule for annual progress and final reports; include adequate time for peer review for the final report/manuscript. Copies of annual progress reports must be submitted to the Refuge manager by January 1 during each year that the study is in progress. Draft reports/manuscripts must be submitted to the Refuge manager for review prior to submission for consideration of publication. At the conclusion of a research study (manuscripts accepted for publication), an electronic copy of the data (e.g., GIS vegetation layers, animal species composition and numbers, genetics) should be provided to the Refuge manager. For long-term monitoring projects, the Service may request raw data for management and planning purposes for the refuges.

Publications

Describe the ultimate disposition of study results as publications in scientific journals, presentation at professional symposiums, or final reports. Publications must also credit the Service and staff.

Disposition of samples

If the project entails the collection of biotic and/or abiotic (e.g., sediment) samples, then describe their storage. Although the samples may be in the possession of scientists for the purposes of conducting research in accordance with the special use permit, the USFWS retains ownership of all samples collected on refuge lands. If the samples will be used for subsequent research activities that are not described within the original proposal, an addendum to the original proposal must be submitted to the Refuge manager to obtain a new special use permit before initiation of the follow-up project. After conclusion of the research activities, consult with the Refuge manager regarding the final disposition of the samples.

Attachment 2

ANNUAL PROGRESS REPORTS FOR REFUGE RESEARCH AND LONG-TERM MONITORING PROJECTS

Study title:

Fiscal year:

Progress:

In a narrative format, summarize the work that was completed on the study including the number and types of samples collected and/or data analyses.

Important findings:

In narrative format, generally describe any conclusions and/or management recommendations that may be drawn from the work completed to date.

Describe problems encountered:

In narrative format, describe any problems that were encountered during the year and their effects upon the study.

Proposed resolution to problems:

For each problem encountered, describe the actions that have been taken to remediate it.

Preparer:

Date prepared:

Attachment 3

**MEMORANDUM OF UNDERSTANDING
FOR CURATORIAL SERVICES
BETWEEN THE**

(Name of the Federal agency)

AND THE

(**Name of the Repository**)

This Memorandum of Understanding is entered into this (**day**) day of (**month and year**), between the United States of America, acting by and through the (**name of the Federal agency**), hereinafter called the Depositor, and the (**name of the Repository**), hereinafter called the Repository, in the State/Territory of (**name of the State/Territory**).

The Parties do witness that

WHEREAS, the Depositor has the responsibility under Federal law to preserve for future use certain collections of paleontological specimens and/or biological samples as well as associated records, herein called the Collection, listed in Attachment A which is attached hereto and made a part hereof, and is desirous of obtaining curatorial services; and

WHEREAS, the Repository is desirous of obtaining, housing and maintaining the Collection, and recognizes the benefits which will accrue to it, the public and scientific interests by housing and maintaining the Collection for study and other educational purposes; and

WHEREAS, the Parties hereto recognize the Federal Government's continued ownership and control over the Collection and any other U.S. Government-owned personal property, listed in Attachment B which is attached hereto and made a part hereof, provided to the Repository, and the Federal Government's responsibility to ensure that the Collection is suitably managed and preserved for the public good; and

WHEREAS, the Parties hereto recognize the mutual benefits to be derived by having the Collection suitably housed and maintained by the Repository;

NOW THEREFORE, the Parties do mutually agree as follows:

1. The Repository shall:

a. Provide for the professional care and management of the Collection from the (**names of the resources**) sites, assigned (**list site numbers**) site numbers. The collections were recovered in connection with the (**name of the Federal or federally authorized project)** project, located in (**name of the nearest city or town**), (**name of the county, if applicable**) county, in the State/Territory of (**name of the State/Territory**)-

b. Assign as the Curator, the Collections Manager and the Conservator having responsibility for the work under this Memorandum, persons who are qualified museum professionals and whose expertise is appropriate to the nature and content of the Collection.

c. Begin all work on or about (**month, date and year**) and continue for a period of (**number of years**) years or until sooner terminated or revoked in accordance with the terms set forth herein.

d. Provide and maintain a repository facility having requisite equipment, space and adequate safeguards for the physical security and controlled environment for the Collection and any other U.S. Government-owned personal property in the possession of the Repository.

e. Not in any way adversely alter or deface any of the Collection except as may be absolutely necessary in the course of stabilization, conservation, scientific study, analysis and research. Any activity that will involve the intentional destruction of any of the Collection must be approved in advance and in writing by the Depositor.

f. Annually inspect the facilities, the Collection and any other U.S. Government-owned personal property. Every **(number of years**) years inventory the Collection and any other U.S. Government-owned personal property. Perform only those conservation treatments as are absolutely necessary to ensure the physical stability and integrity of the Collection, and report the results of all inventories, inspections and treatments to the Depositor.

g. Within five (5) days of discovery, report all instances of *and* circumstances surrounding loss of, deterioration and damage to, or destruction of the Collection and any other U.S. Government-owned personal property to the Depositor, and those actions taken to stabilize the Collection and to correct any deficiencies in the physical plant or operating procedures that may have contributed to the loss, deterioration, damage or destruction. Any actions that will involve the repair and restoration of *any of* the Collection and any other U.S. Government-owned personal property must be approved in advance and in writing by the Depositor.

h. Review and approve or deny requests for access to or short-term loan of the Collection (or a part thereof) for scientific and educational uses. In addition, refer requests for consumptive uses of the Collection (or a part thereof) to the Depositor for approval or denial.

i. Not mortgage, pledge, assign, repatriate, transfer, exchange, give, sublet, discard or part with possession of any of the Collection or any other U.S. Government-owned personal property in any manner to any third party either directly or indirectly without the prior written permission of the Depositor, and redirect any such request to the Depositor for response. In addition, not take any action whereby any of the Collection or any other U.S. Government-owned personal property shall or may be encumbered, seized, taken in execution, sold, attached, lost, stolen, destroyed or damaged.

2. The Depositor shall:

a. On or about (month, date and year), deliver or cause to be delivered to the Repository the Collection, as described in Attachment A, and any other U.S. Government-owned personal property, as described in Attachment B.

b. Assign as the Depositor's Representative having full authority with regard to this Memorandum, a person who meets pertinent professional qualifications.

c. Every (number of years) years, jointly with the Repository's designated representative, have the Depositor's Representative inspect and inventory the Collection and any other U.S. Government-owned personal property, and inspect the repository facility.

d. Review and approve or deny requests for consumptively using the Collection (or a part thereof).

3. Removal of all or any portion of the Collection from the premises of the Repository for scientific or educational purposes; any conditions for handling, packaging and transporting the Collection; and other conditions that may be specified by the Repository to prevent breakage, deterioration and contamination.

4. The Collection or portions thereof may be exhibited, photographed or otherwise reproduced and studied in accordance with the terms and conditions stipulated in Attachment C to this Memorandum. All exhibits, reproductions and studies shall credit the Depositor, and read as follows: "Courtesy of the **(name of the Federal agency**)."The Repository agrees to provide the Depositor with copies of any resulting publications.

5. The Repository shall maintain complete and accurate records of the Collection and any other U.S. Government-owned personal property, including information on the study, use, loan and location of said Collection which has been removed from the premises of the Repository.

6. Upon execution by both parties, this Memorandum of Understanding shall be effective on this **(day**) day of **(month and year**), and shall remain in effect for (**number of years**) years, at which time it will be reviewed, revised, as necessary, and reaffirmed or terminated. This Memorandum may be revised or extended by mutual consent of both parties, or by issuance of a written amendment signed and dated by both parties. Either party may terminate this Memorandum by providing 90 days written notice. Upon termination, the Repository shall return such Collection and any other U.S. Government-owned personal property to the destination directed by the Depositor and in such manner to preclude breakage, loss, deterioration and contamination during handling, packaging and shipping, and in accordance with other conditions specified in writing by the Depositor. If the Repository terminates, or is in default of, this Memorandum, the Repository shall fund the packaging and transportation costs. If the Depositor terminates this Memorandum, the Depositor shall fund the packaging and transportation costs.

7. Title to the Collection being cared for and maintained under this Memorandum lies with the Federal Government.

IN WITNESS WHEREOF, the Parties hereto have executed this Memorandum.

Signed: (**signature of the Federal Agency Official**) **Date:** (**date**)

Signed: (**signature of the Repository Official**) **Date:** (**date**)

Attachment 3A: Inventory of the Collection

Attachment 3B: Inventory of any other U.S. Government-owned Personal Property

Attachment 3C: Terms and Conditions Required by the Depositor

Use: University of Hawai‘i Field Station

Refuge Name: Hakalau Forest National Wildlife Refuge (NWR)

City/County and State: Hawai‘i County, State of Hawai‘i

Establishing and Acquisition Authority:

Hakalau Forest NWR was established on October 29, 1985, under the authority of the Endangered Species Act of 1973, 16 U.S.C. 1534.

Refuge Purpose(s):

The Administration Act directs the U.S. Fish and Wildlife Service (Service) to manage each refuge to fulfill the Refuge System mission, to maintain and where appropriate, restore the refuge's ecological integrity; and achieve the specific purpose(s) for which the refuge was established.

Hakalau Forest Unit

The purpose of Hakalau Forest NWR is "... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ..." 16 U.S.C. Sec. 1534 (ESA).

Kona Forest Unit

The purpose of Kona Forest Unit is "... to conserve (A) fish or wildlife which are listed as endangered species or threatened species ....or (B) plants ..." 16 U.S.C. Sec. 1534 (ESA). More specifically, the unit was established to provide habitat for the ‘alalā and to assist the ‘Alalā Recovery Program's repatriation efforts.

National Wildlife Refuge System Mission:

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans (the Administration Act of 1966).

Description of Use(s):

The University of Hawai‘i (UH) operates a biological field station located on the Hakalau Forest NWR Administrative Site. Operation of the field station is described in a Memorandum of Agreement (MOA), dated October 29, 1985 (Contract No. 14-48-0001-95500) between the Service and UH. That agreement expired on October 24, 2009. The field station is used to house and support UH faculty, students, and visiting scientists conducting research supporting the conservation and restoration of native species and habitats at Hakalau Forest NWR. Maintaining a collaborative research environment on the Refuge with various partners is strongly encouraged. Studies conducted on the Refuge require a Special Use Permit and Refuge Manager's approval. This compatibility determination is confined to the field station; individual research projects taking place at the Refuge are covered under a separate compatibility determination titled “Research, Scientific Collecting, and Surveys.” A separate CD is required because some research activity at Hakalau Forest NWR is independent of and accommodated without the use of the UH facility. All operations at the field station, including expected dates of overnight stays and the purpose for each visit must be coordinated with the Refuge Manager in advance. UH bears all operational and maintenance costs related to the station and thus does not require routine involvement by Refuge staff working at the Administration Site. Access to the Refuge requires guests to be given secure combination lock numbers that are strictly confidential. UH activities not directly pertaining to activities conducted on the Refuge are not covered in this determination and are thus subject to separate review and appropriate use considerations if the station is used for offsite projects.

Research is a specialized use (603 FW1) and, therefore, it is not considered a priority public use by Refuge System policy. Refuge plans and actions based on research and monitoring provide an informed approach to habitat, wildlife, and public use management programs. Forest bird conservation and management at the Refuge are based upon best available scientific information from research combined with long-term monitoring. Some research is used to address specific wildlife conservation questions, such as understanding the causes of reduced or declining forest bird populations and development of tools and techniques to aid recovery of threatened or endangered species. Other research has broader applicability, such as using a suite of forest birds as indicators of native forest health conditions, and to document change in the larger island environment and associated impacts related to climate change and global warming.

The Service’s Appropriate Refuge Uses policies (603 FW1.10D (4)) indicate priority for research that contributes to the enhancement, protection, use, preservation, and management of native wildlife populations and their habitat as well as their natural diversity. Projects that contribute to refuge-specific and/or wilderness management, where applicable, would be given a higher priority over other requests. Research applicants must submit a detailed proposal that would outline:

1) Objectives of the study;
2) Justification for the study;
3) Detailed methodology and schedule;
4) Potential impacts on Refuge wildlife or habitat, including disturbance (short and long term), injury and/or mortality. This includes a description of measures the researcher will take to reduce disturbance or impacts;
5) Personnel required;
6) Costs to the Refuge, if any, including staff time and equipment;
7) Expected outcomes or results; and
8) A time line for submitting progress reports and final products (e.g., reports, theses, dissertations, publications).

UH research proposed to be conducted on the Refuge would be reviewed by Refuge staff and others as appropriate, to weigh the anticipated impacts versus the benefits of the research activity to Refuge management and understanding of natural systems. This would form the basis for allowing the project to proceed or be denied. If the proposal is approved, the Refuge Manager would issue a SUP(s) which would set the terms and conditions of the study to avoid and/or minimize the impacts on Refuge resources, public use activities, and Refuge field operations. All research projects would be assessed during implementation to ensure that impacts remain within acceptable levels.

Research would not be allowed on Refuge lands if one or more of the following criteria apply to a project proposal:

- Research that conflicts with other ongoing research, monitoring, or management programs will not be granted;
- Highly intrusive or manipulative research is generally not permitted in order to protect native birds and other wildlife populations and wilderness values;
- Research projects that can be accomplished off the Refuge are less likely to be approved;
- Research which causes undue disturbance or is more than minimally intrusive is not likely to be granted;
- The level and type of disturbance will be carefully evaluated when considering a request. Strategies to minimize disturbance through study design, including location, timing, scope, number of permittees, study methods, number of study sites, etc., will be required;
- If staffing or logistics make it impossible for Refuge staff to monitor the researcher, the permit is likely to be denied; and
- If the activity is in a sensitive area, the research request may be denied, depending on the specific circumstances.

Availability of Resources:

Normally, minimal Refuge staff resources are required to provide coordination and oversight for activities conducted on the Refuge and supported by the operation of the field station:

Category and Itemization	One-time ($)	Annual ($/yr)
Administration and Management	No fees charged	$9,300

The above annual cost reflects the cost to provide oversight for the UH field station facility and prevent impacts to natural resources. The cost was conservatively estimated as requiring 2 percent of the base cost of a GS-12 Deputy Refuge Manager, 3 percent of the GS-13 Refuge Manager, 2 percent of the GS-12 Wildlife Biologist, 1 percent of the GS-9 Administrative, and 1 percent of the Maintenance Supervisor's staff time, based on the assumption that this activity would use that portion of the year to administer and coordinate activities conducted on the Refuge and supported by the operation of the field station.

The estimated administration and management cost reflects the portion of each year necessary to work with UH faculty to assure appropriate, compatible use of the field station in accordance with the MOA. Depending upon the amount of activity planned for the field station in a given year, the actual amount of time and funding required to administer the operation could vary significantly.

Anticipated Impacts of the Use(s):

The field station is situated within the 15-acre Hakalau Forest NWR Administrative Site situated at the upper (western) boundary of the Refuge. Much of the vicinity understory and ground cover has been disturbed by more than 100 years of cattle grazing and pig rooting, primarily preceding the establishment of the Refuge. This resulted in conversion of native forest habitats to open rangeland carpeted with nonnative grasses. Since construction of the field station, the immediate vicinity surrounding the Administrative Site has been restored with planted koa. The area surrounding the field station is not high quality habitat for imperiled Refuge species, with the exception of the nēnē. Because it is necessary to maintain an open area to store and maintain equipment and facilities, and because of resident nēnē nesting in the area, there are no plans to restore forest within the boundaries of the 15-acre Administrative Site.

Operation and maintenance of the station has little if any impact on forest birds and the ‘ōpe‘ape‘a. Impacts to nēnē are minimal and limited to temporary displacement of individuals by vehicles and pedestrian traffic in and around the building structures and area roads. During the nēnē breeding season of 2009-10, two pairs of geese nested beneath the field station building and entranceway decking.

Operation of the field station is intended to provide benefits to the management of the Refuge by facilitating research contributing to conservation of resident Refuge species and restoration of Refuge habitats. Numerous studies that have taken place at the Refuge over the last 16 years would likely have been infeasible without use of the field station on site at the Refuge.

Use of Hakalau Forest NWR to conduct research, scientific collection, and surveys will generally benefit plant populations, wildlife, and habitats. The impacts of research activities would be project- and site-specific, and would vary depending on the scope and type of research conducted. Scientific findings gained through these projects provide important information regarding life-history needs of species and species groups, as well as identify or refine management actions to achieve resource management objectives in refuge management plans (especially CCPs). Reducing uncertainty regarding wildlife and habitat responses to refuge management actions in order to achieve desired outcomes reflected in resource management objectives is essential for adaptive management in accordance with 522 DM 1.

If project methods impact or conflict with Refuge resources, other public-uses, other high-priority research, and Refuge management programs, then it must be clearly demonstrated that scientific findings will be essential to resource management and that the project cannot be conducted off Refuge lands for the project to be compatible. The investigator(s) must identify methods/strategies in advance required to minimize or eliminate the potential impact(s) and conflict(s). If unacceptable impacts cannot be avoided, then the project will not be compatible and not be approved. Projects that represent public or private economic use of the natural resources of any national wildlife refuge (e.g., bioprospecting), in accordance with 16 U.S.C. 715s, must contribute to the achievement of the national wildlife refuge purposes or the Refuge System mission to be compatible (50 C.F.R. 29.1).

Impacts would be project- and site-specific, where they will vary depending upon nature and scope of the field work. Data collection techniques will generally have negligible animal mortality or disturbance, habitat destruction, no introduction of contaminants, and no introduction of nonindigenous species. In contrast, projects involving the collection of biotic samples (plants or animals) or requiring intensive ground-based data or sample collection will have short-term impacts. To reduce impacts, the minimum number of samples (e.g., water, soils, vegetative litter, plants, invertebrates, vertebrates) will be collected for identification and/or experimentation and statistical analysis. Where possible, researchers would coordinate and share collections to reduce sampling needed for multiple projects.

Some level of disturbance is expected with all research activities since most researchers will be entering areas that are normally closed to the public and, depending on specific research activities, may also be collecting samples or handling wildlife. However, minimal impact to Refuge wildlife and habitats will be expected with research studies because SUPs will include conditions to ensure that impacts to wildlife and habitats are kept to a minimum (see discussion above).

Direct damage or alteration to the habitat from researchers would be minor due to the research proposal evaluation process and stipulations imposed through the SUP. However, some increase in invasive plants is possible from ground disturbance and/or transportation of source seed on research equipment and personnel, and rodents and disease organisms could potentially be transferred from boots and trapping equipment. Likewise, there could be localized and temporary effects resulting in direct impacts of vegetation trampling, collecting soil and plant samples, or trapping and handling wildlife. Other potential, but localized and temporary, effects would include wildlife disturbance, which is expected with some research activities. Researcher disturbance could result in altering wildlife behavior. However, only research with reasonably certain short-term effects from disturbance would be permitted. Only the minimum of samples (e.g., water, soils, vegetative litter, plants, invertebrates, tissue, etc.) required for identification and/or experimentation and statistical analysis would be permitted.

State and Federal collecting permits will also ensure minimal impacts to fish, wildlife, plants, and their habitats. A Section 7 consultation under the ESA will be required for activities that may affect a federally listed species and/or critical habitat.

At least 6 months before initiation of field work (unless an exception is made by prior approval of the Refuge Manager), project investigator(s) must submit a detailed proposal using the format provided in Attachment 1 to the Research CD. Project proposals will be reviewed by Refuge staff and others, as needed, to assess the potential impacts (short-, long-term, and cumulative) relative to benefits of the investigation to Refuge management issues and understanding of natural systems. This assessment will form the primary basis for allowing or denying a specific project. Projects which result in unacceptable Refuge impacts will not be found compatible and will not be approved.

If the proposal is approved, then the Refuge Manager will issue a SUP(s) with required stipulations (terms and conditions) of the project to avoid and/or minimize potential impacts to Refuge resources as well as conflicts with other public-use activities and Refuge field management operations.

The combination of stipulations identified above and conditions included in any SUP(s) will ensure that proposed projects contribute to the enhancement, protection, conservation, and management of native wildlife populations and their habitats on the Refuge. As a result, these projects will help fulfill Refuge purposes; contribute to the Refuge System mission; and maintain the biological integrity, diversity, and environmental health of the Refuge.

Spread of invasive plants and/or pathogens is possible from ground disturbance and/or transportation of project equipment and personnel, but it will be minimized or eliminated by requiring proper cleaning of investigator equipment and clothing as well as quarantine methods, where necessary. If after all practical measures are taken an unacceptable spread of invasive species is anticipated to occur, the project will be found not compatible without a restoration or mitigation plan.

There also could be localized and temporary effects from vegetation trampling, collecting of soil and plant samples, or trapping and handling of wildlife. Impacts may also occur from infrastructure necessary to support projects (e.g., permanent transects or plot markers, exclosure devices, monitoring equipment, solar panels to power unattended monitoring equipment). Some level of disturbance is expected with these projects, especially if investigator(s) enter areas closed to the public and collect samples or handle wildlife. However, wildlife disturbance (including altered behavior) will be localized and temporary in nature. Where long-term or cumulative unacceptable effects cannot be avoidable, the project will not be found compatible. Project proposals will be reviewed by Refuge staff and others, as needed, to assess the potential impacts (short, long-term, and cumulative) relative to benefits of the investigation to Refuge management issues and understanding of natural systems. This assessment will form the primary basis for allowing or denying a specific project.

Public Review and Comment:

This determination was issued for public review and comment as part of the Hakalau Forest NWR Draft Comprehensive Conservation Plan and Environmental Assessment between August 16, 2010-September 15, 2010. An open house was held and written comments were solicited from the public during this period for the CCP via news release, website posting, extensive mailing as well as e-mail list, and circulation of Planning Update 3. No public comment was received on this compatibility determination.

Determination:

___ Use is Not Compatible

_X_ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

Conditions have changed since the original MOA was established. This compatibility determination establishes a basis for the operation of a field station on the grounds of the Refuge. The uses described here are conditional upon the development of a new Memorandum of Agreement or Cooperative Agreement that is acceptable under current Refuge System standards. The previous MOA expired on October 24, 2009. A current, fully executed MOA must be in place at all times for this use to be permitted by the Refuge Manager. Any new MOA needs to be revised to include, but not limited to, the following conditions:

The field station will be operated solely for the purpose of conducting environmental, conservation, biotic, climatic, and management studies that will assist the Service in accomplishing the objectives for which the Refuge was established.

1. Most of the Refuge is not open to the public, therefore access to the Field Station is restricted and subject to Service approval. Access codes for entry to the Refuge may change from time to time and will be provided by the Refuge as needed. Standard notification for visits scheduled by permit holders to the Refuge is 7 days from the time of anticipated use. The UH will maintain a log of visitors to the facility stating name, affiliation, contact information, vehicle identification information, and purpose for the visit, citing relevant SUPs, project or coordination needs. The Refuge Manager or his /her agent will be provided with this

information upon request or, at a minimum, within 30 days of the end of each calendar year (January 30).

2. The UH shall have the use of a site approved by the Service for operation and maintenance of a biological field station at no cost to the Service. The site consists of an existing facility used under prior (expired) agreement as a research station located on Refuge land within the Administration Site for the Refuge as identified on the approved site plan.

3. It is expressly agreed by the parties that the UH is solely responsible for the cost of the maintenance of the field station, pursuant to the terms of this permit. Continued maintenance of and related operating expenses for the facility subsequent to occupation is to be borne by the designated unit of the UH. The Service will not be responsible for capital costs for future construction or additional maintenance expenses that may occur as a result of this SUP.

4. Use of the field station and all use of premises outside such buildings located on the Refuge will be coordinated with and subject to the approval of the Refuge Manager and will be compatible with Refuge objectives and operation. Individual research projects will require approval and issuance of SUPs by the Refuge Manager.

5. Use of the field station will be limited to scientists, professors, students, volunteers, and UH officials and others designated to conduct authorized research and educational programs on the Refuge or official purposes related to facility operations and coordination with the Refuge. No unapproved guests are authorized on the Refuge at any time.

6. The UH shall develop a policy for assigning residency at the field station by mutual agreement with the Refuge, and priority shall be given to those individuals and projects conducted on the Refuge. This policy shall include acceptable provisions for accommodating visiting scientists and other authorized professionals who are not associated with the University (e.g., visiting scientists and students) on a space available basis. Access to the Refuge and use of the facility for offsite researchers, contractors, interns, etc., is not authorized by this permit.

7. The Service shall at all times have the right of access to the land and facilities covered by this permit. The Service, owing to site and space limitations, may by prior arrangement with UH, occasionally reserve the field station for meeting space for official business (e.g., internal or partnership meetings) and may arrange use of the dorm/kitchen when Service cabins are full and space is available.

8. At the discretion of the Refuge, the field station may not be available to any person who is not in good standing with the Refuge due to noncompliance with the Refuge SUP conditions.

9. Permittee agrees that all users of the facility agree to comply with all Federal, State, and County laws and Refuge regulations applicable to the Refuge and the UH’s occupancy and use of the land and facilities.

10. All research and study projects undertaken by UH that involve the use of the Refuge must be approved in advance by the Refuge manager. Applications for a SUP require a completed research/management study proposal.

11. Permittee agrees to take such soil and resource conservation and protection measures including weed control, on the land covered by this Agreement as the Refuge Manager may request.

12. Permittee agrees to pay the United States the full value for damages to the lands or other property of the United States caused by UH, its officers, employees, students, interns and agents, and to hold the United States harmless against any liability not caused by negligence or intentional acts of Service employees for damages to life, person, or property arising from UH that it is legally empowered to do so under the laws of the State of Hawaiʻi, including but not limited to Chapters 661 and 662, Hawaii Revised Statutes, and subject legislative appropriation.

13. Permittee agrees to provide the use of the Station's catchment tank water supply to the County of Hawaiʻi, State of Hawaiʻi, and Service firefighters for emergencies involving wildland and structural fire suppression efforts.

The MOA between the Service and UH requires Refuge Manager approval of individual research projects based out of the field station. Residential use of the field station is limited to scientists, professors, students, volunteers, and UH officials conducting activities determined by the Refuge Manager to benefit the Refuge. The Refuge Manager will ensure all operations of the field station remain compatible with the purpose for which the Refuge was established.

Permits will be issued for all research activities conducted from the field station and will list the conditions the Refuge manager determines necessary to ensure compatibility. The MOA between the Refuge and UH for operation of the field station may be terminated at any time for noncompliance with MOA conditions. The MOA may be modified, redesigned, or terminated upon determination by the Refuge Manager that field station activities exceed MOA parameters or are causing unanticipated adverse impacts to wildlife, wildlife habitat, approved priority public uses, noncompliance with Special Use Permit conditions, or other Refuge management activities.

Special conditions to protect fragile Refuge habitats will be incorporated. These include taking precautions to prevent the introduction of nonnative plants and insects to the Refuge. Vehicles, boots, clothing, and equipment must be cleaned and inspected for seeds, eggs, and larvae prior to entry to the Refuge. Cutting or clearing vegetation is not permitted. Other conditions prohibit fires and require the removal of all trash.

If the proposed research methods would impact or potentially impact Refuge resources (habitat or wildlife), it must be demonstrated that the research is essential (i.e., critical to the survival of a species; Refuge lands provide the only or critical habitat for a species; contributes significantly to understanding of impacts from climate change; or assessment and/or restoration after cataclysmic events), and the researcher must identify the issues in advance of the impact. Highly intrusive or manipulative research is generally not permitted in order to protect native bird populations.

All SUPs will have a definite termination date. Renewals will be subject to Refuge Manager review and approval based on timely submission of and content in progress reports, compliance with SUP stipulations, and required permits. Other stipulations and provisions would include the following:

- Potential researchers must submit a written, detailed research proposal to the Refuge Manager at least 6 months prior to start of field work. The required proposal format would be provided to researchers (see Attachment 1 to the Research CD);
- Researchers are responsible for acquiring and/or renewing any necessary State and Federal permits prior to beginning or continuing their project;
- A Section 7 consultation under the ESA would be required for research activities that may affect a federally threatened, endangered, or proposed species;
- Research that does not involve birds generally will only be allowed outside of the breeding season of avian species, unless it can be demonstrated that there likely will be no impact to those breeding species. If a research project can only be conducted during the breeding season, such studies will only be permitted where there are specific protocols to minimize disturbance;
- Research will adhere to scientifically defensible protocols for data collection, where available and feasible;
- Approved research projects will be conducted under a Refuge-issued Special Use Permit which will have additional project-specific stipulations;
- Annual or other short-term Special Use Permits are preferred; however, some permits will be a longer period, if needed, to facilitate the research. All Special Use Permits will have a definite termination date. Renewals will be subject to Refuge Manager review of research data, status reports, compliance with compatibility determination and permit stipulations, and other permits;
- If unacceptable impacts or issues arise or be noted by the Refuge staff, then the Refuge Manager can suspend/modify conditions/terminate on Refuge research that is already permitted and in progress;
- Research progress reports are required at least annually, and final reports are due within 1 year of the completion of the project, unless negotiated otherwise. The minimum required elements for a progress report will be provided to investigator(s);
- The Refuge staff will be given the opportunity to review draft manuscript(s) from the project before being submitted to a scientific journal(s) for consideration of publication;
- The Refuge staff will be provided with copies of raw data (preferably electronic database format) at the conclusion of the project;
- The Refuge staff will be provided with copies of all publications developed from Refuge research projects;
- The Service and the Refuge will be appropriately cited and acknowledged in all written and oral presentations resulting from the research on the Refuge;
- Where appropriate, the Refuge staff reserves the right to be coauthor(s) on any reports or publications resulting from the study conducted on the Refuge. Authorship is appropriate where justifiably based upon participation in the project over the course of implementation occurs (e.g., field work, data analyses, summary of findings);
- Upon completion of the project or annually, research sites must be cleaned up to the Refuge Manager's satisfaction and all physical markers removed. For long-term projects, conditions for clean up and removal of equipment and physical markers would be stipulated in the Special Use Permit;
- All samples collected on Refuge lands are the property of the Service even while in the possession of the investigator(s). Any future work with previously collected samples not clearly

identified in the project proposal will require submission of a subsequent proposal for review and approval. In addition, a new SUP will be required for additional project work;
- Investigator(s) and support staff will follow all Refuge-specific regulations that specify access and travel on the Refuge;
- At any time, Refuge staff may accompany the researchers;
- Only projects which have no effect or will result in not likely to adversely affect determinations will be considered compatible;
- After approval, all projects also will be assessed during implementation to ensure impacts and conflicts remain within acceptable levels; and
- Projects which are not covered by the CCP or subsequent stepdown plans may require additional NEPA documentation.

Justification:

Operation of the UH field station at the Refuge can contribute to the achievement of the Refuge purpose and the mission of the Service. Research performed by UH faculty and students and other research partners expands understanding of the unique wildlife, diverse native habitats, management programs, and mission of Hakalau Forest NWR and the Refuge System.

Because the aforementioned MOA contains specific conditions for minimizing adverse effects to Refuge resources associated with operation of the field station, it is anticipated that wildlife populations will find sufficient food resources and resting places such that their abundance and use of the Refuge will not be measurably lessened from these activities. The relatively limited number of individuals expected to be adversely affected from these activities will not cause wildlife populations to materially decline, the physiological condition and production of native wildlife species will not be impaired, their behavior and normal activity patterns will not be altered dramatically, and their overall welfare will not be negatively impacted. Allowing field station operations to occur with stipulations will not materially detract or interfere with the purposes for which the Refuge was established or the Refuge System mission.

Mandatory 10- or 15-year Reevaluation Date:

____________ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

_____X______ Mandatory 10-year reevaluation date (for nonwildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision (check one below)

___Categorical Exclusion without Environmental Action Statement

___Categorical Exclusion and Environmental Action Statement

_X_ Environmental Assessment and Finding of No Significant Impact

___Environmental Impact Statement and Record of Decision

References Cited:

U.S. Fish and Wildlife Service. 1994. Memorandum of Agreement between the University of Hawaii and the U.S. Fish and Wildlife Service for the Construction and Maintenance of a Biological Field Station at the Hakalau Forest National Wildlife Refuge, Hawaii County, Hawaii.

Refuge Preparation and Determination:

Refuge Manager
Hakalau Forest National Wildlife Refuge

(Signature) 9/24/10 (Date)

Concurrence:

Project Leader
Hawaiian and Pacific Islands NWRC

(Signature) 9/24/10 (Date)

Regional Chief
National Wildlife Refuge System

(Signature) 9/28/10 (Date)

Appendix C. Plan Implementation

Overview

The Comprehensive Conservation Plan proposes numerous projects to be implemented over the next 15 years. Implementation of the CCP will require increased funding, which will be sought from a variety of sources. This plan will depend on additional congressional allocations, partnerships, and grants. There are no guarantees that additional Federal funds will be made available to implement any of these projects. Other sources of funds (both public and private) will need to be obtained. Activities and projects identified will be implemented as funds become available. The 5-year intervals column indicates the Service anticipating implementation during the first, second, and third 5-year period of the 15-year life of the CCP (e.g., 2015, 2020, 2025).

Many of these projects are included in either the Refuge Operational Needs System (RONS) or Service Asset Maintenance and Management System (SAMMS), both of which are used to document funding needs and request funding from Congress. The RONS database tracks proposed new projects to implement the CCP to meet refuge goals and objectives and legal mandates. The SAMMS database documents and tracks repairs, replacements, and maintenance of facilities and equipment. Smaller proposed projects will be implemented as funding allows, and funding will be sought for these projects through a variety of resources and partnerships.

Monitoring

Monitoring activities will be conducted on a percentage of all new and existing projects and activities to document wildlife populations and changes across time, habitat conditions, and response to management practices. General monitoring activities are discussed in Chapter 2 under Goal 6, as well as existing monitoring activities summarized in Appendix L. Additionally, under each objective in Chapter 2, attributes have been identified that serve as monitoring indicators.

Monitoring of CCP implementation is addressed in the last section of this appendix.

Costs to Implement CCP

A. One-time and recurring costs

The following sections detail both one-time and recurring costs for various projects. One-time costs reflect the initial costs associated with a project, such as the purchase of equipment, contracting services, construction, etc. Recurring costs reflect the future operational and maintenance costs associated with the project. The following tables primarily document projects with a physically visible, trackable “on-the-ground” component, such as public use and management facilities and structures, habitat restoration, research, and monitoring and surveys. The scope and costs for “administrative” activities such as MOAs, reporting, and establishment of partnerships are difficult to estimate in advance and thus are not accounted for in the tables below. Cost estimates are in 2010 dollars and do not account for future inflation and other anticipated rising costs.

One-time costs are project costs that have a start-up cost associated with them, such as purchasing a new vehicle for wildlife and habitat monitoring, or designing and installing an interpretive sign. Some are full project costs for those projects that can be completed in 3 years or less. One-time costs can include the cost of temporary or term salary associated with a short-term project. Salary for existing and new positions, and operational costs, are reflected in operational (or recurring) costs.

Funds for one-time costs will be sought through increases in Refuge base funding, special project funds, and grants. Projects listed below show one-time costs, such as those associated with building and facility needs including offices, road improvements, or new signs. One-time costs are also associated with projects such as habitat restoration, invasive plant and animal control, and research.

Operational costs reflect Refuge spending of base funds allocated each year. These are also known as recurring costs and are usually associated with day-to-day operations and projects that last longer than 3 years. The CCP will require increased funding for new or expanded public uses and facilities, habitat restoration and conservation activities, and new monitoring needs. The table below includes operational expenditures such as supplies, utilities, and maintenance costs. Project costs include seasonal staff needed year after year to accomplish each project; these staffing costs are not isolated in this table but are included as part of the entire project cost. Staffing costs are addressed in table C-4 later in this appendix.

Note that for the implementation timeline, priority is not indicated by the 5-year interval identified. If a strategy is identified for implementation in the first 5-year interval, this does not indicate priority, but rather fiscal and logistical realities that allow for that activity to occur the first 5 years. Additionally, some strategies are sequential and depend on other strategies or may require additional planning (e.g., step-down plans) before they can be implemented, thereby moving them into the second or third 5-year interval segments. Also note that additional explanatory text for activities identified in tables C-1 and C-2 can be found under sections outlining maintenance costs and partnering projects.

Funding for the Refuge in FY2010 was $1,168,098.

Table C-1. One-time Costs Related to CCP Implementation.

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
One-time Cost				
Fence construction:				
KFU fenced (15 mile fencing including 15 ft wide fuel breaks)	2015	1-2	$1,246,097	In-hand (R1/ENG)
HFU units 9 and A-F	2020	3-5	• Unit 9: $334,000; • Units A-F, TBD	DM, 1113(ES)
Site-specific fencing to protect endangered plant populations at both units	2020	1,3	KFU: $25,000	DM, 1113 (ES)

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
Construct fence to protect *Carex* bog habitats where feasible at HFU	2020	3	TBD	1113(ES)
Construct fence for 15-acre grassland breeding for nēnē at Pua ʻĀkala	2015	5	$45,000	1113(ES)
Species and Habitat restoration and protection:				
Removal of existing abandoned fence and other former ranch debris at both units	2015	1, 3	12.12 mi barbed fence at HFU: $230,500	DM, 1113(ES)
Land acquisitions at both units to enhance Refuge purposes	2025	1, 3, 4	$12-20 million	LWCF
Site preparation for outplanting to restore montane mesic koa forest	2015	3	TBD	TBD
Install excluder device to control the impact of turkeys on koa seedlings and improve planting survival	2015	3	$75,000	1113(ES)
Surveys, inventories, and monitoring:				
Inventory and map lava tube and skylight communities at KFU	2015	2	TBD	1113(ES)
Inventory vegetation communities at HFU	2020	3	TBD	1113(ES)
Develop an updated vegetation cover map for both units	2020	6	TBD	USGS, IPIF
Inventory streams and stream corridors at HFU	2020	4	TBD	USGS, Watershed Partners
Inventory endemic species in all aquatic habitats	2020	6	TBD	USGS, Watershed Partners
Survey extent and number of bogs	2020	4	TBD	USGS
Inventory endemic species in all forest habitats	2020	6	Plants: $260,000 Animals: TBD	USGS
Inventory plants, invertebrates, vertebrates at both units	2020	6	TBD	USGS
Develop early detection and rapid response monitoring to identify new or spread invasive plant problems	2015	6	TBD	ISST
Inventory endemic species, subfossil remains, and cultural	2015	6	TBD	RONS, USGS

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
resources associated with lava tube and skylight ecosystems at KFU				
Identify pest plant and animal species presence, distribution, abundance, and trends	2015	6	TBD	1113(ES)
Develop a soil survey map	2020	6	n/a	NRCS (in process)
Evaluate known/potential Refuge cultural resources and historic sites	2020	8	TBD	1263
Conduct a comprehensive cultural resources investigation of both units	2020	8	TBD	1263
Threat mitigation:				
Remove all ungulates, nonnative mammalian predators, and dogs and cats at both units	2015	1-5	TBD	1113(ES)
Establish a fire prevention program (includes signage, education, fire closure criteria) at both units	2020	1, 3	TBD	1263
Control or eradicate invasive plants at both units	2025	1, 2, 3	build 600 sq ft storage building for materials $100,000	ISST, USFS, 1262
Research (note additional projects in partnering projects section):				
Investigate methods for forest regeneration and reforestation techniques	2020	6	TBD	USFS
Conduct research to determine arthropod abundance	2020	6	TBD	USGS
Conduct research to determine species-specific thresholds for disturbances from Refuge uses such as outplanting and bird watching activities	2020	6	TBD	1113(ES), USGS
Conduct an investigation to identify and quantify avian and plant disease issues	2020	6	TBD	1113(ES), USGS
Research demography, life-history, carrying capacity, and competition for native forest birds	2015	6	$340,000	1113(ES), USGS

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
Support research to determine ecological parameters for ʻōpeʻapeʻa	2020	6	TBD	1113(ES), USGS
Complete global climate change impacts assessment for the Refuge	2020	6	TBD	PICCC
Facilities development:				
Establish native plant nursery at field camp site at KFU	2020	1	$35,000	1113(ES), PEPP
Expand native plant nursery at administration site at HFU	2015	3	$14,000	1113(ES), PEPP
Develop 0.3-0.5 mile wildlife trail with interpretive signs and associated parking area on the Upper Maulua Tract	2020	7	$77,757 (signs and kiosk)	1263, Friends of Hakalau Forest (NFWF),VFE
Public Use:				
Develop interpretive brochures	2015	7	TBD	1263, Friends of Hakalau Forest (NFWF), 8081,VFE
Develop and expand interpretive programming relative to cultural resources and historic sites	2020	7	TBD	1263, 8081, VFE
Coordinate with County, State, and NGO partners for offsite environmental education opportunities, including Kīpuka 21	2020	7	$30,000	CCS, NFWF, 1113(ES)

Table C-2. Recurring Costs Related to CCP Implementation.

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
Operational (Recurring) Costs ***Note that cost estimate = annual costs and Year 2025 indicates ongoing for 15 years***				
Threat mitigation:				
Control or eradicate invasive plants at both units	2025	1-5	$150,000 annual; $200,00 every 5th year;	USFS Forest Health, USFWS/ISST, 1113 (ES), 1261,1262
Control or eradicate pest animals (e.g., ungulates, invertebrates, cats/dogs, rats, mongooses, etc.) at both units	2025	1-5	$250,000/year	USFS Forest Health, USFWS/ISST,1261, 1113(ES)
Conduct hazardous fuels treatment to reduce threats from wildland fires at both units	2025	1, 3	TBD	9264, 1262
Maintain fire prevention program (includes fuel breaks and education) at both units	2025	1, 3	$ 40,000/year	1262, USFS Forest Health, 9264
Conduct annual surveys for invasive species (absence/presence and percent cover) at both units	2025	1-5	$35,000/year	USFS Forest Health, USFWS/ISST
Conduct surveys for pest animals such as ungulates, nonnative mammalian predators, invertebrates, cats and dogs at both units	2025	1-5	TBD	USFS Forest Health, USFWS/ISST,1261, 1113(ES)
Species and Habitat restoration and protection:				
Outplanting endangered plants at both units	2025	1, 3	$15,000/year	USFS Forest Health, USFWS/ISST, 1261, 1113(ES)
Outplant common native plants for reforestation and restoration at both units	2025	1, 3	$10,000/year	USFS Forest Health, USFWS/ISST, 1261, 1113(ES)
Research: note additional projects in partnering projects section				
Surveys, inventories, and monitoring:				
Continue annual Hawai‘i Forest Bird Surveys	2025	1-6	TBD	USGS and partners
Survey for endemic invertebrates at HFU ponds	2025	4	TBD	1261,1113(ES)

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate	Potential fund source
Test water quality for reduced levels of disease, sediments, contaminants (e.g., fecal coliform)	2025	4	TBD	1261,1113(ES)
Annual transect surveys to monitor species and habitat response to management actions	2025	1-6	TBD	1261,1113(ES)
Monitor nesting density and success of nēnē	2025	6	$35,000/year	1261,1113(ES)
Monitor plant and animal disease (e.g., ‘ōhi‘a rust, koa wilt, avian malaria and pox)	2025	6	TBD	1261,1113(ES)
Monitor global climate change parameters (e.g., temperature, CO2, etc.)	2025	6	TBD	1261,1113(ES), PICCC
Monitor public uses (e.g., disturbances)	2025	6	TBD	1261,1113(ES)
Investigate and monitor endangered plant propagation and outplanting strategies	2025	6	TBD	1261,1113(ES)
Conduct surveys to determine role of predators in native flora and fauna abundance	2025	6	TBD	1261,1113(ES)
Public Use:				
Administer volunteer program and develop partnerships to support nursery and outplanting program within 7 years at KFU	2017	1	$15,000/year	1263,8081, VFE
Maintain volunteer program at HFU	2025	7	$150,000/year	1263, 8081, VFE
Provide 35-40 weekend-long service opportunities with partner organizations	2025	7	See above	1263, 8081, VFE
Maintain annual open house	2025	7	$3,500/year	1263, 8081, VFE, Grants

Activity	5-year intervals: 2015, 2020, 2025	CCP Goals	Cost Estimate (numbering = priority level)	Potential fund source
***Facilities maintenance**:*				
Maintain (include both repair and replacement costs) existing fences (45 miles in units 1-8), new fences (KFU and units A-F at HFU), endangered plant exclosures, *Carex* bog fencing; 15 acre nēnē breeding site	2025	1-5	See deferred maintenance table below for some cost, others TBD	DM
Maintain existing structures (roads, parking area, trail, signage, cabins, nurseries, bunkhouse, power supply building, garage, storage sheds, equipment storage building, utilities, vehicles	2025	All goals	See deferred maintenance table below for some cost, others TBD	DM
Maintain administrative office (rent, computer equipment, utilities, etc.)	2025	All goals	$90,000/year	1261,1262,1263

B. Maintenance costs

The maintenance need over the next 15 years is defined as funds needed to repair or replace building, equipment, signs, facilities and other structures. Maintenance includes preventative maintenance, cyclical maintenance, repairs, replacement of parts, components, or items of equipment, adjustments, lubrication, cleaning of equipment, painting, resurfacing, rehabilitation, special safety inspections, and other actions to assure continuing service and to prevent breakdown. Maintenance costs include the maintenance “backlog” – maintenance needs that have come due but are yet unfunded, as well as the increased maintenance need associated with facilities and infrastructure.

The facilities and maintenance currently associated with Hakalau Forest NWR include management of (unpaved) roads, parking area, cabins, nursery, bunkhouse, power supply building, garage, storage sheds, equipment storage building, and utilities. Proposed new facilities and infrastructure include an interpretive walking trail, parking area, signage (for interpretive, Refuge welcome and identification, and fire purposes), and an additional nursery at KFU as well as expanded nursery at HFU.

Maintenance costs comprised approximately 28 percent of the total FY2010 Refuge budget.

Table C-3. Deferred Maintenance and Construction Projects.

Rank	Project	Estimated Cost
Capital Improvement		
1	Construct a fence to exclude cattle and pigs from the 1,800-acre Middle Maulua Feral Ungulate Management Unit (Unit 9). Approximately 32,000 ft of fence is required. Cattle and pigs will be removed from the exclosure to enable recovery of native vegetation as habitat for six species of endangered plants and provide optimal habitat for eight species of endangered birds and the endangered ‘ōpe‘ape‘a.	$ 334,000
2	Construct clear directional and entrance signs and a kiosk with welcoming and orienting information to meet public use standards for visitors. The kiosk will provide a map and visitor orientation information on the Service’s mission, Refuge goals, Refuge wildlife, and habitat management. This Refuge receives between 1,500-3,500 visitors per year but currently has no visitor facilities.	$ 77,757
3	A contractor will be hired to fence 1,800-acre North Lower Maulua Unit to exclude ungulates. Approximately 42,000 ft of fence is required. Ungulates will be removed from the exclosures to enable recovery of native vegetation as habitat for six species of endangered plants and provide optimal habitat for eight species of endangered birds and the endangered ‘ōpe‘ape‘a.	$ 482,000
4	A contractor will be hired to fence 1,800-acre South Lower Maulua Unit to exclude ungulates (Figure 2-1). Approximately 23,000 ft of fence is required. Ungulates will be removed from the exclosures to enable recovery of native vegetation as habitat for six species of endangered plants and provide optimal habitat for eight species of endangered birds and the endangered ‘ōpe‘ape‘a.	$ 264,000
5	Construct a 600 square ft hazardous materials and fuel storage building for safe storage of materials such as paint, pesticide, and petroleum projects. The structure will reduce fire hazards and increase safety.	$ 100,000
6	A contractor will be hired to fence seven new management units (Figure 2-1) totaling 13,200 acres to exclude ungulates. Approximately 199,000 ft of fence is required. Ungulates will be removed from the exclosures to enable recovery of native vegetation as habitat for six species of endangered plants and provide optimal habitat for eight species of endangered birds and the endangered ‘ōpe‘ape‘a.	$ 697,000
Deferred Maintenance		
1	Rehabilitate 6.45 miles of fence surrounding the Shipman Feral Ungulate Management Unit. The fences exclude ungulates from native rain forest that provides habitat for eight endangered bird species, the endangered ‘ōpe‘ape‘a, nine species of endangered plants, and a wide diversity of other Hawaiian plants and animals.	$ 140,000
2	Rehabilitate 2.38-mile Frog Pond Road, which provides access to portions of the Shipman and Upper Honohina Management Units. The project will provide all-weather access to facilitate wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that will benefit 15 endangered species.	$ 321,900

Rank	Project	Estimated Cost
3	Rehabilitate 2.5-mile Alleyway Road, which provides access to the Upper, Middle, and Lower Honohina Units and the northern portion of the Middle Hakalau Unit. Repairs will provide all-weather access to maintain upland habitat in desired condition by facilitating critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that will benefit 15 endangered species.	$ 319,300
4	Rehabilitate 4 miles of eroded dirt road that provides access to the upper portions of the Pua ʻĀkala, Hakalau, and Honohina Tracts. Repairs will provide all-weather access to maintain upland habitat in desired condition by facilitating wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that will benefit 15 endangered species.	$ 511,700
5	Rehabilitate the 2.1-mile fence surrounding the Pua ʻĀkala Feral Ungulate Management Unit. The fence will exclude ungulates from 500 acres of upland native rain forest habitat used to maintain populations of eight endangered bird species, the endangered ʻōpeʻapeʻa, and nine species of endangered plants.	$ 120,100
6	Rehabilitate 0.6 miles of road on a private lands easement to allow access to the KFU. Repairs will provide all-weather access to maintain upland habitat in desired condition by facilitating fence maintenance, ungulate control, weed removal, and wildlife population monitoring, which will help lead to the recovery of 17 endangered species.	$ 56,500
7	Remove 12.12 miles of abandoned barbed wire fences on the HFU. These fences were erected during the ranching operations of previous landowners. They are all in poor condition and no longer functional. The fences impede access by staff engaged in weed and ungulate control, interfere with tree planting and wildlife viewing by visitors, and are a safety hazard when the wire becomes hidden by grass or tangled in vegetation.	$ 230,500
8	Rehabilitate dilapidated 115-year-old Pua ʻĀkala Cabin and outbuilding to preserve the historic structures. A November 2002 Architectural Survey by the National Park Service contractors concluded that Pua ʻĀkala Cabin and outbuilding are eligible for the National Register of Historic Places and that immediate steps should be taken to prevent further deterioration.	$ 583,400
9	Rehabilitate 1.87-mile Hakalau Stream Road, which provides access to the midsection of the Shipman Management Unit. Repairs will provide all-weather access to maintain upland habitat in desired condition by facilitating fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting to benefit 15 endangered species.	$ 341,000
10	Rehabilitate 2.87 mile Nauhi Road, an eroded dirt road that provides access to Nauhi Cabin and 3 management units. Repairs will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting to benefit 15 endangered species.	$ 378,000

Rank	Project	Estimated Cost
11	Replace the photovoltaic system located in the Battery Building, which is used to generate electric power for eight Refuge-owned structures. The building itself is in good condition, but the photovoltaic subsystem is deteriorating and becoming increasingly unreliable. The photovoltaic subsystem directly supports activities that benefit endangered species.	$ 68,800
12	Rehabilitate 1.69-mile Pua ʻĀkala Road, which provides access to the midsection of the Pua ʻĀkala Management Unit. Project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that will benefit 15 endangered species.	$ 210,163
13	Rehabilitate 0.36-mile Honohina Cut-off Road, which provides access to the midsection of the Upper Honohina Management Unit. The project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting, which will benefit 15 endangered species.	$ 65,700
14	Repair 1 mile of Kona Forest's 4,800 ft road to provide daily and emergency access for staff. This project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as endangered species recovery, fence maintenance, ungulate control, weed removal and population monitoring.	$ 437,144
15	Rehabilitate 2.7-miles of Pedro Road, which provides access to the midsection of the Shipman Management Unit. The project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting which will benefit 15 endangered species.	$ 239,832
16	Repair Hakalau staff residence at the Administrative Site by repainting. The structure is a single-story, wood-frame building. The project will repaint the exterior walls, window frames, doors, decks, railings, and steps to protect them from the harsh weather. The staff residence provides housing and operation support for staff involved in habitat recovery work for native and endangered species.	$ 27,000
17	Rehabilitate Biological Resources Discipline Cabin. The cabin needs to be painted and plumbing fixtures (i.e., sink, shower and toilet) need to be replaced. The cabin is occupied by researchers, contractors, and volunteers who control nonnative species, repair fences and facilities, plant trees, and conduct biological surveys to recover 15 endangered species and conserve native plants and animals.	$ 27,099
18	Rehabilitate 1.9-mile Nobriga Road, which provides access to the midsection of the Upper Maulua Management Unit. Project will provide all-weather access to facilitate wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that will benefit 15 endangered species.	$ 270,033

Rank	Project	Estimated Cost
19	Rehabilitate 1.16-mile Halfway Road, which provides access to the midsection of the Upper Maulua Management Unit. The project will provide all-weather access to facilitate wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that benefit 15 endangered species.	$ 206,077
20	Rehabilitate 0.3-mile Freddy's Pond Road, which provides access to the midsection of the Upper Maulua Management Unit. The project will provide all-weather access to conduct critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that benefit 15 endangered species.	$ 54,900
21	Rehabilitate 1.45-mile Bottom Road, which provides access to the midsection of the Upper Maulua Management Unit. The project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that benefit 15 endangered species.	$ 180,318
22	Rehabilitate 1.01-mile Maulua/Piha Road, which provides access to the Upper Maulua Management Unit. The project will provide all-weather access to facilitate critical wildlife and habitat management efforts such as fence maintenance, pig control, weed removal, population monitoring, biological research, and tree planting that benefit 15 endangered species.	$ 179,430
	Road Improvement Projects	
	Condition assessment for Maulua Road (Rte. 100) based upon inventory of 4/21/2004 found the road to be in poor condition. Cost estimate to correct deficiencies in the 0.41 miles of road.	$ 494,628
	Assessment was performed on Asset #10042056 (Pua ʻĀkala Road). Assessment Documents are located at Regional Office. Material cost was $524,385. Labor cost was $0. Total item cost was $524,385. Repair total was $524,385. Assessor notes said FHA condition rating poor.	$ 524,385
	FHWA condition assessment for Administrative Access Road (Rte. 102) based upon inventory of 4/7/2004 found the parking area to be in poor condition. Cost estimate to correct deficiencies in the 0.34 miles of road.	$ 434,856
	Conduct CCA on Asset #10042145 (Hakalau greenhouse loop road). Assessment was performed on 4/21/2004 and Assessment Documents are located at Regional Office. Material cost was $179,870. Labor cost was $0. Total item cost was $179,870. Repair total was $179,870. Assessor notes said FHA condition rating poor.	$ 179,870
	Conduct CCA on Asset #10042102 (Pua ʻĀkala cabin road). Assessment was performed on 4/21/2004 and Assessment Documents are located at Regional Office. Material cost was $243,008. Labor cost was $0. Total item cost was $24,3008. Repair total was $243,008. Assessor notes said FHA condition rating poor.	$ 243,008
	FHWA condition assessment for Pua ʻĀkala Parking (Rte. 900) based upon inventory of 4/14/2004 found the parking area to be in fair condition. Cost estimate to correct deficiencies in the 7,564 sq. ft of parking area.	$ 8,849

Rank	Project	Estimated Cost
	FHWA condition assessment for New Housing Parking (Rte. 902) based upon inventory of 4/7/2004 found the parking area to be in fair condition. Cost estimate to correct deficiencies in the 4,396 sq. ft of parking area.	$ 5,144
	FHWA condition assessment for Housing Parking (Rte. 903) based upon inventory of 4/7/2004 found the parking area to be in fair condition. Cost estimate to correct deficiencies in the 9,002 sq. ft of parking area.	$ 10,531
	FHWA condition assessment for Greenhouse Parking (Rte. 904) based upon inventory of 4/7/2004 found the parking area to be in fair condition. Cost estimate to correct deficiencies in the 4,134 square feet of parking area.	$ 4,134

D. Staffing

Necessary staffing as projected by the Service's National Staffing Model generated 15 positions for Hakalau Forest NWR (Big Island NWR Complex). The existing, core-funded staff is only 7; therefore the Refuge is 8 additional positions under necessary conditions to effectively fulfill current obligations and agreements based on anticipated workload with the existing land base of 38,030 acres. Dedicated staffing for the KFU was initially established after acquisition and later eliminated years ago due to legal disputes over access to Refuge lands. Some previously established positions were temporarily reassigned and not returned. Access issues have since been resolved and work on the KFU, starting with boundary clearing, has resumed using staff stationed at Hilo. However, given the long distance to KFU (it takes 2.5 hours one-way from Hilo), this further stretches available Refuge staff resources as KFU activities come on line, compromising the success of efforts to date such as greenhouse operation, ungulate control, and invasive species control efforts, with less time spent at HFU. Restoring staffing levels to a "critical mass" to also manage the KFU is a key aspect of our planning effort. The additional staffing would provide increased coordination with other Federal, State, and local agencies, neighboring landowners, and local communities; additional capacity to conduct biological inventory, monitoring, and research; improved maintenance capability for visitor facilities and Refuge buildings; visitor safety and law enforcement to reduce wildlife disturbance; environmental education and interpretation of Refuge resources; and invasive species control.

The table below outlines permanent staffing needs considered core to implementing the CCP (numbering does not indicate priority). The table outlines salary/benefits for each position. These costs are considered recurring (annual) costs. For 2010, projected staffing costs for full-time and term employees were expected to comprise 86 percent of the base budget although significant staff turnover and resulting salary savings resulted in only 67 percent of the base being used for staffing during the fiscal year.

Table C-4. Current and Proposed Staffing to Implement CCP*.

Staff position	GS & grade	Annual cost (salary & benefits)	Funding source
1. Refuge Manager	GS-13	$127,922	1261,1263
2. Deputy Refuge Manager	GS-12	$110,557	1261,1263
3. Wildlife Biologist	GS-12	$107,570	1261
4. Horticulturist	GS-11	$ 87, 254	1261
5. Maintenance Supervisor	WS-4	$ 84,737	1262
6. Maintenance Worker Leader	WG-8	$ 73,917	1262
7. Administrative Officer	GS-9	$ 76,241	1261,1263
8. Park Ranger/Volunteer Coordinator (HFU)	GS-5/7/9	$117,598	FY10-1992
9. Maintenance/Pest Control Worker (HFU)	WG-5/6	$84,583	FY08-5988
10. Maintenance/Pest Control Worker (HFU)	WG-5/6	$84,583	FY08-5971
11. Maintenance/Pest Control Worker (HFU)	WG-5/6	$84,583	FY08-5989
12. Maintenance Worker (HFU)	WG-5/6	$84,583	FY08-5989
13. Wildlife Biologist/GIS	GS-9/11	$142,274	FY08-6703
14. Budget Technician	GS-5/6	$77,165	FY08-6702
15. Wildlife Refuge Specialist	GS-9/11	$142,000	FY08 5965
16. Maintenance/Pest Control Worker (KFU)	*WG 5/6*	*$84,583*	*FY08-6709*
17. Maintenance/Pest Control Worker (KFU)	*WG 5/6*	*$84,583*	*FY08-5990*
18. Maintenance/Pest Control Worker (KFU)	*WG 5/6*	*$84,583*	*RONS*
19. Park Ranger/Volunteer Coordinator (KFU)	*GS-5/7/9*	*$120,000*	*RONS*
20. Visitor Services Specialist	*GS-5/7*	*$90,000*	*RONS*
21. Wildlife Biologist (KFU)	*GS-5/7/9*	*$120,000*	*FY08-5965*
22. Park Ranger/Law Enforcement (HFU)	*GS-5/7/9*	*$120,000*	*FY10-1292*
23. Park Ranger/Law Enforcement (KFU)	*GS-5/7/9*	*$120,000*	*FY10-1293*
24. Office Assistant	*GS-4/5*	*$65,000*	*RONS*
25. Fuels Specialist (Fire)	*GS-9/11*	*$142,000*	*RONS*
26. Horticulturist	*GS-11*	*$142,000*	*RONS*

*Shaded cells indicate positions that are currently approved and filled. Highlighted cells indicate permanent full time positions needed under current management (based on the National Staffing Model). Italicized positions indicate additional staff required to implement the CCP.

Partnering Projects

Current funding at Hakalau Forest NWR cannot meet all management needs. As a result, we rely on working with various partners to assist with implementation. The projects identified below are potential research and resource management actions and opportunities proposed by partner organizations and academic investigators as well as include Service database projects currently used for budget purposes. If pursued, these projects will be opportunistically pursued through internal and external funding sources. Following is a brief list of unranked projects which could assist the Refuge with implementing portions of its CCP. Adaptive approaches to meeting our funding needs will be applied throughout the plan period to achieve Refuge objectives.

A) Forest bird survey training workshop

To support goal six and objective "annual transect surveys to monitor species and habitat response to management actions," funding is needed to host and coordinate a forest bird survey/training workshop to increase the number of qualified forest bird surveyors available to monitor population trends of these endangered species. With projected climate change impacts expected to severely affect Hakalau Forest NWR birds and habitats, it is essential to improve our collective capacity to document and detect gradual changes and trends in populations. The high elevation old growth koa/'ōhi'a forests at Hakalau are largely considered one of the best remaining refugia for these species.

Based on results of a forest bird workshop held in October 2008, the need for replacing older, more experienced observers who have retired or are soon to retire from the field with a younger or expanded cadre of capable field biologists to carry on decades of specialized survey efforts is an acute crisis that needs to be addressed. Hakalau Forest NWR is uniquely situated to host such an exercise due to its complement of endangered birds, available facilities on site to train and house participants, long-history of established bird transects and readings, and ease of transportation to and from airport facilities. This would be an interagency initiative with invitations to USGS-BRD, the Service, DOFAW, UH, USFS, nongovernmental organizations, and private sector specialists in Hawaiian bird conservation, as well as nominated/sponsored trainees with basic field proficiencies all participating. Appropriate species experts would conduct the training. Funding would be available to support travel needs of participants, training equipment, materials, and supplies in the field. The desired outcome would be to increase the number of available forest bird monitors/surveyors in partner agencies and organizations and spur the potential for the next generation of forest bird experts to take over this essential function.
Cost estimate: $57,000

B) Population dynamics and viability of 'ākepa and other species in Hakalau Forest NWR: Influences of management, environmental factors, and potential nonnative competitors

Identify changes in trends of Hakalau birds with best available models. Evaluate the best models to estimate trend and viability of monitored Hakalau birds using stochastic models. Evaluate uncertainty in estimates of trend and viability metrics and partition this variation into its sources, including model form, estimation method, parameter estimation, etc., to assist managers in reducing uncertainty in viability predictions. Set up viable population monitoring (VPM) for managers to monitor changes in short-term viability of Hakalau birds. Evaluate methods for improving predictions of models, including habitat characteristics, oceanic condition indices, weather, predator/parasite indices, global climate change forecasts, etc. Cluster spatial locations surveyed across each of the reforested pastureland, open forest, and closed forest regions for reanalysis as spatial replicates to estimate dynamics of Hakalau birds using the best models identified.

Estimate the magnitude of the effect of increasing abundance of Japanese white eyes on ‘ākepa over the past 20 years by applying the best available models to annual population estimates for both species in closed forest and open forest regions of the Refuge. Evaluate effects of habitat restoration using best models above applied to spatial replicates identified above.

Organize, train, supervise, and provide logistical support for observers. Conduct and analyze paired observer variable circular plot survey to obtain unbiased abundance estimates for endangered, native and nonnative bird species occupying upper elevation newly reforested abandoned pasture lands and mid-elevation open forest and closed forests of Hakalau NWR.
Cost Estimate: $140,000

C) Foraging ecology and competition among native and nonnative forest bird species at Hakalau Forest NWR

A detailed knowledge of feeding ecology is important to the conservation of Hawaiian forest bird populations and their habitats. Recent studies have indicated that populations of many feeding specialists have declined historically, in part because food webs have been disrupted by nonnative species. A wide range of nonnative species have been identified as potential competitors for important foods of Hawaiian forest birds; nevertheless, much attention has focused on the role of nonnative bird species, particularly the introduced Japanese white-eye, which is a widespread and generalist forager.

Studies have inferred the existence of competition between native forest birds and Japanese white-eyes through analyses of population distributions, demographic changes, or reductions in juvenile sizes and weights of native species. Claims that the foraging behavior of Japanese white-eyes and native bird species overlap sufficiently to be causing food limitation, leading to a severe decline in numbers of ‘ākepa at Hakalau Forest NWR need to be further evaluated. A quantitative evaluation of the degree of overlap between forest bird species in foraging behavior or the use of resources will be useful in this evaluation.

Preliminary analyses of fecal samples from Hakalau Forest NWR indicate relatively little overlap between native and nonnative bird species in the use of arthropod prey (U.S. Geological Survey unpublished data). Additional research is needed on the foraging behavior of bird species. In particular, it is important to determine the degree of overlap in the use of habitat types, plant species, and foraging substrates (e.g., foliage, small branches, large branches, etc.). Results from these studies will help managers evaluate threats from nonnative species and assess their options for protecting populations of endangered bird species.

Research will identify the means by which forest bird species at Hakalau Forest NWR obtain food over time and space, determine how bird species partition resources, and directly assess the extent to which species may compete for food due to overlapping niche requirements. This research will evaluate overlap among species in the use of:

1. habitat types (e.g., old-growth forest, planted koa stands, other plantings);

2. plant species (e.g., canopy tree species, understory species, rare species);
3. foraging substrates (e.g., foliage, branches);
4. foraging maneuvers (e.g., gleaning, probing); and
5. food types (e.g., nectar, fruit, arthropods).

To investigate forest bird foraging behavior, we will first identify the most effective methods for observing birds and scoring their behavior. Bird behavior will be recorded while narrating behavioral events. Recorded sessions will be transferred to computers and behaviors will be scored later for analysis. Both methods require close tracking of individual birds under conditions that frequently make bird behavior difficult to interpret; nevertheless, videography offers at least the promise of being able to review questionable behaviors multiple times, whereas without it, the observer's initial interpretation is the final interpretation.

Appropriate criteria for distinguishing habitat types across Hakalau will be established. Old-growth forest (both ‘ōhi‘a and mixed ‘ōhi‘a-koa), planted stands of koa, and patches of other planted species (e.g., *Clermontia pyrularia*, *Cyanea shipmanii*) will be determined. Each observation will be georeferenced using GPS, and forest community structure and composition will be characterized. Foraging data will be collected near established bird survey stations to relate the foraging behavior of particular species to the historical values of the frequency of occurrence and abundance of the same or other species.

Plants species on which birds are foraging will be recorded. The foraging height of birds in the forest (e.g., canopy, subcanopy, and understory) would also be noted along with the species of tree, shrub, or epiphyte in which the bird is feeding. Substrates on which birds are foraging would be designated by various categories, including foliage, terminal branches (i.e., twigs), medium branches (< 3 cm diameter), large branches, and trunks. Finally, a characterization of the types of foods being exploited, including nectar, fruit, and arthropods is required.
Cost Estimate: $50,000/year, $200,000 total

D) Avian disease distribution and climate change

To support Goal 6 and objective "monitor plant and animal disease (e.g., ‘ōhi‘a rust, koa wilt, avian malaria and pox)", a related subset of this strategy is research into climate change and avian disease distribution at Hakalau Forest NWR. Avian disease and their mosquito vectors have not been sampled at the Refuge since 1999. More than 300 native and nonnative birds were sampled at high elevation Nauhi Camp, and mid-elevation Maulua and Pua ‘Ākala in 1998 and 1999 for avian malaria, and detailed mosquito surveys were conducted at mid-elevation sites. This baseline data on disease prevalence provides a reference point for measuring changes in malaria prevalence under changing climatic conditions. Since that time a temperate mosquito, *Aedes japonicus*, has become established on the island and malaria prevalence has increased elsewhere in the islands.
Cost Estimate: TBD

E) Climate change assessment and development of management options for endangered species on NPS and Service lands in Hawai‘i

In supporting the development of Land Protection Planning and related species/habitat research under goals 1, 5, and 6, working with the Pacific Islands Climate Change Cooperative will be key.

The effects of climate change on Hawaiian ecosystems and species is considered a significant priority by land management agencies in Hawai‘i. This project seeks to provide land managers with the information they need to manage their biological resources. USGS recently completed a climate model for the Hawai‘i region to:

- Map the predicted 2100 AD distributions of important management species from Haleakalā National Park and Hakalau Forest NWR (e.g., endangered species, forest dominants, and key invasive species);
- Assess the impacts of climate change on these species; and
- Develop options for land managers to mitigate the effects of climate change on endangered species and their habitats.

Recent USGS funded regional climate models provide the basic physical inputs that will be used to modify existing species distribution models and then predict future potential distributions for endangered Hawaiian plants and birds. Future and current distributions of each species will be compared. Each species will be independently assessed to determine the relative risk that a changing climate poses to it. Options to mitigate or minimize these risks will be developed and assessed for their likelihood of succeeding. Land management scientists will be integral members of the research team. The resulting maps of species distributions, risk assessments, and potential management options will be directly applicable to the management of these two areas and those responsible for management of the target species. Land and species managers of adjacent state and private lands will also benefit from these results. This study is directly relevant to the National Climate Change and Wildlife Science Center charge, USGS Science Strategy, the DOI climate change strategy, Service needs, and National Park Service needs.

This project will assess the impacts of climate change to Federally threatened and endangered species in two, highly-significant biodiversity reserves: Haleakalā National Park on Maui and Hakalau Forest NWR on the Island of Hawai‘i. Following the assessment, the project will focus on developing mitigation options and then evaluating their likelihood of success. Land managers from these two areas have identified a number of key information needs.

The primary issues of concern for Hakalau Forest NWR deal with how endangered and native species are affected by changing temperature and rainfall patterns and how avian disease distributions and prevalence change as climate changes. Additional issues of concern include how climate change will impact the spread of invasive weeds as well as change fire cycle regimes.
To address key management and information needs the project will focus on three major areas:

1. Use a recently completed statistical downscaled climate change projections for the Hawai‘i region to predict the 2100 AD potential distributions of species of management concern; specifically:
   a. All Federally endangered plants and birds known from Haleakalā National Park (24 species) and Hakalau Forest NWR (12 species);
   b. Additional Federally endangered plants known from areas adjacent to Haleakalā National Park (11 species) that are likely to have new habitat created in the Park;
   c. Key forest dominants for Haleakalā National Park (4 species) and Hakalau Forest NWR (4 species);
   d. Key invasive species that pose threats to Haleakalā National Park and Hakalau Forest NWR (6 species); and

   e. ʻIʻiwi, a nonendangered but recently declining endemic forest bird, shared by Haleakalā National Park and Hakalau Forest NWR.

2. Assess how predicted climate changes are likely to affect the habitat and population viability of Haleakalā and Hakalau's endangered species and other management species.

3. Work with Haleakalā and Hakalau to develop management options for land managers to mitigate the effects of climate change on their species and habitats.

Expected Products:

- Updated moisture availability base layer for the islands of Maui and Hawaiʻi;
- Species distribution maps for all threatened and endangered species, forest dominants, a common flagship bird species, ʻiʻiwi, and key invasive species threats for Haleakalā National Park and Hakalau Forest NWR;
- Maps will show three spatially explicit types of habitat:
  - Currently unsuitable habitat that becomes suitable by 2100AD;
  - Current habitat that remains suitable in 2100 AD; and
  - Current habitat that becomes unsuitable by 2100 AD;
- Assessment of each species and its habitat with respect to physical or land use barriers to migration/colonization;
- Assessment of the potential for endangered species from adjacent properties to move on to Park and Refuge lands; and
- Comparison of potential management options with respect to their ability to provide for the recovery of listed species.

Cost Estimate: 3 years @ $273,000 (average cost/yr). Total funding needed: $818,000

F) Conduct endangered and threatened plant survey, HFU

Some of the rarest plants in the world are known from the eastern slopes of Mauna Kea including Hakalau Forest NWR. Very little of the Refuge has been adequately surveyed for rare plants. Currently, 18 rare plant species, including endangered, threatened, and species of concern, are known from the Refuge's 33,000 acres. Botanists will conduct rare plant surveys in unsurveyed areas of the Refuge. Rare plant locations will be gleaned from existing data and maps from the Hawaiʻi Forest Bird Surveys. Plants will be plotted using a hand held GPS unit, inputted into ArcView data base and mapped. Due to the higher plant diversity and greater numbers of rare plant species, the survey will begin in the Middle and Lower Maulua and the Lower Honohina Units of the Refuge to determine locations of rare plants on the Refuge and recommend means to protect them from the destructive forces of feral ungulates and rats. Once found, the plants can be propagated and outplanted to assist in the recovery of the species. Conduct/contract for a rare plant search/survey, especially for mid-elevation portions of the Refuge, focusing initially on the Middle Maulua Unit.
Cost Estimate: $260,000

G) Invasive weed control and monitoring efforts at Hakalau Forest NWR

This proposal requests $150,000 annually for 5 years to continue control efforts for Florida blackberry and other invasive weed species at Hakalau Forest NWR. A 5-year management plan is currently in preparation to facilitate multiyear funding for this program. The funds will be used to contract for labor and equipment and to purchase herbicide to spray blackberry and other invasive species. Backpack sprayers will be used to spray patches of blackberry scattered throughout the forest. The contractor will also be asked to provide a tractor-mounted spray rig (with two spray wands) for use on larger patches located in more accessible areas within the grasslands and upper edge of the forest. The Refuge will direct the contractor where to spray, provide herbicide, provide water at minimal distance to the operational area, and do everything possible to maximize efficiency. Concurrently, Refuge staff will continue their blackberry control efforts (spray application of herbicide, pig control and reforestation) at similar levels to those of the past few years. Outlying blackberry colonies will receive highest priority for eradication. As the periphery is controlled, the effort will constrict inward toward the core infestation, where blackberry patches reach their greatest size and density.

Monitoring will consist of continuing annual weed and ungulate surveys on established transect lines. Every fifth year a more intensive survey methodology will be applied to assess control efforts and make adaptive adjustments to the control approach. Progress of the blackberry eradication effort will be monitored though annual weed and ungulate surveys using established transect methods. Gross changes in distribution and abundance will be monitored through collection of presence/absence and density data within a contiguous series of 5 x 10 meter plots along the 17 transects. This will maintain the continuous series of data collected annually since 1995 and sporadically before that date. Continued funding for weed and ungulate surveys will be essential through the planning period, beginning in FY2010 and beyond.

Six endangered bird species (ʻakiapōlā’au, Hawai‘i ʻākepa, Hawai‘i creeper, ʻio, nēnē, and koloa maoli) the endangered ʻōpeʻapeʻa, six endangered plant species, and the diverse assemblage of other native plants and animals that inhabit the Refuge will all benefit from blackberry and other invasive weed species control efforts. Endangered and native plants will experience reduced competition for space, light and nutrients. Areas currently occupied by blackberry and other invasives will be recolonized by native plants that provide food and habitat for the native animals and plants the Refuge is mandated to protect. The absence of thorny blackberry thickets will facilitate fence maintenance, tree planting efforts, and the ability of staff and visitors to walk and work in the forest. The biodiversity and health of the native forest community will increase.

A weed control program will be established on the Kona Forest Unit to promote restoration of the forest understory to benefit native wildlife species. Intensive weed monitoring and control efforts at the Kona Forest Unit will require resources that are not currently available. It is hoped that during the plan period resources can be obtained that will make the program viable on the Kona Unit modeled loosely on what has been done at the Hakalau Unit (i.e., use of staff, partner and contractor resources as available).
Cost Estimate: $150K annually, $200,000 every 5th year

H) Predator exclusionary fence for nēnē nesting at Hakalau Forest NWR

Nēnē at Hakalau Forest NWR thrive well, except during breeding when predation on nēnē goslings by cats, mongooses, and possibly ʻio has been a problem. The current fences in the area are not working well. The fences are outdated, too small, and do not prevent predation. A 15-acre fenced exclosure will be built using predator proof fencing materials to reduce predation by terrestrial predators. Reproductive success is measured each year at Hakalau Forest NWR, and comparisons

between years will show changes in reproductive success once an exclusionary fence is installed. The objective of this project is to minimize predation of nēnē goslings at the Refuge.
Cost Estimate: $75,000

I) Fence Middle Maulua Unit at Hakalau Forest NWR

Construct a fence to exclude cattle and pigs from the 1,800 acre Middle Maulua Feral Ungulate Management Unit (Unit 9). Approximately 32,000 ft of fence is required. The Middle Maulua Unit is considered by Refuge staff to be the highest priority for additional fencing on the Refuge and is consistent with trying to remove ungulates from the next lowest elevation gradient on the Refuge as a priority for limiting forest bird exposure to mosquitos and thus avian malaria. Cattle and pigs will be removed from the exclosure to enable recovery of native vegetation as habitat for six species of endangered plants and provide optimal habitat for eight species of endangered birds and the endangered ʻōpeʻapeʻa.
Cost Estimate: $334,000

J) Expand greenhouse capacity at Hakalau Forest NWR

Additional greenhouse space is needed to provide room for propagation and outplanting of rare plants. A simple expansion of the existing greenhouse space is possible on an area already graded and previously used for equipment and vehicle storage but now available for use due to completion of a maintenance storage building project in 2010. Expanding the greenhouse program will increase carrying capacity for rare plants prior to outplanting on the Refuge.
Cost Estimate: $14,000

K) Install rare plant exclosures on the Kona Forest Unit

The Kona Forest Unit is expected to be fenced in the immediate future with funding previously obtained for the purpose. On the ground management in this area has thus far been minimal, but with access issues resolved and an approved fencing plan, immediate conservation gains may be realized. Within the three management units that will have permanent fencing, smaller temporary exclosures (1-5 acre) specifically set up for outplanting appropriate rare plant species indigenous to the area can be achieved by Refuge and partner organizations staff. As ungulate control efforts succeed in the area, the need for these subexclosures will diminish over time and plantings can extend to the rest of the Refuge unit.

Outplanting of propagules of geographically isolated individual(s) and/or population(s) found on similar habitats, and consolidating these relics at protected sites, preserves genetic diversity (maximize founder representation) within the species and ensures demographic persistence and stability for each species. The mixing of as many relic founders as possible can potentially reintroduce genetic vigor (viability) back into a population that suffers from the effects of genetic bottleneck (genetic drift).

The construction of several exclosure fences to exclude destructive nonnative animals is the necessary first step in the protection and recovery of the proposed federally listed as well as the rare to uncommon native Hawaiian plant species outplantings. The goal of these exclosure fences is to preclude nonnative animal ingress, thereby allowing the establishment of these outplantings enabling them to thrive within the protected units, ultimately providing a safe haven for these critically imperiled native plant species.

The Plant Extinction Prevention program (PEP) (formerly the Genetic Safety Net) operates under several directives of which the chief directive is to secure seeds and/or cuttings (propagules) of the rarest and most critically endangered native plant species regardless of their Federal status listing. The most critically imperiled native plant species are ones that are currently known to have less than 50 individuals in the wild and are on-the-brink of extinction. Surveying, monitoring, and collecting material for propagation from the remaining wild individual(s)/population(s) of PEP species are the primary activities mandated by this program. The preservation of these species through collection, storage and propagation ensures genetic representation for the future.

Another goal of this program is to ensure that these on the brink of extinction plant species are protected from major threats in a manner consistent with Federal and State laws and regulations. Working cooperatively and developing long term partnerships with the Hawaiʻi Department of Land and Natural Resources, National Park Service, U.S. Army, The Nature Conservancy, Three Mountain Alliance, Kohala Watershed Partnership, and private landowners will help to identify potential refugia and recommend (and provide) the implementation of conservation management actions (fencing, nonnative animal and plant removal, restoration, outplanting, and monitoring). These newly identified protected sites can serve as the repatriation point sources that will ensure the long term potential survival of these species.
Cost Estimate: $25,000

L) Investigate the impact of rats on forest birds and habitat and develop indices for rat population monitoring and control methodology for the Refuge

Studies to investigate the impact of rat predation on forest birds at Hakalau Forest and development of appropriate site specific rat population indices and control measures for Hakalau are needed to assist refuge management in addressing this threat. Previous efforts have not been conclusive and require follow up. In addition, no exclosure design has been applied at Hakalau to assess the efficacy of rat control and exclusion as a means of enhancing nesting success for forest bird species.
Cost Estimate: $ 100K/year for 3 years

M) Remove invasive rats from an 1,000 acre area in Unit 2

Rats are known to be predators of native forest birds as well as waterbirds. They are also known to consume native seeds. Removal of this threat will aid in recovery of these listed species as well as inform on project L above.
Cost Estimate: $ 195,000 (FY08-6055)

Monitoring CCP Implementation

Successful implementation of this CCP relies on our ability to secure funding, personnel, infrastructure, and other resources to accomplish the strategies identified. Monitoring of CCP implementation has been described in part of the costs analysis above as well as part of the strategies where a time element is identified. Additional ways in which the CCP implementation will be integrated with existing Service processes include budget requests tied into CCP goals, objectives, and strategies (e.g., RONS, SAMM, etc.), workplans, staff performance evaluations, and continued engagement with partners and the larger public who have helped to develop this CCP. Where feasible, 5-year updates (possibly on the Refuge website or continuation of planning updates) can be considered. CCP implementation will also follow adaptive management per policy 602 FW 1 and 522 DM 1.

As part of implementing the CCP, step-down management plans have been identified. These plans are the formulation of detailed plans for meeting goals and objectives identified in the CCP. All step-down plans require appropriate NEPA compliance and implementation may require additional permits. Project-specific plans, with appropriate NEPA compliance, may be prepared outside of these step-down plans. Step-down plans for the Refuge are as follows:

Step-Down Plans Identified in CCP Strategies:

Land Protection Plan	2011
Inventory and Monitoring Plan	2013
Cultural Resources Management Plan	2014
Proposed Wilderness Study	2015
Visitor Services Plan	2020

Appendix D. Wilderness Review for Hakalau Forest National Wildlife Refuge

General Information on Wilderness Reviews

Wilderness review is the process used to determine whether or not to recommend lands or waters in the Refuge System to the Congress for designation as wilderness. Planning policy for the Refuge System (602 FW 3) mandates conducting wilderness reviews every 15 years through the Comprehensive Conservation Planning (CCP) process.

The wilderness review has three phases: inventory, study, and recommendation. After first identifying lands and waters that meet the minimum criteria for wilderness, the resulting wilderness study areas (WSA) are further evaluated to determine if they merit recommendation from the Service to the Secretary of the Interior for inclusion in the National Wilderness Preservation System (NWPS). Areas recommended for designation are managed to maintain wilderness character in accordance with management goals, objectives, and strategies outlined in the final CCP until Congress makes a decision or the CCP is amended to modify or remove the wilderness proposal. A brief discussion of wilderness inventory, study, and recommendation follows.

Wilderness Inventory

The wilderness inventory consists of identifying areas that minimally meet the requirements for wilderness as defined in the Wilderness Act of 1964 (Wilderness Act). Wilderness is defined as an area which:

- Has at least 5,000 acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition, or be capable of restoration to wilderness character through appropriate management at the time of review, or be a roadless island;
- Generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable;
- Has outstanding opportunities for solitude or a primitive and unconfined type of recreation; and
- May also contain ecological, geological, or other features of scientific, educational, scenic, or historic value. These features and values, though desirable, are not necessary for an area to qualify as a wilderness.

Wilderness Study

During the study phase, lands and waters qualifying for wilderness as a result of the inventory are studied to analyze values (ecological, recreational, cultural, spiritual, economic), resources (e.g., wildlife, water, vegetation, minerals, soils), and uses (habitat management, public use) within the area. These values, resources, and uses are analyzed to determine whether the refuge can be managed effectively to achieve its purposes while also preserving wilderness character. The findings of the study determine whether to recommend the area for designation as wilderness.

Wilderness Recommendation

Once a wilderness study determines that a WSA meets the requirements for inclusion in the NWPS, a wilderness study report that presents the results of the wilderness review, accompanied by a Legislative Environmental Impact Statement (LEIS), is prepared. The wilderness study report and

LEIS that support wilderness designation are then transmitted through the Secretary of the Interior to the President of the United States, and ultimately to the Congress for approval.

The following section summarizes the inventory phase of the wilderness review for the Hakalau Forest NWR.

Wilderness Inventory

The wilderness inventory is a broad look at the planning area to identify WSAs. These WSAs are roadless areas within refuge boundaries, including submerged lands and their associated water column, that meet the minimum criteria for wilderness identified in Sect. 2(c) of the Wilderness Act. A WSA must meet the minimum size criteria (or be a roadless island), appear natural, and provide outstanding opportunities for solitude or primitive recreation. Other supplemental values are evaluated, but not required. Three inventory units were identified in order to evaluate whether the lands and waters of Hakalau Forest NWR meet the minimum criteria for a WSA. These inventory units are identified in Figures D-1 and D-2 as Inventory Unit A on the Kona Forest Unit (KFU) and Inventory Units B1 and B2 on the Hakalau Forest Unit (HFU).

Note that management activities for wilderness areas can be conducted in a manner that maintains the wilderness character by using the minimal tools necessary to achieve Refuge purposes, as required under the Wilderness Act and Service policy (610 FW 1-4, Wilderness Stewardship). For Hakalau Forest NWR, this would include ongoing management activities such as fence construction, inspection, and repairs, a variety of surveys, threat mitigation (e.g., ungulate removal, predator control, invasive weed management, etc.), and outplantings. These activities currently occur in inventory unit B1 and are planned for inventory units A and B2.

Kona Forest Unit

Inventory Unit A consists of the entire KFU, which is located on the leeward slope of Mauna Loa. The 5,300 acre Refuge supports diverse native bird and plant species as well as the rare habitats found in lava tubes and lava tube skylights.

Hakalau Forest Units

1. Inventory Unit B1 includes the management Units that are located in the upper elevation and contain the existing access roads and facilities. This unit contains approximately 9,000 acres and includes all Refuge lands above approximately 5,000 feet elevation.

2. Inventory Unit B2 contains approximately 23,000 acres and includes all Refuge lands below approximately 5,000 feet elevation.

<u>Evaluation of Size Criteria for Roadless Areas, Roadless Islands, and Submerged Lands and Associated Water Column</u>
Identification of roadless areas, roadless islands, and submerged lands and associated water column required gathering land status maps, land use and road inventory data, satellite imagery, aerial photographs, and personal observations of areas within Refuge boundaries. “Roadless” refers to the absence of improved roads suitable and maintained for public travel by means of motorized vehicles primarily intended for highway use.

Figure D-1. HFU wilderness inventory units.

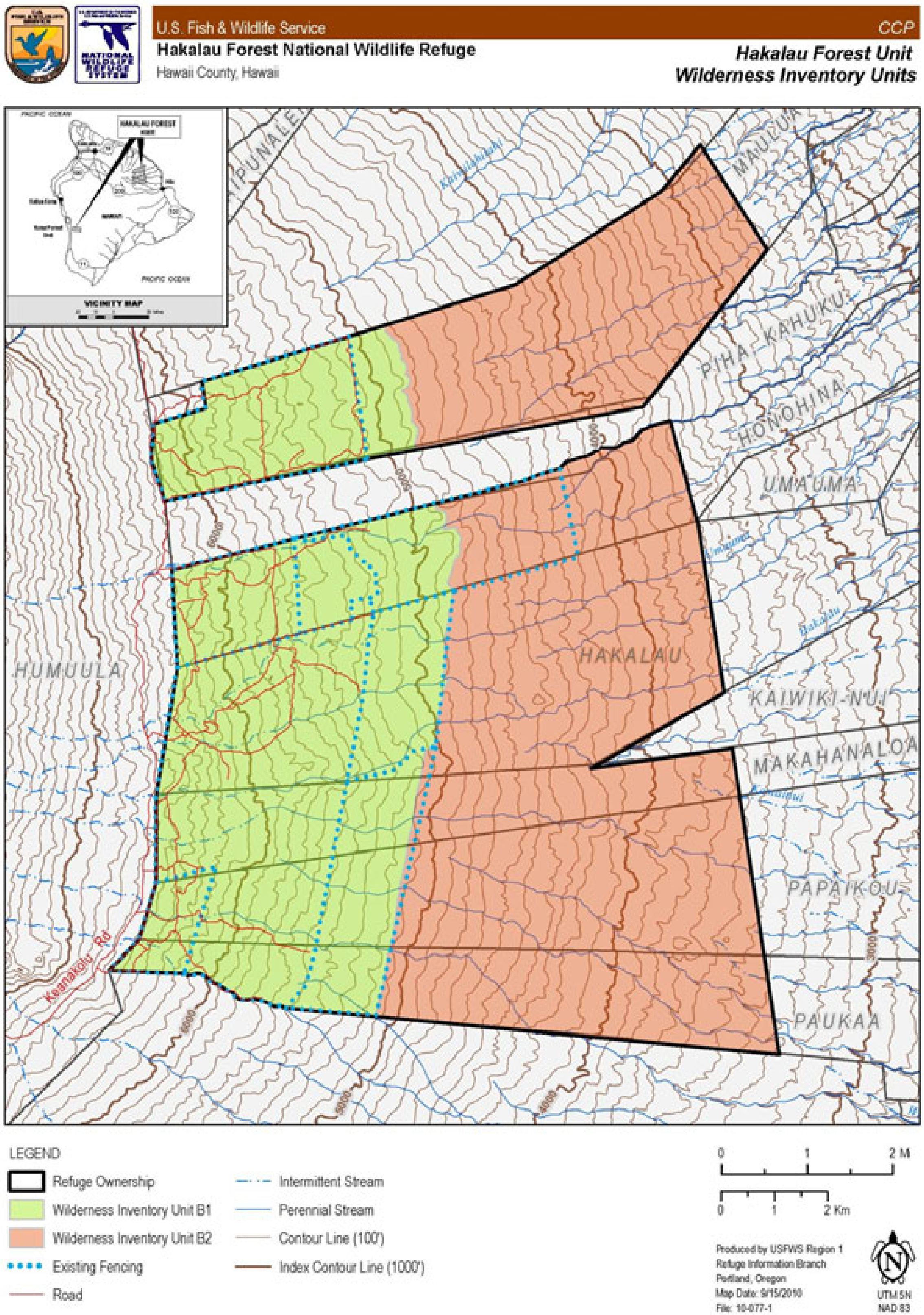

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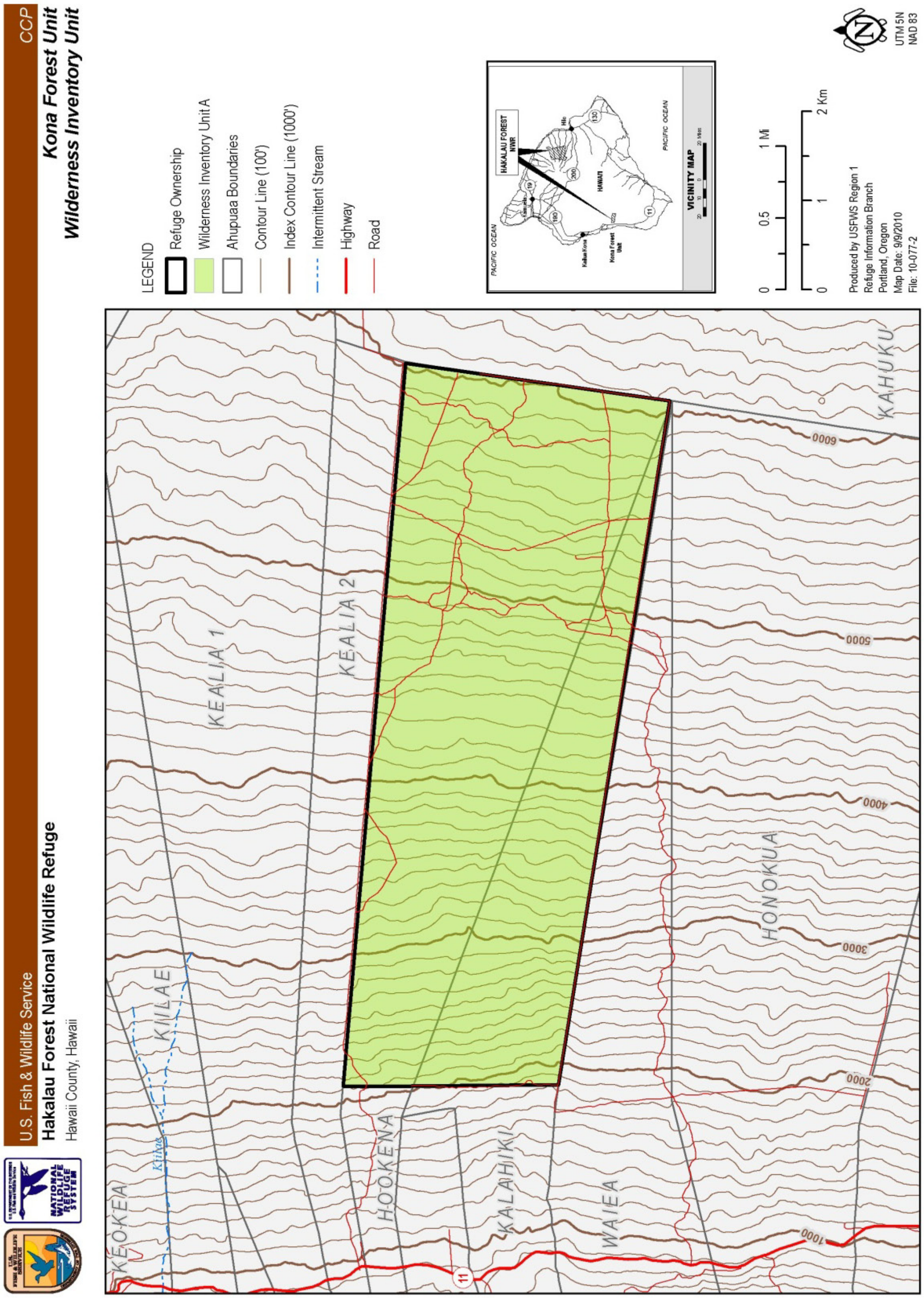
Figure D-2. KFU wilderness inventory unit.



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Inventory units meet the size criteria for a WSA if any one of the following standards applies:

- An area with over 5,000 contiguous acres. State and private lands are not included in making this acreage determination;
- A roadless island of any size. A roadless island is defined as an area surrounded by permanent waters or that is markedly distinguished from the surrounding lands by topographical or ecological features;
- An area of less than 5,000 contiguous Federal acres that is of sufficient size as to make practicable its preservation and use in an unimpaired condition, and of a size suitable for wilderness management; or
- An area of less than 5,000 contiguous Federal acres that is contiguous with a designated wilderness, recommended wilderness, or area under wilderness review by another Federal wilderness managing agency such as the Forest Service, National Park Service, or Bureau of Land Management.

Inventory Unit A is approximately 5,300 acres, which is just above the minimum threshold for wilderness consideration. Large numbers of access road trails are used for Refuge management. Although not suitable for public access, the road trails will be maintained and used to access the difficult terrain that exists at the KFU. Inventory Unit A meets the minimum size criteria and roadless as defined in the Wilderness Act does not apply. Therefore this unit meets this criteria for Wilderness Study Area designation.

Inventory Unit B1 is approximately 9,000 acres. Large numbers of access road trails are used for Refuge management. Although not suitable for access with standard vehicles, they are available to four-wheel drive vehicles. The road trails will be maintained and used to access the HFU and administrative site. Inventory Unit B1 meets the minimum size criteria and roadless as defined in the Wilderness Act does not apply. Therefore this unit meets this criteria for Wilderness Study Area designation.

Inventory Unit B2 is approximately 23,000 acres of roadless land. This unit meets the minimum size and roadless criteria for Wilderness Study Area designation. Inventory Unit B2 meets the minimum size criteria and roadless as defined in the Wilderness Act does not apply. Therefore this unit meets this criteria for Wilderness Study Area designation.

<u>Evaluation of the Naturalness Criteria</u>

A WSA must meet the naturalness criteria. Section 2(c) of the Wilderness Act defines wilderness as an area that "…generally appears to have been affected primarily by the forces of nature with the imprint of man's work substantially unnoticeable." The presence of ecologically accurate, historical landscape conditions is not required. An area may include some manmade features and human impacts provided they are substantially unnoticeable in the unit as a whole. Human-caused hazards, such as the presence of unexploded ordnance from military activity, and the physical impacts of refuge management facilities and activities are also considered in the evaluation of the naturalness criteria. An area may not be considered unnatural in appearance solely on the basis of "sights and sounds" of human impacts and activities outside the boundary of the unit. The cumulative effects of these factors were considered in the evaluation of naturalness for each wilderness inventory unit.

In the wilderness inventory, specific manmade features and other human impacts need to be identified that affect the overall apparent naturalness of the tract. The following factors were primary considerations in evaluating the naturalness of the inventory units:

Inventory Unit A:

- Field Camp;
- Remnant ranch fences, galvanized pipes, corrals, and agricultural equipment;
- High percentage of nonnative groundcover species;
- Ungulates and other animal pest species; and
- Gates, fences, and access road trails.

Inventory Unit B1:

- Administrative site including, maintenance building, housing cabins, greenhouse with outbuildings, powerplant building, weather ports, UH field station;
- Remnant ranch fences, galvanized pipes, corrals, and agricultural equipment;
- High percentage of nonnative groundcover species;
- Ungulates and other animal pest species; and
- Gates, fences, parking areas, and access road trails.

Inventory Unit B2:

- Nonnative groundcover species, particularly at lowest elevations;
- Ungulates and other nonnative animal pest species present; and
- Remnant fences and gates left by previous owner.

Though in the CCP, removal of ranch debris has been identified as a strategy (which will improve the naturalness of the area), inventory Unit A still contains numerous roadways, fences, gates, and administrative field camp structures. This inventory unit does not meet the naturalness criteria.

Inventory Unit B1 is also a highly modified former ranchland area, containing stock ponds, corrals, fences, nonnative tree plantings, administrative site buildings, and roadways. Water quality in streams and rivers has been degraded through the introduction of sediment, animal waste, and diseases. This inventory unit does not meet the naturalness criteria.

Inventory Unit B2 contains remnant abandoned fences and gates that only slightly detract from the naturalness of the Unit and are a minor component of the landscape. Vegetative growth has muted any visual impact and these manmade structures are substantially unnoticeable in the area as a whole. Removal of these features would promote restoration of the natural character of this Unit. Overall, the forces of nature sculpt the forest resources of this Unit. The naturalness of the forest in the upper elevations of unit B2 has been modified somewhat with regard to species composition by invasion of cattle and pigs from adjoining areas. The understory and groundcover have been altered through eating and rooting by ungulates and has a groundcover that consists of mainly nonnative species. There are areas of high rainfall that have been turned into mud wallows by pig rooting and soil compaction from movement of cows and pigs. Water quality in streams and rivers may be degraded through the introduction of sediment, animal waste, and diseases (e.g., leptospirosis) caused by ungulates damaging understory and groundcover plants. Nonnative mosquitoes breed in the standing water in wallows created by pigs and spread avian malaria and pox to native bird populations that have completely eliminated native forest bird populations below 4,500 ft. However, native forest birds in some areas are showing apparent signs of resistance to avian malaria and cases of reoccupation of former habitat by native birds have been documented on the islands of Hawaiʻi and Molokaʻi. Using IPM strategies identified in this CCP, native forest ecosystem restoration can occur over time. Therefore, while these invasive species attributes of inventory unit B2 currently detract somewhat from the naturalness criteria, over time wilderness values associated with the natural character of this Unit can be improved through implementation of this CCP. This unit is considered to meet the naturalness criteria.

Evaluation of Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation

In addition to meeting the size and naturalness criteria, a WSA must provide outstanding opportunities for solitude or primitive recreation. The area does not have to possess outstanding opportunities for both solitude and primitive and unconfined recreation, and does not need to have outstanding opportunities on every acre. Further, an area does not have to be open to public use and access to qualify under these criteria. Congress has designated a number of wilderness areas in the NWPS that are closed to public access to protect ecological resource values.

Opportunities for solitude refer to the ability of a visitor to be alone and secluded from other visitors in the area. Primitive and unconfined recreation means nonmotorized, dispersed outdoor recreation activities that do not require developed facilities or mechanical transport. These primitive recreation activities may provide opportunities to experience challenge and risk, self reliance, and adventure.

These two opportunity "elements" are not well defined by the Wilderness Act but in most cases can be expected to occur together. However, an outstanding opportunity for solitude may be present in an area offering only limited primitive recreation potential. Conversely, an area may be so attractive for recreation use that experiencing solitude is not an option.

Inventory Unit A has not been opened to the public and is unstaffed. The dangers associated with the lava tubes and lava tube skylights would focus use in road corridors and could considerably limit opportunities for solitude, yet meet the recreation criteria of providing an opportunity to experience challenge and risk. Current construction of perimeter as well as internal fencing could impact opportunities for solitude. Additionally, this unit is surrounded by working private ranches as well as a major highway which can impact opportunities for solitude (Unit A is about a mile wide at the narrow configuration). Though not considered in this analysis, it should be noted future management plans (when funding becomes available) could impact solitude as they include adding volunteer work weekends, where groups of volunteers would help with management needs such as outplanting and invasive weed work and ongoing management of the unit, which would require human presence to conduct fencing inspections and repairs, a variety of surveys for monitoring, and permitted research. Therefore this unit does not meet the solitude criteria, but does meet the recreation criteria.

Inventory Unit B1 is currently open to the public under SUP or by reservation in Upper Maulua. The reservation area is generally open to motor vehicles on the roads and hiking from pull-off areas. Additionally this unit houses much of the Refuge management facilities such as a maintenance building, housing cabins, greenhouse with outbuildings, powerplant building, weather ports, and UH field station. As such, the recreational opportunities are neither primitive nor offer outstanding opportunities for solitude.

Inventory Unit B2 has not been opened to the public. Public access is not a requirement for wilderness designation. Due to the naturalness of this unit and its isolation and difficult access, it would provide for both primitive and unconfined recreation. Similar to unit A, planned management actions for this unit would require human presence to conduct fencing inspections and repairs, a variety of surveys for monitoring, and permitted research. As such solitude could be impacted if these management actions were implemented. However, given the vast acreage of this unit, such activity would likely go unnoticed. Therefore, this unit is considered to meet both the recreation and the outstanding opportunities for solitude criteria.

Evaluation of Supplemental Values

Supplemental values are defined by the Wilderness Act as “ecological, geological, or other features of scientific, educational, scenic, or historic value.” Unit A contains unique lava tube and lava tube skylight formations. In addition, it contains rare forest bird and native plant species. Units B1 and B2 contain rare species of forest bird and native plants. The ecological values of these units enhance the potential wilderness characteristics.

Inventory Findings

Inventory units A and B1 do not meet the minimum criteria for consideration as a WSA (Table D-1). Unit B2 meets the minimum criteria for wilderness and will be considered as a WSA. The study is expected to take some time to complete. If unresolved before such time, the HFU WSA Inventory Unit B2 will be included in the wilderness study conducted for all of the Hawaiian and Pacific Islands NWRs at the completion of the CCP process for all refuges. The WSA will be considered with regard to this status as management actions are undertaken to improve the naturalness of the area through control and/or removal of nonnative species and subsequent fencing projects. A minimum requirements analysis will be used as part of the management planning for this area. As explained above, the naturalness criteria are somewhat compromised at present due primarily to nonnative species of plants and animals in the area. Expected management actions will improve these qualities with regard to the habitat needs of native species and potential future wilderness designation. Conversely, additional study may result in ultimately withdrawing the area from consideration.

Table D-1. Wilderness Inventory Summary.

	Inventory Unit A: Kona Forest NWR (5,300 acres)	**Inventory Unit B1:** Hakalau Forest Unit (9,000 acres)	**Inventory Unit B2:** Hakalau Forest Unit (23,000 acres)
(1) Has at least 5,000 acres of roadless land or is of sufficient size to make practicable its preservation and use in an unconfined condition, or is a roadless island.	Yes	Yes	Yes
(2) Generally appears to have been affected primarily by the forces of nature, with the imprint of man’s work substantially unnoticeable.	No	No	Yes
(3a) Has outstanding opportunities for solitude.	No	No	Yes

	Inventory Unit A: Kona Forest NWR (5,300 acres)	**Inventory Unit B1:** Hakalau Forest Unit (9,000 acres)	**Inventory Unit B2:** Hakalau Forest Unit (23,000 acres)
(3b) Has outstanding opportunities for a primitive and unconfined type of recreation.	Yes	No	Yes
(4) Contains ecological, geological or other features of scientific, educational, scenic, or historic value.	Yes	Yes	Yes
Parcel qualifies as a wilderness study area (meets criteria 1, 2 & 3a or 3b).	No	No	Yes

Appendix E. Forest Bird Workshop Report

Report on U.S. Fish and Wildlife Service's
Implementing Recovery for Endangered Forest Bird Species in Hawai'i Workshop
Hilo, Hawai'i
October 8-10, 2008

Background:

The U. S. Fish and Service (Service) has received contradictory information over the population status of the Hawai'i 'akepa in a portion of the Hakalau Forest National Wildlife Refuge (Refuge) – a major stronghold of the endangered Hawai'i 'akepa – over the last several years. It was deemed necessary to clarify the current status of the Hawai'i 'akepa and other endangered Hawaiian forest birds at the Refuge for development of efficacious management alternatives in the 3-year Comprehensive Conservation Plan (CCP) The Regional Director obtained the assistance of the U.S. Geological Survey's (USGS) Dr. J. Michael Scott in conducting a review of available information on the Hawai'i 'akepa, and decided to hold a workshop with partner agencies, renowned forest bird researchers, and statisticians to further expand this review.

Process:

Working with Dr. Scott, the eventual moderator of the workshop, employees in both the National Wildlife Refuge System and Ecological Services programs of the Service prepared a draft agenda for the workshop that included purposes and objectives, major discussion topics, potential speakers, etc. From a group of invitees developed by the Service and USGS, volunteers to serve on a workshop steering committee were selected. These individuals and their affiliations were:

1. Dr. Sheila Conant (Steering Committee Chair) University of Hawai'i- Mānoa;
2. Dr. Leonard Freed, University of Hawai'i- Mānoa;
3. Dr. David Leonard, Hawai'i State Division of Forestry and Wildlife;
4. Dr. Loyal Mehrhoff, USGS-BRD;
5. Dr. J. Michael Scott, USGS-BRD; and
6. Gina Shultz, Deputy Field Supervisor, FWS-Ecological Services Honolulu Office.

The steering committee pared down the agenda from a broader scope in terms of both geographic area and species to focusing on the endangered Hawaiian forest birds found at the Refuge. It was hoped that although focusing on the Refuge, much of the information shared at the workshop would be applicable to these species throughout their ranges and to the broader Mauna Kea and Hawai'i Island ecosystems or forest bird survey methodology in general. Originally development of a step-down work plan for the Recovery Plan for Endangered Hawaiian Forest Birds was an objective, but with the narrowing of the workshop focus it was decided that the Refuge CCP would capture most of those actions for these species in that geographic area.
The final workshop purposes and objectives were:

1) Identify and prioritize management needs and activities, including research, at Hakalau Forest National Wildlife Refuge to recover endangered Hawaiian forest birds;
2) Incorporate identified needs and activities in the Hakalau Forest 15-year Comprehensive Conservation Plan; and
3) Extrapolate Hakalau-specific information to the broader Mauna Kea area and other geographic areas and bird species and suites of birds as appropriate.

The final workshop agenda is included at the end of this report for reference. This report was shared with all meeting participants on October 24, 2008, for 2 work weeks for their concurrence for accurate representation of their contributions and overall outcomes.

The major points or conclusions of each presenter are as follows:

<u>Day 1 – October 8</u>

<u>Stieglitz:</u> Meeting outcome will provide products that will assist in setting management alternative priorities for the Refuge CCP. The products from the workshop will include a ‘white paper report’ from the workshop, an action plan, and a summary evaluation from the participants. The products will be sent to the participants for review and evaluation.

<u>Bohan:</u> Protection, reforestation, and restoration are vitally important for endangered plants and animals found on refuges. Adaptive management, research, and partnerships will provide the refuge with input and information needed to protect endangered species. The CCP will provide a plan for the future direction of management of endangered species at the refuge and provide avenues for staffing and funding to accomplish the management actions. The refuge is interested in and committed to obtaining input from other agencies and the public in the development and implementation of the CCP.

<u>Pratt:</u> “Population status of threatened and endangered forest birds in Hawaiʻi” Hawaiʻi’s native forest birds have suffered great losses over the last 200 years with almost 50 species lost to extinction due to habitat loss, predation, competition, and avian disease. Mosquito-borne avian diseases have almost completely eliminated native forest birds below 1500 meters on all islands, making high elevation habitat essential to protecting forest birds. The Refuge contains critically important high elevation habitat. The Hawaiʻi Interagency Data Base Program team (USGS-BRD) has analyzed forest bird survey data collected on all of the Hawaiian Islands since 1976. These data show that throughout the State there is one consistent theme: forest bird populations in managed areas are stable or increasing; forest bird populations in nonmanaged areas are stable or decreasing.

<u>Scott:</u> Conservation in Hawaiʻi has been building on a foundation of research and management over the last 30 years to protect endangered species and prevent extinctions. Because of its isolation and progress in the field of conservation, Hawaiʻi is the “window to the future” for endangered species. Important tools are needed to move forward (research, habitat restoration). It is of utmost importance to get the research information to the people that make funding decisions. Policy changes will allow for funding for research that is needed to make management decisions on a temporal and landscape scale.

Camp: "Densities and trends in Hakalau Forest Birds" The Refuge was established in 1985 to protect native forest birds and their habitat. Refuge forest bird surveys were conducted between 1987 and 2007. The USGS-BRD Interagency Database Program team analyzed all Refuge forest bird survey data using a Bayesian approach to log linear regression. They tested for changes in bird densities in 3 study areas: previously heavily grazed middle elevation forest, upper elevation pasture that was reforested and lower elevation relatively intact forest. They found that densities of the ʻelepaio and the endangered ʻakiapolaʻau and creeper increased in the middle area forests. All other forest bird species showed stable trends in the middle area with no evidence of decline as seen elsewhere in Hawaiʻi. Trends for alien birds were also stable except for the house finch, which is declining. However, short term trajectories for some native species (ʻelepaio, ʻamakihi, ʻakepa, ʻiʻiwi, and ʻapapane) at middle elevations from 1999-2007 showed a decline, whereas the Japanese white-eye showed a stable to increasing trajectory. At lower elevations creeper and ʻakepa showed increasing trajectories, and densities have declined for the other native species. In the upper pastures densities increased for three common native species--ʻamakihi, ʻiʻiwi, and ʻapapane--and two alien species—Japanese white-eye and house finch. We advise caution on relying on short-term trajectories to assess population status. These trends show some of the first results of habitat improvement for forest birds in Hawaiʻi. Also, 1) There was no change in detectability for ʻakepa or ʻamakihi over that time span, 2) long term population trends for all native species in forested areas showed no decreasing trends, and 3) Hawaiʻi ʻakepa showed stable to increasing densities over the study time period. Additional analytical techniques, such as species habitat models and spatial pattern analysis should also be used in the future.

Freed (I): "Chewing lice and competition from Japanese White eye are synergistically starving every native species at Hakalau Forest NWR" Food competition from an increasing population of introduced Japanese white-eyes in the Pua ʻĀkala area, and the resultant increase in chewing lice, have synergistically increased food requirements and reduced food levels for all native birds at the Refuge. All life history parameters of ʻakepa (fledgling mass, bill length, fat levels, feather degradation, call rates, breeding success, sex ratio of young, juvenile survival, and adult survival) have become significantly lower, making the population non-viable as reflected in a shift in lambda to significantly less than one. The ʻakepa at the 1650 m site, with lowest number of white-eye, still appears to be viable based on fledgling mass. Mist-netting data show that the white-eye is replacing the ʻakepa at elevations between 1900 and 1770 m. The decline became more severe between 2006-2008 at these elevations, which represent the former site of highest density of the ʻakepa on the Refuge. There are also changes in numbers and begging behavior of the endangered Hawaiʻi Creeper. Control of white-eye numbers is essential to reverse the decline of the ʻakepa and other forest birds.

Freed (II): "When Methodologies collide: Issues of scale, assumptions of models and appropriate analysis" Two study sites on the Refuge appear to be at different stages of effects by Japanese white-eyes. No decline in ʻakepa has been detected at the Pedro study site as occurred at the Pua ʻĀkala study site after 2005. Pedro previously had a much lower density of ʻakepa associated with lower number of big trees with cavities for nesting. Based on mist-netting in the 1990's, ʻakepa and white-eye appeared to be at comparable density. Survey of birds during March 2008 revealed more white-eye than ʻakepa. More Japanese white-eyes, or longer exposure to the same increase in white-eyes, might be necessary to generate the same competitive effect observed in higher density areas such as Pua ʻĀkala. The early stages at Pedro may be revealed by the absence of calling by ʻakepa and mate feeding observed in silence. The Pedro site might be especially important for determining if there is a delayed response to white-eye increase in lower density ‘akepa populations that may be previously limited by cavities more than food.

VCP methodology is based on numerous assumptions. Some of these assumptions may be being violated, which may lead to misleading conclusions. Fixed plot surveys may be more accurate than VCP. With any statistical analysis, violation of assumptions of a model can lead to erroneous results. One problem involves scale. A decline in one section of the refuge, analyzed separately, may not be apparent when the refuge is analyzed as a whole. Analyses should be performed for separate portions of the Refuge, especially where endangered birds used to be common.

<u>Gorreson:</u> “Time series analysis of spatial patterns in species abundance at Hakalau Forest NWR” Two questions need to be answered: 1) are Hawai‘i ‘akepa populations in decline at Hakalau?, and 2) are Hawai‘i ‘akepa in competition with Japanese white-eyes? Forest bird survey data collected 1977-2007 were analyzed using Spatial Analysis by Distance Indices (SADIE). The data show that Hawai‘i ‘akepa have strong cluster-gap patterns. They are centered in the south of the Refuge (Pua ‘Ākala area). Japanese white-eyes are highly variable with moderately weak patterns and are mostly centered in the north of the Refuge but eruptive patterns do occur in some years, which weakened between 1987 and 1998 but have stabilized since 1999. Japanese white-eye distribution does not show consistent association with ‘akepa distribution. There is no evidence that ‘akepa are declining or that Japanese white-eyes are displacing ‘akepa.

<u>Garton (I):</u> “Interspecific competition between ‘akepa and Japanese white-eye in Hakalau NWR” Four different models were used to analyze the refuge forest bird survey data: 1.) the Null model (No density dependence); 2.) The Ricker model (density dependence on $N_{t,}$, 3.) the Gompertz model (density dependence on ln*Nt),* and 4.) the Theta model (density dependence on N_t^{θ}). Each of the models shows different levels of competition between ‘akepa and Japanese white-eyes, but none of these models show any significant effect. Because these effects are minor, it is difficult to tease out the other environmental factors that may have other negative effects. Through modeling it appears that environmental parameters that benefit ‘akepa also benefit Japanese white-eyes.

<u>Day 2 – October 9</u>

<u>Horne:</u> “Distance estimation of abundance: Assumptions and possible sources of bias” Distance sampling is a good way for estimating forest bird abundance because it can provide unbiased estimates and is relatively easy and inexpensive to implement. Distance sampling assumes that: 1) the density of animals (forest birds) is homogenous in the area surveyed, 2) the probability of an individual being detected is related to the distance from the observer, and 3) that all individuals at close distances are observed. Increased detectability of individuals in a population, due to possible changes in behavior of stressed individuals, affects abundance estimates based on distance sampling. While increased detectability results in more individuals being counted, estimates of abundance are unaffected by the change as long as the probability of detection at close distances is one (or does not change). However, if greater detectability also results in a greater proportion of detections at very close distances, then estimates will be affected by changes in detectability. Even if detectability changes over time, trend analyses based on these abundance estimates remain valid if the changes are random about some constant mean. In this case, the abundance estimates become an index and the changes in detectability are subsumed in observation error. If there are systematic changes in detectability over time, abundance estimates can be corrected using recently developed paired observer methods.

Garton (II): “Adaptive Management of the ‘akepa and Japanese white-eye” Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Garton compared two different adaptive management definitions from Walters’ (1986) Four Fundamentals of Adaptive Management of Natural Resources, and the Williams, Szaro, & Shapiro(2007) 9 Step Program used by USDI. By using several predictive mathematical models (with different sensitivities, and changing the parameters of the model, i.e., habitat improvement (reforestation, removal of grazers etc.) removing predators), predictions can be made on the potential consequences of each management action. With a Time Series Model, predictions show that both ‘akepa and Japanese white-eye densities increase with positive habitat changes, removal of Japanese white-eyes will actually reduce ‘akepa densities, and that, if the current management continues, it is unlikely that ‘akepa will go extinct with in the next 30 years.

Dennis: “Analysis of population trend: Getting the details right” Regression of log-abundance of a population versus time is often used to estimate the population's trend. It is not widely realized that such regression carries implicit assumptions about how the trend and the variability in the population abundances arise. If the statistical model does not adequately describe the process by which the data are produced, the trend estimate can be seriously in error. Three different models for estimating population trend are described and are different stochastic versions of the exponential growth model: 1) observation error only, 2) environmental process noise only, and 3) a state space model which combines both observation error and process noise. Each model leads to a different statistical calculation for obtaining estimates of model parameters, including trend, for time series abundance data. Log-abundance regression turns out to correspond to deterministic exponential growth with observation error only that is, model 1. In computer simulations, model 3 provides confidence intervals for trend that remain valid when data are generated under models 1 and 2. Confidence intervals calculated with models 1 or 2; however, fail miserably when data are generated under each other or under model 3. The hugely volatile Hawai‘i ‘akepa data (conforest time series) analyzed with model 3 yield a wide 95% confidence interval for trend that contains zero. The analysis suggests that the time series abundances contain substantial amounts of both environmental process noise and observation error. Building a density dependent model for this data set with environmental driving variables included might produce results more useful to management.

Duffy: “Rightsizing the Ark: Exclosures for Hawaiian Forest Birds” To protect native species, we need to fence at a scale appropriate to protect landscapes that will conserve bird populations large enough to survive at the scale of centuries, or we are wasting our time and money, and should spend it on other organisms. We have to operate at the appropriate scale, and this information needs to be presented to funding agencies and policy makers. With global warming, highland forests won’t be safe from avian malaria. Fencing and removing feral ungulates at the upper and mid elevations will create buffers where mosquitoes cannot breed, helping to keep mosquitoes at lower elevations and outside of the refuge.

In the late afternoons of October 8 and 9, Dr. Scott led discussions of the days’ presentations.

The focus on October 8 was identifying major threats to the forest birds at the Refuge. Dr. Scott used a multi-voting technique for workshop participants to describe and rank the immediate threats to forest birds at the refuge. Each attendee was given the opportunity to vote for any of the “Threats to Hawaiian forest birds” decided upon earlier in the workshop. The threats identified, and their ranking of importance by participants was:

Immediate Threats to Hawaiian Forest Birds at Hakalau Forest NWR

Feral Ungulates (24 votes)
Lack of Habitat (21)
Invasive Plants (12 votes)
Predation (7 votes)
Data Insufficient to meet Management Needs (8 votes)
Parasites (2 votes)
Interspecific Competition (1 vote)
Avian Disease (no votes were received, so removed from list)

The focus on October 9 was identifying and prioritizing major management actions and research necessary to recover the forest birds found at the Refuge. These management actions and research (collectively, activities) were also ranked using a multi-voting technique as follows:

Management Actions (Priority Ranked by Voting)

1) *Grazers/browsers (Habitat destruction/mosquito production) – High (overall 24 votes)
- Fence construction, maintenance, and removal of animals (combined total = 30 votes)
- See Research Priorities

2) Habitat Restoration – High (21 votes)
- Revegetation of pasture land (15 votes)
- Improve ʻohiʻa densities (7 votes)

3) Invasive plants – High (overall 12 votes)
- Continue invasive species control (blackberry, banana poka, gorse) (11 votes)
- Prevent and eliminate incipient weeds (2 votes)
- See Research Priorities

4) Monitoring and Data Needs – High (overall 8 votes)
- See Research priorities
- Delivery of technical information (2 votes)

5) Predation – Medium (overall 7 votes)
- See Research priorities

6) Parasites – Low (overall 2 votes)
- Incipient invasive parasites, true population counts, de-louse birds (2 votes)

7) Interspecific competition – Low (overall 1 vote)
- See Research priorities
- Identify ectoparasites/mites

Research Priorities (Priority Ranked by Voting)

1) Monitoring and Data: Expand point counts/banding data – 15 votes
(combined primary counter training (8 votes), consider use of a B-Bird (Breeding Biology Research and Monitoring Database) system (http://www.umt.edu/bbird/info.htm) (7 votes), and threat surveillance (1 vote))

2) Predation: Investigate effects of rats on forest birds (9 votes); rodent population index (2 votes) – 11 votes

3) Invasive Plants: Develop effective biocontrols – 8 votes

4)*Grazers/Browsers: Predator proof fencing – 7 votes

5) Invasive Plants: Develop more efficient control methods and registration of herbicides – 4 votes

5) Determine the effects of global climate change at the Refuge – 4 votes

6) Develop more effective cat control techniques – 2 votes

6) Determine effects of ectoparasites on non-endangered bird populations – 2 votes

7) Experimental control of Japanese white-eyes – 1 vote

*Caveat: Activities to construct an ungulate proof fence and a predator-proof fence caused some confusion amongst the participants. Dr. Scott obtained consensus that these activities could be combined with a third separate but related activity of removing feral ungulates.

Conclusion:

A workshop evaluation was distributed to all participants on October 24, 2008. Of the 37 participants, 11 provided evaluations (= respondents). A number of Service employees, as organizers of the workshop and authors of this summary, did not provide written evaluations, so the response rate is actually higher than it initially appears. A summary of the evaluations is attached as Appendix A. In short, however, findings of the evaluations were:

Overall the perception of the workshop organization and format was entirely positive. However, some respondents felt the workshop purpose and objectives fluctuated too much in advance of the workshop, were unclear, or were known but unstated. While this was in part a result of 'adaptive management' of the agenda and a deliberative process by the steering committee, more, earlier input from potential participants would help address this criticism for future workshops.

The presentations themselves were largely felt to be very informative and address the workshop purpose and objectives, given the previously mentioned concerns about those objectives. The amount of time allotted to presentations was generally thought adequate, and the facilitation by Dr. J. Michael Scott very good.

Regarding present and future management and research management actions at Hakalau Forest NWR, respondents were generally positive. Some thought, however, that we had merely validated current management actions – a positive in the eyes of the refuge staff and this author – but others saw this as "reinventing the wheel" and unnecessary.

The field trip on Day 3 was very positively received.

In summary, the workshop was very useful in clarifying the status of the endangered Hawai'i 'akepa, with most respondents supporting the interpretation of survey data indicating stable or increasing population trends. In turn, this finding validates the substantial investment of resources and energy at the Hakalau Forest NWR over the last 20 years, specifically the fencing/ungulate removal, reforestation, and invasive species removal programs. Finally, the priority activities (management actions and research) identified at the workshop will be used during the development of the Hakalau Forest National Wildlife Refuge CCP and provide a road map to guide Service staff in the management and recovery of Hawaiian forest birds at Hakalau Forest NWR.

Future workshops should be designed with special attention to purpose and objectives, leaving additional time to address the "what is not known" question and develop priority research to answer that question, and ensure early input from all potential participants and stakeholders (especially on workshop purpose and objectives).

Attachment 1

Summary of Evaluation of Hawaiian Forest Birds Workshop

October 8-10, 2008
Hilo, Hawai'i

Total number of participants: **37**
Total number of participants who completed evaluation forms: **11**
Total number of participants who provided comments on workshop notes: **2**

1. The organization/format of the workshop was (*please check one*):

Day One	Day Two	Day Three
Excellent **5** Good **6**	Excellent **4** Good **5** Adequate **2**	Excellent **7**

Comments or Suggestions:

- *It is too bad that more empirical studies were not included.*
- *The field trip was a terrific idea as it gave participants from outside Hawaii and those within the state but less familiar with Hakalau, a great on-the-ground view of the refuge's success with restoration and the richness of the bird community. We saw perhaps a dozen akepa!*
- *This was pretty close to the most informative 3 days I've ever spent in the Service –perhaps in my entire 15 year Fed. Career. Well done to have the room filled with those who know these species and conservation issues the best.*

2. The time allotted for presentations and discussions was (*please check one*):
   Sufficient **11** Insufficient Excessive

Comments or Suggestions:

- *There were some presentations where discussion was cut off early, but not sure that could be helped without eliminating a presentation or going significantly over time.*
- *I appreciated that there was plenty of time for questions and discussion in addition to presentations. Michael Scott did an excellent job guiding the discussion.*
- *I think the time allotted was just right.*

3. The presentations and discussions adequately addressed the workshop purpose and objectives. (*please check one*)
   Strongly Agree **3** Agree **6** Disagree **1** Strongly Disagree

Comments or suggestions:

- *Some excellent presentations on point count methodology – I learned quite a bit. The weakest parts of the workshop were the presentations on competition from white-eyes and ectoparasites – most likely because the data were unverified, highly controversial, and not supported by excessive census data from the refuge.*
- *Did a good job of not allowing discussion to focus solely on the controversy between Lenny and others, which likely would not have been productive. I was not fully aware of the underlying impetus for the workshop prior to Day 1, and it might have helped to have presented in advance the information that now appears at the beginning of the notes (although I understand there was some evolution of the focus of the meeting in the weeks leading up to it, so perhaps there was not time).*
- *This is a loaded statement! In all honesty the stated purpose and objectives kept changing and were never very clear, and from the get-go were counfounded by other well known but unstated objectives, so I'll refrain from checking a box here. For a workshop ostensibly about management priorities as well as research, the presentations mostly treated data analysis and population and trend modeling -- and in fact addressed the unstated objectives better than the stated ones. Is seems that what we had, especially from the University of Idaho participants, was primarily a live performance of contributions to the most recent external review of the survey data from Hakalau to address the Japanese white-eye-Hawai'i 'akepa questions. This was interesting, but I'm not certain it was what best served the participants of this workshop.*
- *Too much time was spent on addressing the competition issue.*
- *There were conflicting data sets and more time should have been used to resolve the conflicts.*
- *This is a difficult question to answer because the workshop purpose was not entirely clear. On the one hand, the workshop seemed focused on whether or not the interspecific competition between Akepa and White-eyes is something to be concerned about, and on the other hand the workshop was also trying to address all management and research priorities for Hakalau. I think we accomplished the former but were less successful on the latter.*
- *Because so much discussion focused on Lenny Freed's concerns about 'akepa, I think he should have spoken more about his data and spent less time critiquing census methods. Plenty of other people did the latter. Lenny changed topics at the last minute, so this was hard to control, but I think we needed to see and hear more of the actual data.*

4. Management needs and activities, including research, at the Hakalau Forest National Wildlife Refuge were properly identified and prioritized to recover endangered Hawaiian forest birds. (*please check one*):
   Strongly Agree **3**   Agree **7**   Disagree   Strongly Disagree **1**

Comments or suggestions:

- *A little too much emphasis on reinventing the wheel. Most of the management needs and activities were identified and prioritized in the Forest Bird Recovery Plan and it was reassuring that these have not changed since the plan was finalized. As someone from the* *workshop pointed out – the most important management needs can be summarized as "Build fence, kill pigs, plant trees, count birds". The refuge has been doing this well the past 20 years and FWS support for the activities should continue.*

- *I agree only in that the "process", such as it was, on the second day clearly demonstrated that a room full of Hawaiian forest bird experts with years or decades of experience do not believe that investigating (or acting on) potential interspecific competition as a threat to endangered birds is a priority. I don't think the results of this workshop lead to a big shift in activities or emphasis at Hakalau, but maybe the view from the Refuge is different…*
- *I think the priorities were properly identified. Funding to implement is still the question to be resolved.*
- *How could the audience ignore the fact that lambda for the akepa was significantly less than one?*
- *I do not think we properly identified management needs for the refuge in the sense that we reaffirmed collectively that the Refuge is very much on the right track. I think we could have done a much better job at identifying research priorities. With much of the refuge staff present, it would have been very useful to ask then to come to the meeting with a list of what they see as research priorities. What data would be helpful in understanding whether their management actions are achieving success? What projects would be useful understanding whether addiditional management actions are necessary? It would have been great to outline and prioritize specific projects and then collectively think about where the funding could come from to support them.*
- *I think we did a pretty comprehensive job, certainly enough to provide pretty specific guidelines for the development of the CCP.*
- *I believe it would be worthwhile to identify additional lines of field investigation to validate Dr. Freed's claims regarding competition from white-eyes and parasitism from ectoparasites. If biologist from the mainland could be encouraged to conduct relevant field studies here, that would bring independence to the findings and generate interest in the wider scientific and conservation communities.*

5. Do the results of this workshop clearly define future research and management actions at Hakalau Forest NWR? (*please check one*):
   Strongly Agree **2** Agree **7** Disagree **1** Strongly Disagree **1**

Comments or suggestions:

- *Seems to me the results just validated what the Refuge is already doing, ES is already helping to fund, and what the wider forest bird conservation community already has identified has priorities – in about the same order.*
- *Yes, for forest birds. Need to have similar discussions relative to plant species management. This was an excellent group of people to address the forest bird issues. I wish we also could have used this group to look at forest bird research and management needs statewide.*
- *They identified management but not address research. There should have been a session on what we need to know that we don't know at present.*
- *There is still a lot of work to be done to "clearly define" research management in the Comprehensive Conservation Plan, but this workshop gave us a very good start.*

- *To me the management actions were more clearly defined than the research actions. I felt that the discussion of research actions did not go far enough beyond what is already being done or considered, and there was no blueprint drafted for follow-through on the few resulting recommendations. Lack of funding, more specifically lack of adequate funding sources, may be discouraging initiative for research.*

Additional Comments:

- *This was an effective venue to try to settle conflicting interpretations of current population trends for Hawaii Akepa and other endangered birds at Hakalau. I hope the majority opinions were clearly heard by USFWS officials.*
- *Overall, a good job of staying on schedule and not letting talks go over. The initial talks occurred ahead of schedule. If possible, this also should be avoided, particularly if people might need to come & go during the workshop.*
- *Refuge staff and officials from Honolulu and region need to direct the workshop to focus discussion on their most significant needs.*
- *I think the discussion should have had very specific questions and objectives spelled out before it started. That would have helped focus our identification of needs and priorities and given us a bit more time to talk about them. Still, between Mike's moderating and Ken's note taking, we did a very good job.*
- *Seemed to me to be a well-organized workshop. The field trip also went extremely well---it was great to see all those birds!*
- *Make explicit any implicit objectives or drivers, and make sure all the key stakeholders are present.*
- *It's a good thing the scope of this workshop was changed, very near the last minute, to Hakalau only (rather than the whole Big Island, or Big Island and Kauai etc.), because the State was represented at the workshop by a total of one person (from DOFAW administrative office).*
- *Ensure that all participants have a 100% clear understanding of the purpose/objectives, the contributions expected of them, and the specific methods that will be used to meet objectives, make decisions etc. To achieve "buy in" or wide agreement, it isn't enough to have a good moderator for individual presentations and discussions (which we did have); the facilitator has to move the whole group toward achieving a small number of very clear objectives, present – up front – a well-defined process or processes for doing that, and resolve procedural concerns or differences of opinion along the way. In this case, the ad hoc "process" we undertook on the second day was reasonably effective, but I think that was largely because the task was a no-brainer for this group, and wide agreement about priorities for forest bird research and conservation already existed. That process was conducted in an extemporaneous manner and without clear explanation of how the results would be used, and would have backfired in a group that was divided over the topics under discussion.*

Appendix F. Biological Integrity, Diversity, and Environmental Health and Resources of Concern

Table F-1. Biological Integrity, Diversity, and Environmental Health (BIDEH).

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
Hakalau Forest Unit			
Montane wet ‘ōhi‘a/*Dicranopteris* sp. forest	The upper canopy is composed of scattered mature (100+ years), and medium stature ‘ōhi‘a (30 ft). The mid-canopy zone (10-15 ft) is dominated by hāpu‘u (tree fern). The vegetation at ground level, up to 6-10 ft, is dominated by dense *Dicranopteris* sp. (matted ferns), making access difficult. This habitat type is found between 2,500 ft - 4,000 ft elevation with many *Carex* sp. bogs found scattered throughout the lower elevations. Plant diversity is low and dominated by ‘ōhi‘a and *Dicranopteris* sp. Although unstudied, it is assumed that invertebrate diversity is also low. Native bird densities are low due to disease such as avian malaria. Consequently, nonnative bird species dominate the avifauna. Potential conservation species in this habitat include endangered plant species, ‘ōpe‘ape‘a, and koloa maoli. However, this habitat type may best be described as a buffer zone for invasive plants encroaching from lower elevations.	The windward east-facing Hakalau Forest Unit receives northeasterly tradewind-dominated rainfall throughout the year with up to 250 inches annually. Heavier rainfall occurs October-March. Mountain slopes are mild. Soils are aged, eroded, and volcanic in origin. Soils are typically poorly drained. The ground surface is bisected by numerous streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep-sided, providing protection to native and endangered plants from grazing ungulates.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Mosquitoes, the vector for avian diseases, breed up to 4,500 feet in elevation. There is limited current and historical human disturbance. The threat of wildfire is slight.

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
Montane wet ‘ōhi‘a forest	The upper canopy of this habitat type is dominated by somewhat taller (60-90 ft) mature closed canopy ‘ōhi‘a. Mid-canopy is dominated by a mix of flowering and fruiting tree species (e.g., ‘ōhi‘a, ‘ōlapa, pilo, kōlea), tree ferns (up to 15 ft), and epiphytes. Ground cover is dominated by mixed ferns, *Astelia* (lilly), ‘ōhelo, kanawao, pūkiawe, and kāwa‘u. This habitat type is found between 4,000-5,000 ft elevation. Compared to lower elevation habitat, the ground level contains downed timber and areas dominated by sphagnum moss. A diverse native bird community first appears in this habitat type, primarily due to elevations above the mosquito zone and a more diverse forest plant community.	The windward east-facing Hakalau Forest Unit receives northeasterly tradewind-dominated rainfall throughout the year with up to 250 inches annually. Heavier rainfall occurs October-March. Mountain slopes are moderate. Soils are aged, eroded, and volcanic in origin. Soils are typically poorly drained. The ground surface is bisected by numerous streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep-sided, providing protection for native and endangered plants from grazing ungulates.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Higher densities of pigs at this elevation have disturbed native *Carex* sp. bogs which have converted to nonnative *Juncus* sp. bogs.
Montane wet koa/‘ōhi‘a forest	This habitat type contains a mixed age class of koa and ‘ōhi‘a-dominated forest and occurs 5,000-6,000 ft in elevation. The mid-canopy is dominated by a mix of flowering and fruiting trees (e.g., ‘ōlapa, ‘ākala, pilo, pūkiawe, ‘ōhelo, kōlea, kāwa‘u), mixed ferns, and epiphytes. A diverse native bird community occurs in this habitat type, primarily due to elevations above mosquito zone and more diverse forest plant community. Other species of conservation and management concern include koloa maoli, ‘ōpe‘ape‘a, and endangered plants.	The windward east-facing Hakalau Forest Unit receives northeasterly tradewind-dominated rainfall throughout the year with up to 275 inches annually. Heavier rainfall occurs October-March. Mountain slopes are moderate. Soils are aged, eroded, and volcanic in origin. Soils are typically poorly drained. The ground surface is bisected by numerous streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep-sided, providing protection to native and	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Past human disturbances include cattle grazing. The effects of this past activity include increased grasslands

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
		endangered plants from grazing ungulates.	and loss of native plant species.
Montane mesic koa forest	This habitat type contains a mixed age class of koa-dominated forest and occurs 6,000 ft - 6,600 ft in elevation. The mid-canopy is dominated by a mix of flowering and fruiting trees (e.g. ‘ōlapa, ‘ākala, pilo, pūkiawe, ‘ōhelo, kōlea, kāwa‘u), mixed ferns, and epiphytes. A diverse native bird community occurs in this habitat type, primarily due to elevations above mosquito zone and more diverse forest plant community. Other species of conservation and management concern include the koloa maoli, ‘ōpe‘ape‘a, and endangered plants.	The windward east-facing Hakalau Forest Unit receives northeasterly tradewind-dominated rainfall throughout the year. This habitat type receives approximately 275 inches of rainfall annually. Heavier rainfall occurs October-March. Mountain slopes are moderate. Soils are aged, eroded, and volcanic in origin. Soils are typically poorly drained. The ground surface is bisected by numerous streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep-sided, providing protection to native and endangered plants from grazing ungulates.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases).
Grasslands/forest restoration area	This park-like habitat contains mixed nonnative grasses and a native grass and is found between 5,600 - 6,500 ft elevation. Scattered mature koa and ‘ōhi‘a trees also occur. Nonnative grasses include *Anthoxanthum* sp., *Holcus* sp., *Pennisetum* sp., and *Ehrharta* sp. Native species include the native grass *Deschampsia* sp., the native shrub *Vaccinium* sp. (‘ōhelo), and a native bracken fern. Mid-canopy vegetation is primarily absent from this habitat.	The windward east-facing Hakalau Forest Unit receives northeasterly tradewind-dominated rainfall throughout the year with up to 275 inches annually. Heavier rainfall occurs October-March. Mountain slopes are moderate. Soils are aged, eroded, and volcanic in origin. Soils are typically poorly drained. The ground surface is bisected by numerous	Former mesic koa forest was historically reduced to grassland by grazing, timber harvest, and fires. Mesic koa habitat is currently being restored. Limiting factors include a lack of native pollinators and several

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
	The forest restoration program has out-planted approximately 382,000 native trees, including koa, ʻōhiʻa, pilo, kōlea, ʻōlapa, māmane, naio, and other natives on approximately 1,700 acres. Approximately 4,000 acres of additional grassland is scheduled to be restored to montane mesic koa forest community. Native forest birds currently occur in this habitat at greatly reduced numbers and diversity when compared to nearby intact forest communities though populations are increasing as forest restoration occurs. Nēnē are found throughout the current habitat. Species of conservation and management concern include the native forest birds, ʻōpeʻapeʻa, and endangered plants.	streams (surface flow). These streams create and maintain stream channels that are highly eroded and steep-sided, providing protection to native and endangered plants from grazing ungulates.	pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). The use of this habitat by ʻio, nēnē, and other endangered species will need to be considered during planning and reforestation activities.
Streams	Streams cross through various habitat types, being intermittent at higher elevations, and perennial at lower elevations. Some streams with steep walls protect endangered and native plants from grazing by ungulates. Fauna within the streams and riparian areas at lower elevations are unstudied and unknown. Although unstudied at higher elevations, the fauna is suspected to be exclusively invertebrate. Other species of conservation and management concern include native forest birds, koloa maoli, and endangered plants.	Glacial meltwater created ravines during the Pleistocene era. Rainfall and runoff currently maintains stream habitat.	Ungulates and rats degrade water quality through soil disturbance and feces deposition. Lack of groundwater retention due to upstream human disturbance (e.g., grazing, soil compaction) can lead to flash floods. Streams also transport and disperse pest plant seeds.

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
Ponds	Semipermanent natural ponds are scattered throughout the upper elevations of the Refuge, all above the mosquito line. Koloa maoli and ʻalae keʻokeʻo are known to frequent these ponds along with migratory shorebirds and invertebrates.	Rainfall current maintains pond habitats.	Seasonality of rainfall and encroachment of ponds by nonnative *Juncus* sp.
Carex Bogs	Bogs naturally occur in flat areas and are dominated by sedges and rushes. Limited areas of open water also occur. Bogs are primarily located below 4,500 ft. While sphagnum exists in these bogs, it is unclear whether it is native. Faunal use of bogs is primarily by invertebrates. However, koloa maoli are known to use bogs. Other species of conservation and management concern include native forest birds, nēnē, and endangered plants.	The hydrology of bogs is driven by the retention of rainfall and surface water retention in a clay layered depression, as opposed to perched (i.e., the expression of groundwater at the surface) water table.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). The conversion of *Carex* sp. to *Juncus* sp. has occurred due to the rooting activities of pigs. Enhanced soil erosion from ungulate activities also has increased the eutrophication of bogs.

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
Kona Forest Unit			
Montane wet ‘ōhi‘a forest	Upper and lower elevation gradients occur in this habitat type. The lower gradient occurs 2,000-3,000 ft elevation. The lower gradient upper tree canopy is dominated by 60-80 ft mature closed canopy ‘ōhi‘a. The mid-canopy is dominated by nonnative Christmas berry, strawberry guava, and a mix of flowering and fruiting tree species (e.g., ‘ōhi‘a, hame, kōlea), tree ferns (up to 15 ft), the vine ‘ie‘ie, and epiphytes. Ground cover is dominated by nonnative *Clidemia* sp., thimbleberry, a mix of nonnative and native ferns, and areas of dense matted ferns. The upper gradient is found between 3,500-4,500 ft elevation. The upper gradient tree canopy is also dominated by 60-80 ft mature closed canopy ‘ōhi‘a. The mid-canopy is dominated by a mix of flowering and fruiting tree species (e.g., ‘ōhi‘a, pilo, C*lermontia* sp., ‘ōlapa, kāwa‘u, kōlea, pūkiawe), tree ferns (up to 15 ft), the vine ‘ie‘ie, and epiphytes. Ground cover is dominated by nonnative grasses, mixed nonnative and native ferns, and areas of dense matted ferns. The primary differences between the upper and lower elevation gradients in this habitat type are the increased plant diversity in the mid-canopy of the upper gradient, and the	The leeward west-facing slopes of the Kona Forest Unit are protected from the majority of tradewind-dominated rainfall which occurs throughout the year. The lower elevation gradient of this habitat type receives approximately 80 inches of rainfall annually. The upper gradient receives approximately 60 inches of rainfall. Heavier rainfall occurs October-March. Moderately steep slope and relatively young lava flows are found along with a thin layer of organic soil. Surface water streams are not present in either the upper or lower elevation gradient.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). Past human disturbances include traditional farming and ranching practices and fire. The effects of this past activity include increased grasslands and a loss of native plant species.

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
	change from a herbaceous ground cover in the lower gradient to a grass-dominated ground cover in the upper gradient. A diverse native bird community first appears in the upper gradient of this habitat type, primarily due to elevations above the mosquito zone and more diverse forest. Other species of conservation and management concern include the ‘alalā, ‘ōpe‘ape‘a, and endangered plants.		
Montane mesic koa/‘ōhi‘a forest	This habitat type contains a mixed age class of koa- and ‘ōhi‘a- dominated forest and occurs 4,500-5,800 ft in elevation. The mid-canopy is dominated by a mix of flowering and fruiting trees (e.g., *Clermontia* sp., pilo, pūkiawe, ‘ōhelo, kōlea, kāwa‘u), tree ferns, mixed ferns, and epiphytes. A diverse native bird community occurs in this habitat type, primarily due to elevations above mosquito zone and more diverse forest plant community. Other species of conservation and management concern include the ‘alalā, ‘ōpe‘ape‘a, endangered plants, and an endangered invertebrate.	The leeward west-facing slopes of the Kona Forest Unit are protected from the majority of tradewind-dominated rainfall which occurs throughout the year. This habitat type receives approximately 75 inches of rainfall annually. Heavier rainfall occurs October-March. Moderately steep slope and relatively young lava flows are found along with a thin layer of organic soil. Surface water streams are not present in this habitat.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases).
Dry koa/‘ōhi‘a/māmane forest	This habitat type contains a mixed age class koa/‘ōhi‘a/māmane co-dominant forest and occurs 5,800 ft - 6,100 ft in elevation. The mid-canopy is dominated by a mix of flowering and fruiting trees (e.g. ‘iliahi (sandalwood), pilo, naio, pūkiawe, ‘ōhelo)	The leeward west-facing slopes of the Kona Forest Unit are protected from the majority of tradewind-dominated rainfall which occurs throughout the year. This habitat type receives approximately 40 inches of rainfall	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes,

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
	and mixed ferns. A diverse native bird community occurs in this habitat type, primarily due to elevations above mosquito zone and more diverse forest plant community. Other species of conservation and management concern include the ‘alalā, the ‘ōpe‘ape‘a, endangered plants, and an endangered invertebrate.	annually. Heavier rainfall occurs October-March. Moderately steep slope and relatively young lava flows are found along with a thin layer of organic soil. Surface water streams are not present in this habitat.	invasive plants, and diseases).
Lava tube caves	Lava tubes contain an endemic subterranean, invertebrate faunal community. Moisture, moist air, relatively constant moderate temperature, and lack of light are required attributes of these cave systems. Sub-fossil bird remains found in the detrital soils inside the cave systems are a valuable resource which can be used to document pre-modern Hawaiian avifauna. Lava tube caves found throughout the Island of Hawai‘i supported use by Native Hawaiians. Insufficient study has occurred on the Refuge to document archeological resources. However, there is the potential that cultural resources do exist in Refuge caves.	During periods of active volcanism, flowing lava often times created subterranean channels where molten lava flowed. When flowing lava subsided, a hollow channel or lava tube was formed, the opening to which creates a lava tube cave. Within the confines of the cave, invertebrates have evolved in this unique habitat. These mostly blind invertebrates feed on ‘ōhi‘a roots that penetrate the lava tube roof.	Trampling or the release of pest species from human disturbance, rats, or breaches in the lava tube ceiling could destroy the entire invertebrate community and destroy sub-fossil and archeological resources.

Habitats (plant communities that represent existing BIDEH)	**Population/Habitat Attributes** (age class, structure, serial stage, species composition)	**Natural Processes** (biotic and abiotic processes responsible for habitat conditions)	**Limiting Factors**
Lava tube skylights [Various above-ground habitats surround skylights, depending upon elevation]	The vertical walls created from the collapse of lava tube roofs naturally protect native plant communities. Skylights, unlike the lava tubes themselves, are exposed to the surface environment of rainfall, sunlight, and temperature fluctuations. These steep-sided depressions prevent degradation from ungulates, thus providing protected habitat for one fern species, *Asplenium peruvianum* var. *insulare* that is unique to skylight habitats, and also high populations of other rare and endangered plant species.	Collapse of lava tube roof and resulting vertical walled opening protects remnants of once common plants, now rare or endangered, from grazing by ungulates.	Limiting factors include a lack of native pollinators and several pest species (e.g., ungulates, rats, mice, slugs, mosquitoes, invasive plants, and diseases). There are a finite number of lava tubes. Typically skylights form shortly after lava tube formation. Human disturbance such as trampling could destroy any sub-fossil or archeological resources.

Note: nomenclature for habitat names follows Jacobi et al. (1989).

Table 4-2. Resources of Concern.

Focal Species	Habitat Type	Habitat Structure	Life History Requirement	Other Benefiting Species
Birds				
‘akiapōlā‘au	Montane wet koa/‘ōhi‘a forest.	A mixed age class of koa- and ‘ōhi‘a-dominated forest, occurring between 5,000-6,000 ft in elevation on the windward slopes of Mauna Kea. The mid-canopy is dominated by a mix of flowering and fruiting trees (e.g., ‘ōlapa, ‘ākala, pilo, pūkiawe, ‘ōhelo, kōlea, kāwa‘u), mixed ferns, and epiphytes. Ground cover is ferns and woody seedlings, herbs and nonnative grasses. A diverse native bird community occurs in this habitat type, primarily due to elevations above mosquito zone and more diverse forest plant community. Other species of conservation and management concern include koloa maoli, ‘ōpe‘ape‘a, and endangered plants.	Nesting and foraging.	All native forest bird species and ‘ōpe‘ape‘a and plants.
‘akiapōlā‘au	Koa/‘ōhi‘a forest-reforestation from grassland.	Koa, in reforestation areas, a minimum 8-10 year old growth, density and height requirements unknown but density is a dependent factor. Above mosquito zone.	Foraging.	‘Amakihi, ‘elepaio, ‘apapane, Hawai‘i creeper.
Hawai‘i ‘ākepa	Native ‘ōhi‘a and koa/‘ōhi‘a forest.	Nesting: Old growth trees, minimum 24 inches dbh with cavities for nesting. Foraging: mixed age class stand native koa and ‘ōhi‘a forest above mosquito zone.	Nesting and foraging.	All native forest bird species and ‘ōpe‘ape‘a and plants.
Hawai‘i creeper	Native ‘ōhi‘a and koa/‘ōhi‘a forest.	Mature koa and ‘ōhi‘a forest with native understory above mosquito zone.	Nesting and foraging.	All native forest bird species and ‘ōpe‘ape‘a and plants.

Focal Species	Habitat Type	Habitat Structure	Life History Requirement	Other Benefiting Species
ʻio	Native ʻōhiʻa and koa/ʻōhiʻa forest.	Mature ʻōhiʻa trees, home range of 7-988 acres.	Nesting.	All native forest bird species and ʻōpeʻapeʻa and plants.
ʻio	Native and nonnative forest and open habitats.	Forests, grasslands, urban areas.	Hunting for prey.	In native forest, all native forest bird species and ʻōpeʻapeʻa and plants.
nēnē	Open shrublands and grasslands.	Short grass, native and nonnative, less than 18 inches, mixed shrubs.	Foraging.	Pueo, ʻio, kōlea, native plant dispersal.
nēnē	Open shrublands and grasslands.	Short grass, native and nonnative, less than 18 inches, mixed shrubs.	Nesting, roosting, foraging	Pueo, ʻio, kōlea.
ʻōʻū	Native koa/ʻōhiʻa forest.	Mature koa and ʻōhiʻa forest with native understory, above mosquito zone.	Nesting and foraging.	All native forest bird species and ʻōpeʻapeʻa and plants.
ʻalalā	Native koa/ʻōhiʻa forest.	Mature koa and ʻōhiʻa forest with native understory, above mosquito zone. Elevational gradient with closed canopy, with mid-canopy understory to seasonally follow maturing fruits.	Nesting and foraging.	All native forest bird species and ʻōpeʻapeʻa and plants.
Hawaiian duck, koloa maoli	Ponds, streams, bogs.	Shallow water, with emergent vegetation edge.	Foraging and nesting.	ʻAlae keʻokeʻo, nēnē
Hawaiian coot, ʻalae keʻokeʻo	Ponds, bogs.	Shallow water, with emergent vegetation edge.	Foraging and nesting.	Koloa maoli and nēnē.

Focal Species	Habitat Type	Habitat Structure	Life History Requirement	Other Benefiting Species
Mammal				
Hawaiian hoary bat, ‘Ōpe‘ape‘a	Native koa/‘ōhi‘a forest and non-native forest.	Mature forest.	Breeding, roosting, and foraging.	All native forest bird species and plants.
Invertebrate				
Drosophila heteroneura, Picture-wing fly	Endemic to west side of Hawai‘i Island, native koa/‘ōhi‘a forest.	Mature mesic native forest with abundant *clermontia* sp.	Breeding and feeding.	All native forest bird species, ‘ōpe‘ape‘a, and plants.
Plants				
Asplenium peruvianum var. *insulare* *Clermontia lindseyana* *Clermontia peleana* *Clermontia pyrularia* *Cyanea hamatiflora* *Cyanea platyphylla* *Cyanea shipmannii* *Cyanea stictophylla* *Cyrtandra tintinabula* *Nothocestrum breviflorum* *Phyllostegia floribunda* *Phyllostegia racemosa* *Phyllostegia velutina* *Sicyos macrophyllus*	Wet ‘ōhi‘a and mesic koa/‘ōhi‘a forests.	Mature, undisturbed, and uneven aged forests.	All life-history stages for all plant species are required.	All native forest bird species, ‘ōpe‘ape‘a, invertebrates, and other forest plant species.
Portulaca sclerocarpa *Silene hawaiiensis*	Dry koa/‘ōhi‘a/māmane forest	Mature, undisturbed, and uneven aged forests.	All life-history stages for all plant species are required.	All native forest bird species, ‘ōpe‘ape‘a, invertebrates, and other forest plant species.

Appendix G. Integrated Pest Management (IPM) Program

1.0 Background

IPM is an interdisciplinary approach utilizing methods to prevent, eliminate, contain, and/or control pest species in concert with other management activities on refuge lands and waters to achieve wildlife and habitat management goals and objectives.[1] IPM is also a scientifically based, adaptive management process where available scientific information and best professional judgment of the refuge staff as well as other resource experts would be used to identify and implement appropriate management strategies that can be modified and/or changed over time to ensure effective, site-specific management of pest species to achieve desired outcomes. In accordance with 43 CFR 46.145, adaptive management would be particularly relevant where long-term impacts may be uncertain and future monitoring would be needed to make adjustments in subsequent implementation decisions. After a tolerable pest population (threshold) is determined considering achievement of refuge resource objectives and the ecology of pest species, one or more methods, or combinations thereof, would be selected that are feasible, efficacious, and most protective of non-target resources, including native species (fish, wildlife, and plants), and Service personnel, Service authorized agents, volunteers, and the public. Staff time and available funding would be considered when determining feasibility/practicality of various treatments.

IPM techniques to address pests are presented as CCP strategies (see Chapter 2 of this CCP) in an adaptive management context to achieve refuge resource objectives. In order to satisfy requirements for IPM planning as identified in the Director's Memo (dated September 9, 2004) entitled *Integrated Pest Management Plans and Pesticide Use Proposals: Updates, Guidance, and an Online Database*, the following elements of an IPM program have been incorporated into this CCP:

- Habitat and/or wildlife objectives that identify pest species and appropriate thresholds to indicate the need for and successful implementation of IPM techniques; and
- Monitoring before and/or after treatment to assess progress toward achieving objectives including pest thresholds.

Where pesticides would be necessary to address pests, this Appendix provides a structured procedure to evaluate potential effects of proposed uses involving ground-based applications to refuge biological resources and environmental quality. Only pesticide uses that likely would cause minor, temporary, or localized effects to refuge biological resources and environmental quality with appropriate best management practices (BMPs), where necessary, would be allowed for use on the refuge.

This Appendix does not describe the more detailed process to evaluate potential effects associated with aerial applications of pesticides. Moreover, it does not address effects of mosquito control with pesticides (larvicides, pupacides, or adulticides) based upon identified human health threats and presence of disease-carrying mosquitoes in sufficient numbers from monitoring conducted on a refuge. However, the basic framework to assess potential effects to refuge biological resources and environmental quality from aerial application of pesticides or use of insecticides for mosquito

[1] This appendix uses the term "pest" to describe those species referred to as "nonnative" in the main body of this CCP. In Hawai‘i, nonnative refers to invasive or introduced species, which also aligns with the 569 FW1 pest definition.

management would be similar to the process described in this Appendix for ground-based treatments of other pesticides.

2.0 Pest Management Laws and Policies

In accordance with Service policy 569 FW 1 (Integrated Pest Management), plant, invertebrate, and vertebrate pests on units of the Refuge System can be controlled to assure balanced wildlife and fish populations in support of refuge-specific wildlife and habitat management objectives. Pest control on Federal (refuge) lands and waters also is authorized under the following legal mandates:

- National Wildlife Refuge System Administration Act of 1966, as amended (16 USC 668dd-668ee);
- Plant Protection Act of 2000 (7 USC 7701 *et seq*.);
- Noxious Weed Control and Eradication Act of 2004 (7 USC 7781-7786, Subtitle E);
- Federal Insecticide, Fungicide, and Rodenticide Act of 1996 (7 USC 136-136y);
- National Invasive Species Act of 1996 (16 USC 4701);
- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (16 USC 4701);
- Food Quality Protection Act of 1996 (7 USC 136);
- Executive Order 13148, Section 601(a);
- Executive Order 13112; and
- Animal Damage Control Act of 1931 (7 USC 426-426c, 46 Stat. 1468).

Pests are defined as "…living organisms that may interfere with the site-specific purposes, operations, or management objectives or that jeopardize human health or safety" from Department policy 517 DM 1 (Integrated Pest Management Policy). Similarly, 569 FW 1 defines pests as "…invasive plants and introduced or native organisms that may interfere with achieving our management goals and objectives on or off our lands, or that jeopardize human health or safety." 517 DM 1 also defines an invasive species as "a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health." Throughout the remainder of this CCP, the terms pest and invasive species are used interchangeably because both can prevent/impede achievement of refuge wildlife and habitat objectives and/or degrade environmental quality.

In general, control of pests (vertebrate or invertebrate) on the refuge would conserve and protect the nation's fish, wildlife, and plant resources as well as maintain environmental quality. From 569 FW 1, animal or plant species, which are considered pests, may be managed if the following criteria are met:[2]

- Threat to human health and well being or private property, the acceptable level of damage by the pest has been exceeded, or State or local government has designated the pest as noxious;
- Detrimental to resource objectives as specified in a refuge resource management plan (e.g., comprehensive conservation plan, habitat management plan), if available; and
- Control would not conflict with attainment of resource objectives or the purpose(s) for which the refuge was established.

[2] Note that during the 15 year life span of the CCP, policies, such as 569 FW 1, may be updated and revised. As such, the Refuge will comply with the most updated Service policies related to IPM.

The specific justifications for pest management activities on the refuge are the following:

- Protect human health and well being;
- Prevent substantial damage to important to refuge resources;
- Protect newly introduced or re-establish native species;
- Control nonnative (exotic) species in order to support existence for populations of native species;
- Prevent damage to private property; and
- Provide the public with quality, compatible wildlife-dependent recreational opportunities.

In accordance with Service policy 620 FW 1 (Habitat Management Plans), there are additional management directives regarding invasive species found on the refuge:

- "We are prohibited by Executive Order, law, and policy from authorizing, funding, or carrying out actions that are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere."
- "Manage invasive species to improve or stabilize biotic communities to minimize unacceptable change to ecosystem structure and function and prevent new and expanded infestations of invasive species. Conduct refuge habitat management activities to prevent, control, or eradicate invasive species..."

Animal species damaging/destroying Federal property and/or detrimental to the management program of a refuge may be controlled as described in 50 CFR 31.14 (Official Animal Control Operations)**.** For example, on the mainland, the incidental removal of beaver damaging refuge infrastructure (e.g., clogging with subsequent damaging of water control structures) and/or negatively affecting habitats (e.g., removing woody species from existing or restored riparian areas) managed on refuge lands may be conducted without a pest control proposal. Exotic nutria, whose denning and burrowing activities in wetland dikes causes cave-ins and breaches, can be controlled using the most effective techniques considering site-specific factors without a pest control proposal. Along with the loss of quality wetland habitats associated with breaching of impoundments, the safety of refuge staffs and public (e.g. auto tour routes) driving on structurally compromised levees and dikes can be threaten by sudden and unexpected cave-ins.

Trespass and feral animals also may be controlled on refuge lands. Based upon 50 CFR 28.43 (Destruction of Dogs and Cats), dogs and cats running at large on a national wildlife refuge and observed in the act of killing, injuring, harassing or molesting humans or wildlife may be disposed of in the interest of public safety and protection of the wildlife. Feral animals should be disposed by the most humane method(s) available and in accordance with relevant Service directives (including Executive Order 11643). Disposed wildlife specimens may be donated or loaned to public institutions. Donation or loans of resident wildlife species will only be made after securing State approval (50 CFR 30.11 (Donation and Loan of Wildlife Specimens)**).** Surplus wildlife specimens may be sold alive or butchered, dressed and processed subject to federal and state laws and regulations (50 CFR 30.12 (Sale of Wildlife Specimens)**).**

3.0 Strategies

To fully embrace IPM as identified in 569 FW 1, the following strategies, where applicable, would be carefully considered on the refuge for each pest species:

- **Prevention.** This is the most effective and least expensive long-term management option for pests. It encompasses methods to prevent new introductions or the spread of the established pests to un-infested areas. It requires identifying potential routes of invasion to reduce the likelihood of infestation. Hazard Analysis and Critical Control Points (HACCP) planning can be used determine if current management activities on a refuge may introduce and/or spread invasive species in order to identify appropriate BMPs for prevention. See http://www.haccp-nrm.org/ for more information about HACCP planning.

  Prevention may include source reduction, using pathogen-free or weed-free seeds or fill; exclusion methods (e.g., barriers) and/or sanitation methods (e.g., wash stations) to prevent re-introductions by various mechanisms including vehicles, personnel, livestock, and horses. Because invasive species are frequently the first to establish newly disturbed sites, prevention would require a reporting mechanism for early detection of new pest occurrences with quick response to eliminate any new satellite pest populations. Prevention would require consideration of the scale and scope of land management activities that may promote pest establishment within uninfested areas or promote reproduction and spread of existing populations. Along with preventing initial introduction, prevention would involve halting the spread of existing infestations to new sites (Mullin et al. 2000). The primary reason of prevention would be to keep pest-free lands or waters from becoming infested. Executive Order 11312 emphasizes the priority for prevention with respect to managing pests.

  The following are methods to prevent the introduction and/or spread of pests on refuge lands:
  - Before beginning ground-disturbing activities (e.g., disking, scraping), inventory and prioritize pest infestations in project operating areas and along access routes. Refuge staff would identify pest species on site or within reasonably expected potential invasion vicinity. Where possible, the refuge staff would begin project activities in uninfested areas before working in pest-infested areas.
  - The refuge staff would locate and use pest-free project staging areas. They would avoid or minimize travel through pest-infested areas, or restrict to those periods when spread of seed or propagules of invasive plants would be least likely.
  - The refuge staff would determine the need for, and when appropriate, identify sanitation sites where equipment can be cleaned of pests. Where possible, the refuge staff would clean equipment before entering lands at on-refuge approved cleaning site(s). This practice does not pertain to vehicles traveling frequently in and out of the project area that will remain on roadways. Seeds and plant parts of pest plants would need to be collected, where practical. The refuge staff would remove mud, dirt, and plant parts from project equipment before moving it into a project area.
  - The refuge staff would clean all equipment, before leaving the project site, if operating in areas infested with pests. The refuge staff would determine the need for, and when appropriate, identify sanitation sites where equipment can be cleaned.
  - Refuge staffs, their authorized agents, and refuge volunteers would, where possible, inspect, remove, and properly dispose of seed and parts of invasive plants found on their clothing and equipment. Proper disposal means bagging the seeds and plant parts and then properly discarding of them (e.g., incinerating).
  - The refuge staff would evaluate options, including closure, to restrict the traffic on sites with on-going restoration of desired vegetation. The refuge staff would revegetate disturbed soil (except travel ways on surfaced projects) to optimize plant establishment for each specific site. Revegetation may include topsoil replacement, planting, seeding,

fertilization, liming, and weed-free mulching as necessary. The refuge staff would use native material, where appropriate and feasible. The refuge staff would use certified weed-free or weed-seed-free hay or straw where certified materials are reasonably available.

- The refuge staff would provide information, training and appropriate pest identification materials to refuge staffs, permit holders, and recreational visitors. The refuge staff would educate them about pest identification, biology, impacts, and effective prevention measures.
- The refuge staff would inspect borrowed material for invasive plants prior to use and transport onto and/or within refuge lands.
- The refuge staff would consider invasive plants in planning for road maintenance activities.
- The refuge staff would restrict off road travel to designated routes.
- In order to confine potential weed introductions to frequently monitored areas, visitors will restrict their activities to roads and established trails whenever possible.
- Permittees and visitors will implement precautions to prevent the introduction of alien plants and arthropods to the Refuge. Vehicles, boots, clothing, day packs, photographic gear and equipment must be cleaned and inspected for seeds, insects, eggs, larvae, etc. prior to entry.
- All researchers and assistants must have and use Refuge-dedicated rain gear, packs and boots. This equipment is to be used and stored only at the Refuge.

These prevention methods to minimize/eliminate the introduction and/or spread of pests were taken verbatim or slightly modified from Appendix E of US Forest Service (2005).

- **Mechanical/Physical Methods.** These methods would remove and destroy, disrupt the growth of, or interfere with the reproduction of pest species. For plants species, these treatments can be accomplished by hand, hand tool (manual), or power tools (mechanical) and include pulling, grubbing, digging, tilling/disking, cutting, swathing, grinding, sheering, girdling, mowing, and mulching of the pest plants.

  For animal species, Service employees or their authorized agents could use mechanical/physical methods (including trapping) to control pests as a refuge management activity. Based upon 50 CFR 31.2, trapping can be used on a refuge to reduce surplus wildlife populations for a “balanced conservation program” in accordance with Federal or state laws and regulations. In some cases, non-lethally trapped animals would be relocated to off-refuge sites with prior approval from the state.

  Each of these tools would be efficacious to some degree and applicable to specific situations. In general, mechanical controls can effectively control annual and biennial pest plants. However, to control perennial plants, the root system has to be destroyed or it would resprout and continue to grow and develop. Mechanical controls are typically not capable of destroying a perennial plant’s root system. Although some mechanical tools (e.g., disking, plowing) may damage root systems, they may stimulate regrowth producing a denser plant population that may aid in the spread depending upon the target species. In addition, steep terrain and soil conditions would be major factors that can limit the use of many mechanical control methods.

Some mechanical control methods (e.g., mowing), used in combination with herbicides, can be a very effective technique to control perennial species. For example, mowing perennial plants followed sequentially by treating the plant regrowth with a systemic herbicide often would improve the efficacy of the herbicide compared to herbicide only treatment.

- **Cultural Methods.** These methods would involve manipulating habitat to increase pest mortality by reducing its suitability to the pest. Cultural methods could include water-level manipulation, mulching, winter cover crops, changing planting dates to minimize pest impact, prescribed burning (facilitate revegetation, increase herbicide efficacy, and remove litter to assist in emergence of desirable species), flaming with propane torches, trap crops, crop rotations that would include non-susceptible crops, moisture management, addition of beneficial insect habitat, reducing clutter, proper trash disposal, planting or seeding desirable species to shade or out-compete invasive plants, applying fertilizer to enhance desirable vegetation, prescriptive grazing, and other habitat alterations.

- **Biological Control Agents.** Classical biological control would involve the deliberate introduction and management of natural enemies (parasites, predators, or pathogens) to reduce pest populations. Many of the most ecologically or economically damaging pest species in the United States originated in foreign countries. These newly introduced pests, which are free from natural enemies found in their country or region of origin, may have a competitive advantage over cultivated and native species. This competitive advantage often allows introduced species to flourish, and they may cause widespread economic damage to crops or out compete and displace native vegetation. Once the introduced pest species population reaches a certain level, traditional methods of pest management may be cost-prohibitive or impractical. Biological controls typically are used when these pest populations have become so widespread that eradication or effective control would be difficult or no longer practical.

  Biological control has advantages as well as disadvantages. Benefits would include reducing pesticide usage, host specificity for target pests, long-term self-perpetuating control, low cost/acre, capacity for searching and locating hosts, synchronizing biological control agents to hosts' life cycles, and the unlikelihood that hosts will develop resistance to agents. Disadvantages would include the following: limited availability of agents from their native lands, the dependence of control on target species density, slow rate at which control occurs, biotype matching, the difficulty and expense of conflicts over control of the target pest, and host specificity when host populations are low.

  A reduction in target species populations from biological controls is typically a slow process, and efficacy can be highly variable. It may not work well in a particular area although it does work well in other areas. Biological control agents would require specific environmental conditions to survive over time. Some of these conditions are understood; whereas, others are only partially understood or not at all.

  Biological control agents will not completely eradicate a target pest. When using biological control agents, residual levels of the target pest typically are expected; the agent population level or survival would be dependent upon the density of its host. After the pest population decreases, the population of the biological control agent would decrease correspondingly. This is a natural cycle. Some pest populations (e.g., invasive plants) would tend to persist for several years after a biological control agent becomes established due to seed reserves in the soil, inefficiencies in the agents search behavior, and the natural lag in population buildup of the agent.

The full range of pest groups potentially found on refuge lands and waters would include diseases, invertebrates, vertebrates and invasive plants (most common group). Often it is assumed that biological control would address many if not most of these pest problems. There are several well-documented success stories of biological control of invasive weed species in the Pacific Northwest including Mediterranean sage, St. Johnswort (Klamath weed) and tansy ragwort. Emerging success stories include Dalmatian toadflax, diffuse knapweed, leafy spurge, purple loosestrife, and yellow star thistle. In Hawai‘i, it would include banana poka and Eurythrina gall wasps. However, historically, each new introduction of a biological control agent in the United States has only about a 30% success rate (Coombs et al. 2004). Refer to Coombs et al. (2004) for the status of biological control agents for invasive plants in the Pacific Northwest.

Introduced species without desirable close relatives in the United States would generally be selected as biological controls. Natural enemies that are restricted to one or a few closely related plants in their country of origin are targeted as biological controls (Center et al. 1997, Hasan and Ayres 1990).

The refuge staff would ensure introduced agents are approved by the applicable authorities. Except for a small number of formulated biological control products registered by EPA under FIFRA, most biological control agents are regulated by the US Department of Agriculture (USDA)-Animal Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ). State departments of agriculture and, in some cases, county agricultural commissioners or weed districts, have additional approval authority.

Federal permits (USDA-APHIS-PPQ Form 526) are required to import biocontrols agents from another state. Form 526 may be obtained by writing:

> USDA-APHIS-PPQ
> Biological Assessment and Taxonomic Support
> 4700 River Road, Unit 113
> Riverdale, MD 20737

or

> through the internet at URL address:
> http://www.aphis.usda.gov/plant_health/permits/organism/plantpest_howtoapply.shtml

The Service strongly supports the development, and legal and responsible use of appropriate, safe, and effective biological control agents for nuisance and non-indigenous or pest species.

State and county agriculture departments may also be sources for biological control agents or they may have information about where biological control agents may be obtained. Commercial sources should have an Application and Permit to Move Live Plant Pests and Noxious Weeds (USDA-PPQ Form 226 USDA-APHIS-PPQ, Biological Assessment and Taxonomic Support, 4700 River Road, Unit 113, Riverdale, MD 20737) to release specific biological control agents in a state and/or county. Furthermore, certification regarding the biological control agent's identity (genus, specific epithet, sub-species and variety) and purity (e.g., parasite free, pathogen free, and biotic and abiotic contaminants) should be specified in purchase orders.

Biological control agents are subject to 7 RM 8 (Exotic Species Introduction and Management). In addition, the refuge staff would follow the International Code of Best Practice for Classical Biological Control of Weeds (http://sric.ucdavis.edu/exotic /exotic.htm) as ratified by delegates to the X International Symposium on Biological Control of Weeds, Bozeman, MT, July 9, 1999. This code identifies the following:

- Release only approved biological control agents;
- Use the most effective agents;
- Document releases; and
- Monitor for impact to the target pest, and nontarget species and the environment.

Biological control agents formulated as pesticide products and registered by the EPA (e.g., *Bti*) are also subject to PUP review and approval (see below).

A record of all releases would be maintained with date(s), location(s), and environmental conditions of the release site(s); the identity, quantity, and condition of the biological control agents released; and other relevant data and comments such as weather conditions. Systematic monitoring to determine the establishment and effectiveness of the release is also recommended.

The NEPA documents regarding biological and other environmental effects of biological control agents prepared by another federal agency, where the scope is relevant to evaluation of releases on refuge lands, would be reviewed. Possible source agencies for such NEPA documents include the Bureau of Land Management, USFS, National Park Service, USDA-APHIS, and the military services. It might be appropriate to incorporate by reference parts or all of existing document(s) from the review. Incorporating by reference (43 CFR 46.135) is a technique used to avoid redundancies in analysis. It also can reduce the bulk of a Service NEPA document, which only must identify the documents that are incorporated by reference. In addition, relevant portions must be summarized in the Service NEPA document to the extent necessary to provide the decision maker and public with an understanding of relevance of the referenced material to the current analysis.

- **Pesticides.** The selective use of pesticides would be based upon pest ecology (including mode of reproduction), the size and distribution of its populations, site-specific conditions (e.g., soils, topography), known efficacy under similar site conditions, and the capability to utilize best management practices (BMPs) to reduce/eliminate potential effects to non-target species, sensitive habitats, and potential to contaminate surface and groundwater. All pesticide usage (pesticide, target species, application rate, and method of application) would comply with the applicable federal (FIFRA) and state regulations pertaining to pesticide use, safety, storage, disposal, and reporting. Before pesticides can be used to eradicate, control, or contain pests on refuge lands and waters, pesticide use proposals (PUPs) would be prepared and approved in accordance with 569 FW 1. The PUP records would provide a detailed, time-, site-, and target-specific description of the proposed use of pesticides on the refuge. All PUPs would be created, approved or disapproved, and stored in the Pesticide Use Proposal System (PUPS), which is a centralized database only accessible on the Service's intranet (https://systems.fws.gov/pups). Only Service employees would be authorized to access PUP records for a refuge in this database.

  Application equipment would be selected to provide site-specific delivery to target pests while minimizing/eliminating direct or indirect (e.g., drift) exposure to non-target areas and degradation of surface and groundwater quality. Where possible, target-specific equipment (e.g., backpack sprayer, wiper) would be used to treat target pests. Other target-specific equipment to apply pesticides would include soaked wicks or paint brushes for wiping vegetation and lances, hatchets, or syringes for direct injection into stems. Granular pesticides may be applied using seeders or other specialized dispensers. In contrast, aerial spraying (e.g., fixed wing or helicopter) would only be used where access is difficult (remoteness) and/or the size/distribution of infestations precludes practical use of ground-based methods.

Because repeated use of one pesticide may allow resistant organisms to survive and reproduce, multiple pesticides with variable modes of action would be considered for treatments on refuge lands and waters. This is especially important if multiple applications within years and/or over a growing season likely would be necessary for habitat maintenance and restoration activities to achieve resource objectives. Integrated chemical and non-chemical controls also are highly effective, where practical, because pesticide resistant organisms can be removed from the site.

Cost may not be the primary factor in selecting a pesticide for use on a refuge. If the least expensive pesticide would potentially harm natural resources or people, then a different product would be selected, if available. The most efficacious pesticide available with the least potential to degrade environment quality (soils, surface water, and groundwater) as well as least potential effect to native species and communities of fish, wildlife, plants, and their habitats would be acceptable for use on refuge lands in the context of an IPM approach.

- **Habitat restoration/maintenance.** Restoration and/or proper maintenance of refuge habitats associated with achieving wildlife and habitat objectives would be essential for long-term prevention, eradication, or control (at or below threshold levels) of pests. Promoting desirable plant communities through the manipulation of species composition, plant density, and growth rate is an essential component of invasive plant management (Masters et al. 1996, Masters and Shelly 2001, Brooks et al. 2004). The following three components of succession could be manipulated through habitat maintenance and restoration: site availability, species availability, and species performance (Cox and Anderson 2004). Although a single method (e.g., herbicide treatment) may eliminate or suppress pest species in the short term, the resulting gaps and bare soil create niches that are conducive to further invasion by the species and/or other invasive plants. On degraded sites where desirable species are absent or in low abundance, revegetation with native/desirable grasses, forbs, and legumes may be necessary to direct and accelerate plant community recovery, and achieve site-specific objectives in a reasonable time frame. The selection of appropriate species for revegetation would be dependent on a number of factors including resource objectives and site-specific, abiotic factors (e.g., soil texture, precipitation/temperature regimes, and shade conditions). Seed availability and cost, ease of establishment, seed production, and competitive ability also would be important considerations.

4.0 Priorities for Treatments

For many refuges, the magnitude (number, distribution, and sizes of infestations) for pest problems is too extensive and beyond the available capital resources to effectively address during any single field season. To manage pests in the refuge, it would be essential to prioritize treatment of infestations. Highest priority treatments would be focused on early detection and rapid response to eliminate infestations of new pests, if possible. This would be especially important for aggressive pests potentially impacting species, species groups, communities, and/or habitats associated refuge purpose(s), Refuge System resources of concern (Federally listed species, migratory birds, selected marine mammals, and interjurisdictional fish), and native species for maintaining/restoring BIDEH.

The next priority would be treating established pests that appear in one or more previously uninfested areas. Moody and Mack (1988) demonstrated through modeling that small, new outbreaks of invasive plants eventually would infest an area larger than the established, source population. They also found that control efforts focusing on the large, main infestation rather than the new, small satellites reduced the chances of overall success. The lowest priority would be treating large infestations (sometimes monotypic stands) of well established pests. In this case, initial efforts would focus upon containment of the perimeter followed by work to control/eradicate the established infested area. If containment and/or control of a large infestation is not effective, then efforts would focus upon halting pest reproduction or managing source populations. Maxwell et al. (2009) found treating fewer populations that are sources represents an effective long-term strategy to reduce of total number of invasive populations and decreasing meta population growth rates.

Although state listed noxious weeds would always be of high priority for management, other pest species known to cause substantial ecological impact would also be considered. For example, cheatgrass may not be listed by a state as noxious, but it can greatly alter fire regimes in shrub steppe habitats resulting in large monotypic stands that displace native bunch grasses, forbs, and shrubs. Pest control would likely require a multi-year commitment from the refuge staff. Essential to the long-term success of pest management would be pre- and post-treatment monitoring, assessment of the successes and failures of treatments, and development of new approaches when proposed methods do not achieve desired outcomes.

5.0 Best Management Practices (BMPs)

The BMPs can minimize or eliminate possible effects associated with pesticide usage to non-target species and/or sensitive habitats as well as degradation of water quality from drift, surface runoff, or leaching. Based upon the Department of Interior Pesticide Use Policy (517 DM 1) and the Service Pest Management Policy and Responsibilities (30 AM 12), the use of applicable BMPs (where feasible) also would likely ensure that pesticide uses may not adversely affect federally listed species and/or their critical habitats through determinations made using the process described in 50 CFR part 402.

The following are BMPs pertaining to mixing/handling and applying pesticides for all ground-based treatments of pesticides, which would be considered and utilized, where feasible, based upon target- and site-specific factors and time-specific environmental conditions. Although not listed below, the most important BMP to eliminate/reduce potential impacts to non-target resources would be an IPM approach to prevent, control, eradicate, and contain pests.

5.1 Pesticide Handling and Mixing

- As a precaution against spilling, spray tanks would not be left unattended during filling.
- All pesticide containers would be triple rinsed and the rinsate would be used as water in the sprayer tank and applied to treatment areas.
- All pesticide spray equipment would be properly cleaned. Where possible, rinsate would be used as part of the makeup water in the sprayer tank and applied to treatment areas.

- The refuge staff would dispose of triple-rinsed pesticide containers per label directions.
- All unused pesticides would be properly discarded at a local "safe send" collection.
- Pesticides and pesticide containers would be lawfully stored, handled, and disposed of in accordance with the label and in a manner safeguarding human health, fish, and wildlife and prevent soil and water contaminant.
- The refuge staff would consider the water quality parameters (e.g., pH, hardness) that are important to ensure greatest efficacy where specified on the pesticide label.
- All pesticide spills would be addressed immediately using procedures identified in the refuge spill respond plan.

5.2 Applying Pesticides

- Pesticide treatments would only be conducted by or under the supervision of Service personnel and non-Service applicators with the appropriate, state or Bureau of Land Management certification to safely and effectively conduct these activities on refuge lands and waters.
- The refuge staff would comply with all federal, state, and local pesticide use laws and regulations as well as Department, Service, and Refuge System pesticide-related policies. For example, the refuge staff would use application equipment and apply rates for the specific pest(s) identified on the pesticide label as required under FIFRA.
- Before each treatment season and prior to mixing or applying any product for the first time each season, all applicators would review the labels, MSDSs, and PUPs for each pesticide, determining the target pest, appropriate mix rate(s), PPE, and other requirements listed on the pesticide label.
- A 1-ft no-spray buffer from the water's edge would be used, where applicable, and it does not detrimentally influence effective control of pest species.
- Use low impact herbicide application techniques (e.g., spot treatment, cut stump, oil basal, Thinvert system applications) rather than broadcast foliar applications (e.g., boom sprayer, other larger tank wand applications), where practical.
- Use low volume rather than high volume foliar applications where low impact methods above are not feasible or practical, to maximize herbicide effectiveness and ensure correct and uniform application rates.
- Applicators would use and adjust spray equipment to apply the coarsest droplet size spectrum with optimal coverage of the target species while reducing drift.
- Applicators would use the largest droplet size that results in uniform coverage.
- Applicators would use drift reduction technologies such as low-drift nozzles, where possible.
- Where possible, spraying would occur during low (average <7mph and preferably 3 - 5 mph) and consistent direction wind conditions with moderate temperatures (typically <85 ^{o}F).
- Where possible, applicators would avoid spraying during inversion conditions (often associated with calm and very low wind conditions) that can cause large-scale herbicide drift to non-target areas.
- Equipment would be calibrated regularly to ensure that the proper rate of pesticide is applied to the target area or species.
- Spray applications would be made at the lowest height for uniform coverage of target pests to minimize/eliminate potential drift.
- If windy conditions frequently occur during afternoons, spraying (especially boom treatments) would typically be conducted during early morning hours.

- Spray applications would not be conducted on days with >30% forecast for rain within 6 hours, except for pesticides that are rapidly rain fast (e.g., glyphosate in 1 hour) to minimize/eliminate potential runoff.
- Where possible, applicators would use drift retardant adjuvants during spray applications, especially adjacent to sensitive areas.
- Where possible, applicators would use a non-toxic dye to aid in identifying target area treated as well as potential over spray or drift. A dye can also aid in detecting equipment leaks. If a leak is discovered, the application would be stopped until repairs can be made to the sprayer.
- For pesticide uses associated with cropland and facilities management, buffers, as appropriate, would be used to protect sensitive habitats, especially wetlands and other aquatic habitats.
- When drift cannot be sufficiently reduced through altering equipment set up and application techniques, buffer zones may be identified to protect sensitive areas downwind of applications. The refuge staff would only apply adjacent to sensitive areas when the wind is blowing the opposite direction.
- Applicators would utilize scouting for early detection of pests to eliminate unnecessary pesticide applications.
- The refuge staff would consider timing of application so native plants are protected (e.g., senescence) while effectively treating invasive plants.
- Rinsate from cleaning spray equipment after application would be recaptured and reused or applied to an appropriate pest plant infestation.
- Application equipment (e.g., sprayer, all-terrain vehicle, tractor) would be thoroughly cleaned and personal protective equipment (PPE) would be removed/disposed of on-site by applicators after treatments to eliminate the potential spread of pests to un-infested areas.

6.0 Safety

6.1 Personal Protective Equipment

All applicators would wear the specific PPE identified on the pesticide label. The appropriate PPE will be worn at all times during handling, mixing, and applying. PPE can include the following: disposable (e.g., Tyvek) or laundered coveralls; gloves (latex, rubber, or nitrile); rubber boots; and/or an NIOSH-approved respirator. Because exposure to concentrated product is usually greatest during mixing, extra care should be taken while preparing pesticide solutions. Persons mixing these solutions can be best protected if they wear long gloves, an apron, footwear, and a face shield.

Coveralls and other protective clothing used during an application would be laundered separately from other laundry items. Transporting, storing, handling, mixing and disposing of pesticide containers will be consistent with label requirements, EPA and OSHA requirements, and Service policy.

If a respirator is necessary for a pesticide use, then the following requirements would be met in accordance with Service safety policy: a written Respirator Program, fit testing, physical examination (including pulmonary function and blood work for contaminants), and proper storage of the respirator.

6.2 Notification

The restricted entry interval (REI) is the time period required after the application at which point someone may safely enter a treated area without PPE. Refuge staff, authorized management agents of the Service, volunteers, and members of the public who could be in or near a pesticide treated area within the stated re-entry time period on the label would be notified about treatment areas. Posting would occur at any site where individuals might inadvertently become exposed to a pesticide during other activities on the refuge. Where required by the label and/or state-specific regulations, sites would also be posted on its perimeter and at other likely locations of entry. The refuge staff would also notify appropriate private property owners of an intended application, including any private individuals have requested notification. Special efforts would be made to contact nearby individuals who are beekeepers or who have expressed chemical sensitivities.

6.3 Medical Surveillance

Medical surveillance may be required for Service personnel and approved volunteers who mix, apply, and/or monitor use of pesticides (see 242 FW 7 (Pesticide Users) and 242 FW 4 (Medical Surveillance)). In accordance with 242 FW 7.12A, Service personnel would be medically monitoring if one or more of the following criteria is met: exposed or may be exposed to concentrations at or above the published permissible exposure limits or threshold limit values (see 242 FW 4); use pesticides in a manner considered "frequent pesticide use"; or use pesticides in a manner that requires a respirator (see 242 FW 14 for respirator use requirements). In 242 FW7.7A, "**Frequent Pesticide Use** means when a person applying pesticide handles, mixes, or applies pesticides, with a Health Hazard rating of 3 or higher, for 8 or more hours in any week or 16 or more hours in any 30-day period." Under some circumstances, individuals may be medically monitored who use pesticides infrequently (see section 7.7), experience an acute exposure (sudden, short-term), or use pesticides with a health hazard ranking of 1 or 2. This decision would consider the individual's health and fitness level, the pesticide's specific health risks, and the potential risks from other pesticide-related activities. Refuge cooperators (e.g., cooperative farmers) and other authorized agents (e.g., state and county employees) would be responsible for their own medical monitoring needs and costs.

Standard examinations (at refuge expense) of appropriate refuge staff would be provided by the nearest certified occupational health and safety physician as determined by Federal Occupational Health.

6.4 Certification and Supervision of Pesticide Applicators

Appropriate refuge staff or approved volunteers handling, mixing, and/or applying or directly supervising others engaged in pesticide use activities would be trained and state or federally (BLM) licensed to apply pesticides to refuge lands or waters. In accordance with 242 FW7.18A and 569 FW 1.10B, certification is required to apply restricted use pesticides based upon EPA regulations. For safety reasons, all individuals participating in pest management activities with general use pesticides also are encouraged to attend appropriate training or acquire pesticide applicator certification. The certification requirement would be for a commercial or private applicator depending upon the state. New staff unfamiliar with proper procedures for storing, mixing, handling, applying, and disposing of herbicides and containers would receive orientation and training before handling or using any products. Documentation of training would be kept in the files at the refuge office.

6.5 Record Keeping

6.5.1 Labels and material safety data sheets

Pesticide labels and material safety data sheets (MSDSs) would be maintained at the refuge shop and laminated copies in the mixing area. These documents also would be carried by field applicators, where possible. A written reference (e.g., note pad, chalk board, dry erase board) for each tank to be mixed would be kept in the mixing area for quick reference while mixing is in progress. In addition, approved PUPs stored in the PUPS database typically contain website links (URLs) to pesticide labels and MSDSs.

6.5.2 Pesticide use proposals (PUPs)

A PUP would be prepared for each proposed pesticide use associated with annual pest management on refuge lands and waters. A PUP would include specific information about the proposed pesticide use including the common and chemical names of the pesticide(s), target pest species, size and location of treatment site(s), application rate(s) and method(s), and federally listed species determinations, where applicable.

In accordance with Service guidelines (Director's memo (December 12, 2007)), a refuge staff may receive up to 5-year approvals for Washington Office and field reviewed proposed pesticide uses based upon meeting identified criteria including an approved IPM plan, where necessary (see http://www.fws.gov/contaminants/Issues/IPM.cfm). For a refuge, an IPM plan (requirements described herein) can be completed independently or in association with a CCP or HMP if IPM strategies and potential environmental effects are adequately addressed within appropriate NEPA documentation.

The PUPs would be created, approved or disapproved, and stored as records in the Pesticide Use Proposal System (PUPS), which is centralized database on the Service's intranet (https://systems.fws.gov/pups). Only Service employees can access PUP records in this database.

6.5.3 Pesticide usage

In accordance with 569 FW 1, the refuge Project Leader would be required to maintain records of all pesticides annually applied on lands or waters under refuge jurisdiction. This would encompass pesticides applied by other Federal agencies, state and county governments, non-government applicators including cooperators and their pest management service providers with Service permission. For clarification, pesticide means all insecticides, insect and plant growth regulators, dessicants, herbicides, fungicides, rodenticides, acaricides, nematicides, fumigants, avicides, and piscicides.

The following usage information can be reported for approved PUPs in the PUPS database:
- Pesticide trade name(s);
- Active ingredient(s);
- Total acres treated;
- Total amount of pesticides used (lbs or gallons);
- Total amount of active ingredient(s) used (lbs);

- Target pest(s); and
- Efficacy (% control).

To determine whether treatments are efficacious (eradicating, controlling, or containing the target pest) and achieving resource objectives, habitat and/or wildlife response would be monitored both pre- and post-treatment, where possible. Considering available annual funding and staffing, appropriate monitoring data regarding characteristics (attributes) of pest infestations (e.g., area, perimeter, degree of infestation-density, % cover, density) as well as habitat and/or wildlife response to treatments may be collected and stored in a relational database (e.g., Refuge Habitat Management Database), preferably a geo-referenced data management system (e.g., Refuge Lands GIS (RLGIS)) to facilitate data analyses and subsequent reporting. In accordance with adaptive management, data analysis and interpretation would allow treatments to be modified or changed over time, as necessary, to achieve resource objectives considering site-specific conditions in conjunction with habitat and/or wildlife responses. Monitoring could also identify short- and long-term impacts to natural resources and environmental quality associated with IPM treatments in accordance with adaptive management principles identified in 43 CFR 46.145.

7.0 Evaluating Pesticide Use Proposals

Pesticides would only be used on refuge lands for habitat management as well as facilities maintenance after approval of a PUP. In general, proposed pesticide uses on refuge lands would only be approved where there would likely be minor, temporary, or localized effects to fish and wildlife species as well as minimal potential to degrade environmental quality. Potential effects to listed and non-listed species would be evaluated with quantitative ecological risk assessments and other screening measures. Potential effects to environmental quality would be based upon pesticide characteristics of environmental fate (water solubility, soil mobility, soil persistence, and volatilization) and other quantitative screening tools. Ecological risk assessments as well as characteristics of environmental fate and potential to degrade environmental quality for pesticides would be documented in Chemical Profiles (see Section 7.5). These profiles would include threshold values for quantitative measures of ecological risk assessments and screening tools for environmental fate that represent minimal potential effects to species and environmental quality. In general, only pesticide uses with appropriate BMPs (see Section 4.0) for habitat management and cropland/facilities maintenance on refuge lands that would potentially have minor, temporary, or localized effects on refuge biological and environmental quality (threshold values not exceeded) would be approved.

7.1 Overview of Ecological Risk Assessment

An ecological risk assessment process would be used to evaluate potential adverse effects to biological resources as a result of a pesticide(s) proposed for use on refuge lands. It is an established quantitative and qualitative methodology for comparing and prioritizing risks of pesticides and conveying an estimate of the potential risk for an adverse effect. This quantitative methodology provides an efficient mechanism to integrate best available scientific information regarding hazard, patterns of use (exposure), and dose-response relationships in a manner that is useful for ecological risk decision-making. It would provide an effective way to evaluate potential effects where there is missing or unavailable scientific information (data gaps) to address reasonable, foreseeable adverse effects in the field as required under 40 CFR Part 1502.22. Protocols for ecological risk assessment of pesticide uses on the refuge were developed through research and established by the EPA (2004). Assumptions for these risk assessments are presented in Section 6.2.3.

The toxicological data used in ecological risk assessments are typically results of standardized laboratory studies provided by pesticide registrants to the EPA to meet regulatory requirements under the Federal Insecticide, Fungicide and Rodenticide Act of 1996 (FIFRA). These studies assess the acute (lethality) and chronic (reproductive) effects associated with short- and long-term exposure to pesticides on representative species of birds, mammals, freshwater fish, aquatic invertebrates, and terrestrial and aquatic plants. Other effects data publicly available would also be utilized for risk assessment protocols described herein. Toxicity endpoint and environmental fate data are available from a variety of resources. Some of the more useful resources can be found in Section 7.5.

Table 1. Ecotoxicity tests used to evaluate potential effects to birds, fish, and mammals to establish toxicity endpoints for risk quotient calculations.

Species Group	Exposure	Measurement endpoint
Bird	Acute	Median Lethal Concentration (LC_{50})
	Chronic	No Observed Effect Concentration (NOEC) or No Observed Adverse Effect Concentration (NOAEC)[1]
Fish	Acute	Median Lethal Concentration (LC_{50})
	Chronic	No Observed Effect Concentration (NOEC) or No Observed Adverse Effect Concentration (NOAEC)[2]
Mammal	Acute	Oral Lethal Dose (LD_{50})
	Chronic	No Observed Effect Concentration (NOEC) or No Observed Adverse Effect Concentration (NOAEC)[3]

[1]Measurement endpoints typically include a variety of reproductive parameters (e.g., number of eggs, number of offspring, eggshell thickness, and number of cracked eggs).
[2]Measurement endpoints for early life stage/life cycle typically include embryo hatch rates, time to hatch, growth, and time to swim-up.
[3]Measurement endpoints include maternal toxicity, teratogenic effects or developmental anomalies, evidence of mutagenicity or genotoxicity, and interference with cellular mechanisms such as DNA synthesis and DNA repair.

7.2 Determining Ecological Risk to Fish and Wildlife

The potential for pesticides used on the refuge to cause direct adverse effects to fish and wildlife would be evaluated using EPA's Ecological Risk Assessment Process (2004). This deterministic approach, which is based upon a two-phase process involving estimation of environmental concentrations and then characterization of risk, would be used for ecological risk assessments. This method integrates exposure estimates (estimated environmental concentration (EEC) and toxicological endpoints (e.g., LC_{50} and oral LD_{50})) to evaluate the potential for adverse effects to species groups (birds, mammals, and fish) representative of legal mandates for managing units of the Refuge System. This integration is achieved through risk quotients (RQs) calculated by dividing the EEC by acute and chronic toxicity values selected from standardized toxicological endpoints or published effect (Table 1).

RQ = EEC/Toxicological Endpoint

The level of risk associated with direct effects of pesticide use would be characterized by comparing calculated RQs to the appropriate Level of Concern (LOC) established by EPA (1998 (Table 2)). The LOC represents a quantitative threshold value for screening potential adverse effects to fish and wildlife resources associated with pesticide use. The following are four exposure-species group scenarios that would be used to characterize ecological risk to fish and wildlife on the refuge: acute-listed species, acute-nonlisted species, chronic-listed species, and chronic-nonlisted species.

Acute risk would indicate the potential for mortality associated with short-term dietary exposure to pesticides immediately after an application. For characterization of acute risks, median values from LC_{50} and LD_{50} tests would be used as toxicological endpoints for RQ calculations. In contrast, chronic risks would indicate the potential for adverse effects associated with long-term dietary exposure to pesticides from a single application or multiple applications over time (within a season and over years). For characterization of chronic risks, the no observed concentration (NOAEC) or no observed effect concentration (NOEC) for reproduction would be used as toxicological endpoints for RQ calculations. Where available, the NOAEC would be preferred over a NOEC value.

Listed species are those federally designated as threatened, endangered, or proposed in accordance with the Endangered Species Act of 1973 (16 USC 1531-1544, 87 Stat. 884, as amended-Public Law 93-205). For listed species, potential adverse effects would be assessed at the individual level because loss of individuals from a population could detrimentally impact a species. In contrast, risks to nonlisted species would consider effects at the population level. A RQ<LOC would indicate the proposed pesticide use "may affect, not likely to adversely effect" individuals (listed species) and it would not pose an unacceptable risk for adverse effects to populations (non-listed species) for each taxonomic group (Table 2). In contrast, a RQ>LOC would indicate a "may affect, likely to adversely affect" for listed species and it would also pose unacceptable ecological risk for adverse effects to nonlisted species.

Table 2. Presumption of unacceptable risk for birds, fish, and mammals (US Environmental Protection Agency 1998).

Risk Presumption		Level of Concern	
		Listed Species	Non-listed Species
Acute	Birds	0.1	0.5
	Fish	0.05	0.5
	Mammals	0.1	0.5
Chronic	Birds	1.0	1.0
	Fish	1.0	1.0
	Mammals	1.0	1.0

7.2.1 Environmental exposure

Following release into the environment through application, pesticides would experience several different routes of environmental fate. Pesticides which would be sprayed can move through the air (e.g., particle or vapor drift) and may eventually end up in other parts of the environment such as non-target vegetation, soil, or water. Pesticides applied directly to the soil may be washed off the soil into nearby bodies of surface water (e.g., surface runoff) or may percolate through the soil to lower soil layers and groundwater (e.g., leaching) (Baker and Miller 1999, Pope et. al. 1999, Butler et. al. 1998, Ramsay et. al. 1995, EXTOXNET 1993*a*). Pesticides which would be injected into the soil may also be subject to the latter two fates. The aforementioned possibilities are by no means complete, but it does indicate movement of pesticides in the environment is very complex with transfers occurring continually among different environmental compartments. In some cases, these exchanges occur not only between areas that are close together, but it also may involve transportation of pesticides over long distances (Barry 2004, Woods 2004).

7.2.1.1 Terrestrial exposure

The estimated environmental concentration (ECC) for exposure to terrestrial wildlife would be quantified using an USEPA screening-level approach (US Environmental Protection Agency 2004). This screening-level approach is not affected by product formulation because it evaluates pesticide active ingredient(s). This approach would vary depending upon the proposed pesticide application method: spray or granular.

7.2.1.1.1 Terrestrial-spray application

For spray applications, exposure would be determined using the Kanaga nomogram method (US Environmental Protection Agency 2005*a*, US Environmental Protection Agency 2004, Pfleeger et al. 1996) through the USEPA's Terrestrial Residue Exposure model (T-REX) version 1.2.3 (US Environmental Protection Agency 2005*b*). To estimate the maximum (initial) pesticide residue on short grass (<20 cm tall) as a general food item category for terrestrial vertebrate species, T-REX input variables would include the following from the pesticide label: maximum pesticide application rate (pounds active ingredient [acid equivalent]/acre) and pesticide half-life (days) in soil. Although there are other food item categories (tall grasses; broadleaf plants and small insects; and fruits, pods, seeds and large insects), short grass was selected because it would yield maximum EECs (240 ppm per lb ai/acre) for worse-case risk assessments. Short grass is not representative of forage for carnivorous species (e.g., raptors), but it would characterize the maximum potential exposure through the diet of avian and mammalian prey items. Consequently, this approach would provide a conservative screening tool for pesticides that do not biomagnify.

For RQ calculations in T-REX, the model would require the weight of surrogate species and Mineau scaling factors (Mineau et. al. 1996). For example, body weights of bobwhite quail and mallard are included in T-REX by default, but body weights of other organisms (Table 3) would be entered manually. The Mineau scaling factor accounts for small-bodied bird species that may be more sensitive to pesticide exposure than would be predicted only by body weight. Mineau scaling factors would be entered manually with values ranging from 1 to 1.55 that are unique to a particular pesticide or group of pesticides. If specific information to select a scaling factor is not available, then a value of 1.15 would be used as a default. Alternatively, zero would be entered if it is known that body weight does not influence toxicity of pesticide(s) being assessed. The upper bound estimate output from the T-REX Kanaga nomogram would be used as an EEC for calculation of RQs. This approach would yield a conservative estimate of ecological risk.

Table 3. Average body weight of selected terrestrial wildlife species frequently used in research to establish toxicological endpoints (Dunning 1984).

Species	Body Weight (kg)
Mammal (15 g)	0.015
House sparrow	0.0277
Mammal (35 g)	0.035
Starling	0.0823
Red-winged blackbird	0.0526
Common grackle	0.114
Japanese quail	0.178
Bobwhite quail	0.178
Rat	0.200
Rock dove (aka pigeon)	0.542
Mammal (1000 g)	1.000
Mallard	1.082
Ring-necked pheasant	1.135

7.2.1.1.2 Terrestrial – granular application

Granular pesticide formulations and pesticide-treated seed would pose a unique route of exposure for avian and mammalian species. The pesticide is applied in discrete units which birds or mammals might ingest accidentally with food items or intentionally as in the case of some bird species actively seeking and picking up gravel or grit to aid digestion or seed as a food source. Granules may also be consumed by wildlife foraging on earthworms, slugs or other soft-bodied soil organisms to which the granules may adhere.

Terrestrial wildlife RQs for granular formulations or seed treatments would be calculated by dividing the maximum milligrams of active ingredient (ai) exposed (e.g., EEC) on the surface of an area equal to 1 square foot by the appropriate LD_{50} value multiplied by the surrogate's body weight (Table 3). An adjustment to surface area calculations would be made for broadcast, banded, and in-furrow applications. An adjustment also would be made for applications with and without incorporation of the granules. Without incorporation, it would be assumed that 100% of the granules remain on the soil surface available to foraging birds and mammals. Press wheels push granules flat with the soil surface, but they are not incorporated into the soil. If granules are incorporated in the soil during band or T-band applications or after broadcast applications, it would be assumed only 15% of the applied granules remain available to wildlife. It would be assumed that only 1% of the granules are available on the soil surface following in-furrow applications.

EECs for pesticides applied in granular form and as seed treatments would be determined considering potential ingestion rates of avian or mammalian species (e.g., 10-30% body weight/day). This would provide an estimate of maximum exposure that may occur as a result of granule or seed treatment spills such as those that commonly occur at end rows during application and planting. The availability of granules and seed treatments to terrestrial vertebrates would also be considered by

calculating the loading per unit area (LD_{50}/ft^2) for comparison to USEPA Level of Concerns (US Environmental Protection Agency 1998). The
T-REX version 1.2.3 (US Environmental Protection Agency 2005*b*) contains a submodel which automates Kanaga exposure calculations for granular pesticides and treated seed.

The following formulas will be used to calculate EECs depending upon the type of granular pesticide application:

- In-furrow applications assume a typical value of 1% granules, bait, or seed remain unincorporated.

mg a.i./ft.^{2} = [(lbs. product/acre)(% a.i.)(453,580 mg/lbs)(1% exposed))] / {[(43,560 ft.^{2}/acre)/(row spacing (ft.))] / (row spacing (ft.)}

or

mg a.i./ft^2 = [(lbs product/1000 ft. row)(% a.i.)(1000 ft row)(453,580 mg/lb.)(1% exposed)

EEC = [(mg a.i./ft.^{2})(% of pesticide biologically available)]

- Incorporated banded treatments assume that 15% of granules, bait, seeds are unincorporated.

mg a.i./ft.^{2} = [(lbs. product/1000 row ft.)(% a.i.)(453,580 mg/lb.)(1-% incorporated)] / (1,000 ft.)(band width (ft.))

EEC = [(mg a.i./ft.^{2})(% of pesticide biologically available)]

- Broadcast treatment without incorporation assumes 100% of granules, bait, seeds are unincorporated.

mg a.i./ft.^{2} = [(lbs. product/acre)(% a.i.)(453,590 mg/lb.)] / (43,560 ft.^{2}/acre)

EEC = [(mg a.i./ft.^{2})(% of pesticide biologically available)]

Where:

- *% of pesticide biologically available = 100% without species specific ingestion rates*

- *Conversion for calculating mg a.i./ft.^{2} using ounces: 453,580 mg/lb. /16 = 28,349 mg/oz.*

The following equation would used to calculate a RQ based on the EEC calculated by one of the above equations. The EEC would divided by the surrogate LD_{50} toxicological endpoint multiplied by the body weight (Table 3) of the surrogate.

$$RQ = EEC / [LD_{50} (mg/kg) * body\ weight\ (kg)]$$

As with other risk assessments, a RQ>LOC would be a presumption of unacceptable ecological risk. A RQ<LOC would be a presumption of acceptable risk with only minor, temporary, or localized effects to species.

7.2.1.2 Aquatic exposure

Exposures to aquatic habitats (e.g., wetlands, meadows, ephemeral pools, water delivery ditches) would be evaluated separately for ground-based pesticide treatments of habitats managed for fish and wildlife compared with cropland/facilities maintenance (for Hakalau Forest NWR, this would be streams and bogs). The primary exposure pathway for aquatic organisms from any ground-based treatments likely would be particle drift during the pesticide application. However, different exposure scenarios would be necessary as a result of contrasting application equipment and techniques as well as pesticides used to control pests on agricultural lands (especially those cultivated by cooperative farmers for economic return from crop yields) (not applicable to Hakalau Forest NWR) and facilities maintenance (e.g., roadsides, parking lots, trails) compared with other managed habitats on the refuge. In addition, pesticide applications may be done <25 feet of the high water mark of aquatic habitats for habitat management treatments; whereas, no-spray buffers (≥25 feet) would be used for croplands/facilities maintenance treatments.

7.2.1.2.1 Habitat treatments

For the worst-case exposure scenario to non-target aquatic habitats, EECs (Table 4) would be would be derived from Urban and Cook (1986) that assumes an intentional overspray to an entire, non-target water body (1-ft depth) from a treatment <25 ft from the high water mark using the max application rate (acid basis [see above]). However, use of BMPs for applying pesticides (see Section 4.2) would likely minimize/eliminate potential drift to non-target aquatic habitats during actual treatments. If there would be unacceptable (acute or chronic) risk to fish and wildlife with the simulated 100% overspray (RQ>LOC), then the proposed pesticide use may be disapproved or the PUP would be approved at a lower application rate to minimize/eliminate unacceptable risk to aquatic organisms (RQ=LOC).

Table 4. Estimated Environmental Concentrations (ppb) of pesticides in aquatic habitats (1 foot depth) immediately after direct application (Urban and Cook 1986).

Lbs/acre	EEC (ppb)
0.10	36.7
0.20	73.5
0.25	91.9
0.30	110.2
0.40	147.0
0.50	183.7
0.75	275.6
1.00	367.5
1.25	459.7
1.50	551.6
1.75	643.5
2.00	735.7
2.25	827.6
2.50	919.4
3.00	1103.5
4.00	1471.4

Lbs/acre	EEC (ppb)
5.00	1839
6.00	2207
7.00	2575
8.00	2943
9.00	3311
10.00	3678

7.2.1.2.2 Cropland/facilities maintenance treatments

Field drift studies conducted by the Spray Drift Task Force, which is a joint project of several agricultural chemical businesses, were used to develop a generic spray drift database. From this database, the AgDRIFT computer model was created to satisfy USEPA pesticide registration spray drift data requirements and as a scientific basis to evaluate off-target movement of pesticides from particle drift and assess potential effects of exposure to wildlife. Several versions of the computer model have been developed (i.e., v2.01 through v2.10). The Spray Drift Task Force AgDRIFT® model version 2.01 (SDTF 2003, AgDRIFT 2001) would be used to derive EECs resulting from drift of pesticides to refuge aquatic resources from ground-based pesticide applications >25 feet from the high water mark. The Spray Drift Task Force AgDRIFT model is publicly available at http://www.agdrift.com. At this website, click "AgDRIFT 2.0" and then click "Download Now" and follow the instructions to obtain the computer model.

The AgDRIFT model is composed of submodels called tiers. Tier I Ground submodel would be used to assess ground-based applications of pesticides. Tier outputs (EECs) would be calculated with AgDRIFT using the following input variables: max application rate (acid basis [see above]), low boom (20 inches), fine to medium droplet size, EPA-defined wetland, and a ≥25-foot distance (buffer) from treated area to water. No croplands exist for Hakalau Forest NWR.

7.2.2 Use of information on effects of biological control agents, pesticides, degradates, and adjuvants

NEPA documents regarding biological and other environmental effects of biological control agents, pesticides, degradates, and adjuvants prepared by another federal agency, where the scope would be relevant to evaluation of effects from pesticide uses on refuge lands, would be reviewed. Possible source agencies for such NEPA documents would include the Bureau of Land Management, US Forest Service, National Park Service, US Department of Agriculture-Animal and Plant Health Inspection Service, and the military services. It might be appropriate to incorporate by reference parts or all of existing document(s). Incorporating by reference (40 CFR 1502.21) is a technique used to avoid redundancies in analysis. It also would reduce the bulk of a Service NEPA document, which only would identify the documents that are incorporated by reference. In addition, relevant portions would be summarized in the Service NEPA document to the extent necessary to provide the decision maker and public with an understanding of relevance of the referenced material to the current analysis.

In accordance with the requirements set forth in 43 CFR 46.135, the Service would specifically incorporate through reference ecological risk assessments prepared by the US Forest Service (http://www.fs.fed.us/r6/invasiveplant-eis/Risk-Assessments/Herbicides-Analyzed-InvPlant-EIS.htm) and Bureau of Land Management (http://www.blm.gov/wo/st/en/prog/more/veg_eis.html). These risk assessments and associated documentation also are available in total with the administrative record for the Final Environmental Impact Statement entitled *Pacific Northwest Region Invasive Plant Program – Preventing and Managing Invasive Plants* (US Forest Service 2005) and *Vegetation Treatments Using Herbicides on Bureau of Land Management Lands in 17 Western States Programmatic EIS (PEIS)* (Bureau of Land Management 2007). In accordance with 43 CRF 46.120(d), use of existing NEPA documents by supplementing, tiering to, incorporating by reference, or adopting previous NEPA environmental analyses would avoid redundancy and unnecessary paperwork.

As a basis for completing "Chemical Profiles" for approving or disapproving refuge PUPs, ecological risk assessments for the following herbicide and adjuvant uses prepared by the US Forest Service would be incorporated by reference:

- 2,4-D;
- Chlorosulfuron;
- Clopyralid;
- Dicamba;
- Glyphosate;
- Imazapic;
- Imazapyr;
- Metsulfuron methyl;
- Picloram;
- Sethoxydim;
- Sulfometuron methyl;
- Triclopyr; and
- Nonylphenol polyethylate (NPE) based surfactants.

As a basis for completing "Chemical Profiles" for approving or disapproving refuge PUPs, ecological risk assessments for the following herbicide uses as well as evaluation of risks associated with pesticide degradates and adjuvants prepared by the Bureau of Land Management would be incorporated by reference:

- Bromacil;
- Chlorsulfuron;
- Diflufenzopyr;
- Diquat;
- Diuron;
- Fluridone;
- Imazapic;
- Overdrive (diflufenzopyr and dicamba);
- Sulfometuron methyl;
- Tebuthiuron;
- Pesticide degradates and adjuvants (*Appendix D – Evaluation of risks from degradates, polyoxyethylene-amine (POEA) and R-11, and endocrine disrupting chemicals*).

7.2.3 Assumptions for ecological risk assessments

There are a number of assumptions involved with the ecological risk assessment process for terrestrial and aquatic organisms associated with utilization of the US Environmental Protection Agency's (2004) process. These assumptions may be risk neutral or may lead to an over- or under-estimation of risk from pesticide exposure depending upon site-specific conditions. The following describes these assumptions, their application to the conditions typically encountered, and whether or not they may lead to recommendations that are risk neutral, underestimate, or overestimate ecological risk from potential pesticide exposure.

- Indirect effects would not be evaluated by ecological risk assessments. These effects include the mechanisms of indirect exposure to pesticides: consuming prey items (fish, birds, or small mammals), reductions in the availability of prey items, and disturbance associated with pesticide application activities.
- Exposure to a pesticide product can be assessed based upon the active ingredient. However, exposure to a chemical mixture (pesticide formulation) may result in effects that are similar or substantially different compared to only the active ingredient. Non-target organisms may be exposed directly to the pesticide formulation or only various constituents of the formulation as they dissipate and partition in the environment. If toxicological information for both the active ingredient and formulated product are available, then data representing the greatest potential toxicity would be selected for use in the risk assessment process (US Environmental Protection Agency 2004). As a result, this conservative approach may lead to an overestimation of risk characterization from pesticide exposure.
- Because toxicity tests with listed or candidate species or closely related species are not available, data for surrogate species would be most often used for risk assessments. Specifically, bobwhite quail and mallard duck are the most frequently used surrogates for evaluating potential toxicity to federally listed avian species. Bluegill sunfish, rainbow trout, and fathead minnow are the most common surrogates for evaluating toxicity for freshwater fishes. However, sheep's head minnow can be an appropriate surrogate marine species for coastal environments. Rats and mice are the most common surrogates for evaluating toxicity for mammals. Interspecies sensitivity is a major source of uncertainty in pesticide assessments. As a result of this uncertainty, data is selected for the most sensitive species tested within a taxonomic group (birds, fish, and mammals) given the quality of the data is acceptable. If additional toxicity data for more species of organisms in a particular group are available, the selected data will not be limited to the species previously listed as common surrogates.
- The Kanaga nomogram outputs maximum EEC values that may be used to calculate an average daily concentration over a specified interval of time, which is referred to as a time-weighted-average (TWA). The maximum EEC would be selected as the exposure input for both acute and chronic risk assessments in the screening-level evaluations. The initial or maximum EEC derived from the Kanaga nomogram represents the maximum expected instantaneous or acute exposure to a pesticide. Acute toxicity endpoints are determined using a single exposure to a known pesticide concentration typically for 48 to 96 hours. This value is assumed to represent ecological risk from acute exposure to a pesticide. On the other hand, chronic risk to pesticide exposure is a function of pesticide concentration and duration of exposure to the pesticide. An organism's response to chronic pesticide exposure may result from either the concentration of the pesticide, length of exposure, or some combination of both factors. Standardized tests for chronic toxicity typically involve exposing an organism to several different pesticide concentrations for a specified length of time (days, weeks, months, years or generations). For

example, avian reproduction tests include a 10-week exposure phase. Because a single length of time is used in the test, time response data is usually not available for inclusion into risk assessments. Without time response data it is difficult to determine the concentration which elicited a toxicological response.

- Using maximum EECs for chronic risk estimates may result in an overestimate of risk, particularly for compounds that dissipate rapidly. Conversely, using TWAs for chronic risk estimates may underestimate risk if it is the concentration rather than the duration of exposure that is primarily responsible for the observed adverse effect. The maximum EEC would be used for chronic risk assessments although it may result in an overestimate of risk. TWAs may be used for chronic risk assessments, but they will be applied judiciously considering the potential for an underestimate or overestimate of risk. For example, the number of days exposure exceeds a Level of Concern may influence the suitability of a pesticide use. The greater the number of days the EEC exceeds the Level of Concern translates into greater the ecological risk. This is a qualitative assessment, and is subject to reviewer's expertise in ecological risk assessment and tolerance for risk.
- The length of time used to calculate the TWA can have a substantial effect on the exposure estimates and there is no standard method for determining the appropriate duration for this estimate. The T-REX model assumes a 21-week exposure period, which is equivalent to avian reproductive studies designed to establish a steady-state concentration for bioaccumulative compounds. However, this does not necessarily define the true exposure duration needed to elicit a toxicological response. Pesticides, which do not bioaccumulate, may achieve a steady-state concentration earlier than 21 weeks. The duration of time for calculating TWAs will require justification and it will not exceed the duration of exposure in the chronic toxicity test (approximately 70 days for the standard avian reproduction study). An alternative to using the duration of the chronic toxicity study is to base the TWA on the application interval. In this case, increasing the application interval would suppress both the estimated peak pesticide concentration and the TWA. Another alternative to using TWAs would be to consider the number of days that a chemical is predicted to exceed the LOC.
- Pesticide dissipation is assumed to be first-order in the absence of data suggesting alternative dissipation patterns such as bi-phasic. Field dissipation data would generally be the most pertinent for assessing exposure in terrestrial species that forage on vegetation. However, this data is often not available and it can be misleading particularly if the compound is prone to "wash-off". Soil half-life is the most common degradation data available. Dissipation or degradation data that would reflect the environmental conditions typical of refuge lands would be utilized, if available.
- For species found in the water column, it would be assumed that the greatest bioavailable fraction of the pesticide active ingredient in surface waters is freely dissolved in the water column.
- Actual habitat requirements of any particular terrestrial species are not considered, and it is assumed that species exclusively and permanently occupy the treated area, or adjacent areas receiving pesticide at rates commensurate with the treatment rate. This assumption would produce a maximum estimate of exposure for risk characterization. This assumption would likely lead to an overestimation of exposure for species that do not permanently and exclusively occupy the treated area (US Environmental Protection Agency 2004).
- Exposure through incidental ingestion of pesticide contaminated soil is not considered in the USEPA risk assessment protocols. Research suggests <15% of the diet can consist of incidentally ingested soil depending upon species and feeding strategy (Beyer et al. 1994). An assessment of pesticide concentrations in soil compared to food item categories in the Kanaga

nomogram indicates incidental soil ingestion will not likely increase dietary exposure to pesticides. Inclusion of soil into the diet would effectively reduce the overall dietary concentration compared to the present assumption that the entire diet consists a contaminated food source (Fletcher et al. 1994). An exception to this may be soil-applied pesticides in which exposure from incidental ingestion of soil may increase. Potential for pesticide exposure under this assumption may be underestimated for soil-applied pesticides and overestimated for foliar-applied pesticides. The concentration of a pesticide in soil would likely be less than predicted on food items.

- Exposure through inhalation of pesticides is not considered in the USEPA risk assessment protocols. Such exposure may occur through three potential sources: spray material in droplet form at time of application, vapor phase with the pesticide volatilizing from treated surfaces, and airborne particulates (soil, vegetative matter, and pesticide dusts). The USEPA (1990) reported exposure from inhaling spray droplets at the time of application is not an appreciable route of exposure for birds. According to research on mallards and bobwhite quail, respirable particle size (particles reaching the lung) in birds is limited to maximum diameter of 2 to 5 microns. The spray droplet spectra covering the majority of pesticide application scenarios indicate that less than 1% of the applied material is within the respirable particle size. This route of exposure is further limited because the permissible spray drop size distribution for ground pesticide applications is restricted to ASAE medium or coarser drop size distribution.
- Inhalation of a pesticide in the vapor phase may be another source of exposure for some pesticides under certain conditions. This mechanism of exposure to pesticides occurs post application and it would pertain to those pesticides with a high vapor pressure. The USEPA is currently evaluating protocols for modeling inhalation exposure from pesticides including near-field and near-ground air concentrations based upon equilibrium and kinetics-based models. Risk characterization for exposure with this mechanism is unavailable.
- The effect from exposure to dusts contaminated with the pesticide cannot be assessed generically as partitioning issues related to application site soils and chemical properties of the applied pesticides render the exposure potential from this route highly situation specific.
- Dermal exposure may occur through three potential sources: direct application of spray to terrestrial wildlife in the treated area or within the drift footprint, incidental contact with contaminated vegetation, or contact with contaminated water or soil. Interception of spray and incidental contact with treated substrates may pose risk to avian wildlife (Driver et al. 1991). However, available research related to wildlife dermal contact with pesticides is extremely limited, except dermal toxicity values are common for some mammals used as human surrogates (rats and mice). The USEPA is currently evaluating protocols for modeling dermal exposure. Risk characterization may be underestimated for this route of exposure, particularly with high risk pesticides such as some organophosphates or carbamate insecticides. If protocols are established by the USEPA for assessing dermal exposure to pesticides, they will be considered for incorporation into pesticide assessment protocols.
- Exposure to a pesticide may occur from consuming surface water, dew or other water on treated surfaces. Water soluble pesticides have potential to dissolve in surface runoff and puddles in a treated area may contain pesticide residues. Similarly, pesticides with lower organic carbon partitioning characteristics and higher solubility in water have a greater potential to dissolve in dew and other water associated with plant surfaces. Estimating the extent to which such pesticide loadings to drinking water occurs is complex and would depend upon the partitioning characteristics of the active ingredient, soils types in the treatment area, and the meteorology of the treatment area. In addition, the use of various water sources by wildlife is highly species-

specific. Currently, risk characterization for this exposure mechanism is not available. The USEPA is actively developing protocols to quantify drinking water exposures from puddles and dew. If and when protocols are formally established by the USEPA for assessing exposure to pesticides through drinking water, these protocols will be incorporated into pesticide risk assessment protocols.

- Risk assessments are based upon the assumption that the entire treatment area would be subject to pesticide application at the rates specified on the label. In most cases, there is potential for uneven application of pesticides through such plausible incidents such as changes in calibration of application equipment, spillage, and localized releases at specific areas in or near the treated field that are associated with mixing and handling and application equipment as well as applicator skill. Inappropriate use of pesticides and the occurrence of spills represent a potential underestimate of risk. It is likely not an important factor for risk characterization. All pesticide applicators are required to be certified by the state in which they apply pesticides. Certification training includes the safe storage, transport, handling, and mixing of pesticides, equipment calibration and proper application with annual continuing education.
- The USEPA relies on Fletcher (1994) for setting the assumed pesticide residues in wildlife dietary items. The USEPA (2004) "believes that these residue assumptions reflect a realistic upper-bound residue estimate, although the degree to which this assumption reflects a specific percentile estimate is difficult to quantify". Fletcher's (1994) research suggests that the pesticide active ingredient residue assumptions used by the USEPA represent a 95^{th} percentile estimate. However, research conducted by Pfleeger et al. (1996) indicates USEPA residue assumptions for short grass was not exceeded. Baehr and Habig (2000) compared USEPA residue assumptions with distributions of measured pesticide residues for the USEPA's UTAB database. Overall residue selection level will tend to overestimate risk characterization. This is particularly evident when wildlife individuals are likely to have selected a variety of food items acquired from multiple locations. Some food items may be contaminated with pesticide residues whereas others are not contaminated. However, it is important to recognize differences in species feeding behavior. Some species may consume whole above-ground plant material, but others will preferentially select different plant structures. Also, species may preferentially select a food item although multiple food items may be present. Without species specific knowledge regarding foraging behavior characterizing ecological risk other than in general terms is not possible.
- Acute and chronic risk assessments rely on comparisons of wildlife dietary residues with LC_{50} or NOEC values expressed as concentrations of pesticides in laboratory feed. These comparisons assume that ingestion of food items in the field occurs at rates commensurate with those in the laboratory. Although the screening assessment process adjusts dry-weight estimates of food intake to reflect the increased mass in fresh-weight wildlife food intake estimates, it does not allow for gross energy and assimilative efficiency differences between wildlife food items and laboratory feed. Differences in assimilative efficiency between laboratory and wild diets suggest that current screening assessment methods are not accounting for a potentially important aspect of food requirements.
- There are several other assumptions that can affect non-target species not considered in the risk assessment process. These include possible additive or synergistic effects from applying two or more pesticides or additives in a single application, co-location of pesticides in the environment, cumulative effects from pesticides with the same mode of action, effects of multiple stressors (e.g., combination of pesticide exposure, adverse abiotic and biotic factors) and behavioral changes induced by exposure to a pesticide. These factors may exist at some level contributing

to adverse affects to non-target species, but they are usually characterized in the published literature in only a general manner limiting their value in the risk assessment process.

- It is assumed that aquatic species exclusively and permanently occupy the water body being assessed. Actual habitat requirements of aquatic species are not considered. With the possible exception of scenarios where pesticides are directly applied to water, it is assumed that no habitat use considerations specific for any species would place the organisms in closer proximity to pesticide use sites. This assumption produces a maximum estimate of exposure or risk characterization. It would likely be realistic for many aquatic species that may be found in aquatic habitats within or in close proximity to treated terrestrial habitats. However, the spatial distribution of wildlife is usually not random because wildlife distributions are often related to habitat requirements of species. Clumped distributions of wildlife may result in an under- or over-estimation of risk depending upon where the initial pesticide concentration occurs relative to the species or species habitat.
- For species found in the water column, it would be assumed that the greatest bioavailable fraction of the pesticide active ingredient in surface waters is freely dissolved in the water column. Additional chemical exposure from materials associated with suspended solids or food items is not considered because partitioning onto sediments likely is minimal. Adsorption and bioconcentration occurs at lower levels for many newer pesticides compared with older more persistent bioaccumulative compounds. Pesticides with RQs close to the listed species level of concern, the potential for additional exposure from these routes may be a limitation of risk assessments, where potential pesticide exposure or risk may be underestimated.
- Mass transport losses of pesticide from a water body (except for losses by volatilization, degradation and sediment partitioning) would not be considered for ecological risk assessment. The water body would be assumed to capture all pesticide active ingredients entering as runoff, drift, and adsorbed to eroded soil particles. It would also be assumed that pesticide active ingredient is not lost from the water body by overtopping or flow-through, nor is concentration reduced by dilution. In total, these assumptions would lead to a near maximum possible water-borne concentration. However, this assumption would not account for potential to concentrate pesticide through the evaporative loss. This limitation may have the greatest impact on water bodies with high surface-to-volume ratios such as ephemeral wetlands, where evaporative losses are accentuated and applied pesticides have low rates of degradation and volatilization.
- For acute risk assessments, there would be no averaging time for exposure. An instantaneous peak concentration would be assumed, where instantaneous exposure is sufficient in duration to elicit acute effects comparable to those observed over more protracted exposure periods (typically 48 to 96 hours) tested in the laboratory. In the absence of data regarding time-to-toxic event, analyses and latent responses to instantaneous exposure, risk would likely be overestimated.
- For chronic exposure risk assessments, the averaging times considered for exposure are commensurate with the duration of invertebrate life-cycle or fish-early life stage tests (e.g., 21-28 days and 56-60 days, respectively). Response profiles (time to effect and latency of effect) to pesticides likely vary widely with mode of action and species and should be evaluated on a case-by-case basis as available data allow. Nevertheless, because the USEPA relies on chronic exposure toxicity endpoints based on a finding of no observed effect, the potential for any latent toxicity effects or averaging time assumptions to alter the results of an acceptable chronic risk assessment prediction is limited. The extent to which duration of exposure from water-borne concentrations overestimate or underestimate actual exposure depends on several factors. These include the following: localized meteorological conditions, runoff characteristics of the

watershed (e.g., soils, topography), the hydrological characteristics of receiving waters, environmental fate of the pesticide active ingredient, and the method of pesticide application. It should also be understood that chronic effects studies are performed using a method that holds water concentration in a steady state. This method is not likely to reflect conditions associated with pesticide runoff. Pesticide concentrations in the field increase and decrease in surface water on a cycle influenced by rainfall, pesticide use patterns, and degradation rates. As a result of the dependency of this assumption on several undefined variables, risk associated with chronic exposure may in some situations underestimate risk and overestimate risk in others.

- There are several other factors that can affect non-target species not considered in the risk assessment process. These would include the following: possible additive or synergistic effects from applying two or more pesticides or additives in a single application, co-location of pesticides in the environment, cumulative effects from pesticides with the same mode of action, effects of multiple stressors (e.g., combination of pesticide exposure, adverse abiotic [not pesticides] and biotic factors), and sub-lethal effects such as behavioral changes induced by exposure to a pesticide. These factors may exist at some level contributing to adverse affects to non-target species, but they are not routinely assessed by regulatory agencies. Therefore, information on the factors is not extensive limiting their value for the risk assessment process. As this type of information becomes available, it would be included, either quantitatively or qualitatively, in this risk assessment process.
- USEPA is required by the Food Quality Protection Act to assess the cumulative risks of pesticides that share common mechanisms of toxicity, or act the same within an organism. Currently, USEPA has identified four groups of pesticides that have a common mechanism of toxicity requiring cumulative risk assessments. These four groups are: the organophosphate insecticides, N-methyl carbamate insecticides, triazine herbicides, and chloroacetanilide herbicides.

7.3 Pesticide Mixtures and Degradates

Pesticide products are usually a formulation of several components generally categorized as active ingredients and inert or other ingredients. The term active ingredient is defined by the FIFRA as preventing, destroying, repelling, or mitigating the effects of a pest, or it is a plant regulator, defoliant, desiccant, or nitrogen stabilizer. In accordance with FIFRA, the active ingredient(s) must be identified by name(s) on the pesticide label along with its relative composition expressed in percentage(s) by weight. In contrast, inert ingredient(s) are not intended to affect a target pest. Their role in the pesticide formulation is to act as a solvent (keep the active ingredient is a liquid phase), an emulsifying or suspending agent (keep the active ingredient from separating out of solution), or a carrier such as clay in which the active ingredient is impregnated on the clay particle in dry formulations. For example, if isopropyl alcohol would be used as a solvent in a pesticide formulation, then it would be considered an inert ingredient. FIFRA only requires that inert ingredients identified as hazardous and associated percent composition, and the total percentage of all inert ingredients must be declared on a product label. Inert ingredients that are not classified as hazardous are not required to be identified.

The USEPA (September 1997) issued Pesticide Regulation Notice 97-6 which encouraged manufacturers, formulators, producers, and registrants of pesticide products to voluntarily substitute the term “other ingredients” for “inert ingredients” in the ingredient statement. This change recognized that all components in a pesticide formulation potentially could elicit or contribute to an adverse effect on non-target organisms and, therefore, are not necessarily inert. Whether referred to as "inerts" or "other ingredients," these constituents within a pesticide product have the potential to affect species or environmental quality. The USEPA categorizes regulated inert ingredients into the following four lists (http://www.epa.gov/opprd001/inerts/index.html):

- List 1 – Inert Ingredients of Toxicological Concern;
- List 2 – Potentially Toxic Inert Ingredients;
- List 3 – Inerts of Unknown Toxicity;
- List 4 – Inerts of Minimal Toxicity.

Several of the List 4 compounds are naturally-occurring earthen materials (e.g., clay materials, simple salts) that would not elicit toxicological response at applied concentrations. However, some of the inerts (particularly the List 3 compounds and unlisted compounds) may have moderate to high potential toxicity to aquatic species based on MSDSs or published data.

Comprehensively assessing potential effects to non-target fish, wildlife, plants, and/or their habitats from pesticide use is a complex task. It would be preferable to assess the cumulative effects from exposure to the active ingredient, its degradates, and inert ingredients as well as other active ingredients in the spray mixture. However, it would only be feasible to conduct deterministic risk assessments for each component in the spray mixture singly. Limited scientific information is available regarding ecological effects (additive or synergistic) from chemical mixtures that typically rely upon broadly encompassing assumptions. For example, the US Forest Service (2005) found that mixtures of pesticides used in land (forest) management likely would not cause additive or synergistic effects to non-target species based upon a review of scientific literature regarding toxicological effects and interactions of agricultural chemicals (ATSDR 2004). Moreover, information on inert ingredients, adjuvants, and degradates is often limited by the availability of and access to reliable toxicological data for these constituents.

Toxicological information regarding "other ingredients" may be available from sources such as the following:

- TOMES (a proprietary toxicological database including USEPA's IRIS, the Hazardous Substance Data Bank, the Registry of Toxic Effects of Chemical Substances [RTECS]).
- USEPA's ECOTOX database, which includes AQUIRE (a database containing scientific papers published on the toxic effects of chemicals to aquatic organisms).
- TOXLINE (a literature searching tool).
- Material Safety Data Sheets (MSDSs) from pesticide suppliers.
- Other sources such as the Farm Chemicals Handbook.

Because there is a lack of specific inert toxicological data, inert(s) in a pesticide may cause adverse ecological effects. However, inert ingredients typically represent only a small percentage of the pesticide spray mixture, and it would be assumed that negligible effects would be expected to result from inert ingredient(s).

Although the potential effects of degradates should be considered when selecting a pesticide, it is beyond the scope of this assessment process to consider all possible breakdown chemicals of the various product formulations containing an active ingredient. Degradates may be more or less mobile and more or less hazardous in the environment than their parent pesticides (Battaglin et al. 2003). Differences in environmental behavior (e.g., mobility) and toxicity between parent pesticides and degradates would make assessing potential degradate effects extremely difficult. For example, a less toxic and more mobile, bioaccumulative, or persistent degradate may have potentially greater effects on species and/or degrade environmental quality. The lack of data on the toxicity of degradates for many pesticides would represent a source of uncertainty for assessing risk.

An USEPA-approved label specifies whether a product can be mixed with one or more pesticides. Without product-specific toxicological data, it would not be possible to quantify the potential effects of these mixtures. In addition, a quantitative analysis could only be conducted if reliable scientific information allowed a determination of whether the joint action of a mixture would be additive, synergistic, or antagonistic. Such information would not likely exist unless the mode of action would be common among the chemicals and receptors. Moreover, the composition of and exposure to mixtures would be highly site- and/or time-specific and, therefore, it would be nearly impossible to assess potential effects to species and environmental quality.

To minimize or eliminate potential negative effects associated with applying two or more pesticides as a mixture, the use would be conducted in accordance with the labeling requirements. Labels for two or more pesticides applied as a mixture should be completely reviewed, where products with the least potential for negative effects would be selected for use on the refuge. This is especially relevant when a mixture would be applied in a manner that may already have the potential for an effect(s) associated with an individual pesticide (e.g., runoff to ponds in sandy watersheds). Use of a tank mix under these conditions would increase the level of uncertainty in terms of risk to species or potential to degrade environmental quality.

Adjuvants generally function to enhance or prolong the activity of pesticide. For terrestrial herbicides, adjuvants aid in the absorption into plant tissue. Adjuvant is a broad term that generally applies to surfactants, selected oils, anti-foaming agents, buffering compounds, drift control agents, compatibility agents, stickers, and spreaders. Adjuvants are not under the same registration requirements as pesticides and the USEPA does not register or approve the labeling of spray adjuvants. Individual pesticide labels identify types of adjuvants approved for use with it. In general, adjuvants compose a relatively small portion of the volume of pesticides applied. Selection of adjuvants with limited toxicity and low volumes would be recommended to reduce the potential for the adjuvant to influence the toxicity of the pesticide.

7.4 Determining Effects to Soil and Water Quality

The approval process for pesticide uses would consider potential to degrade water quality on and off refuge lands. A pesticide can only affect water quality through movement away from the treatment site. After application, pesticide mobilization can be characterized by one or more of the following (Kerle et al. 1996):

- Attach (sorb) to soil, vegetation, or other surfaces and remain at or near the treated area;
- Attach to soil and move off-site through erosion from run-off or wind;
- Dissolve in water that can be subjected to run-off or leaching.

As an initial screening tool, selected chemical characteristics and rating criteria for a pesticide can be evaluated to assess potential to enter ground and/or surface waters. These would include the following: persistence, sorption coefficient (K_{oc}), groundwater ubiquity score (GUS), and solubility.

Persistence, which is expressed as half-life ($t_{½}$), represents the length of time required for 50% of the deposited pesticide to degrade (completely or partially). Persistence in the soil can be categorized as the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days (Kerle et. al. 1996). Half-life data is usually available for aquatic and terrestrial environments.

Another measure of pesticide persistence is dissipation time (DT_{50}). It represents the time required for 50% of the deposited pesticide to degrade and move from a treated site; whereas, half-life describes the rate for degradation only. As for half-life, units of dissipation time are usually expressed in days. Field or foliar dissipation time is the preferred data for use to estimate pesticide concentrations in the environment. However, soil half-life is the most common persistence data cited in published literature. If field or foliar dissipation data is not available, soil half-life data may be used. The average or representative half-life value of most important degradation mechanism will be selected for quantitative analysis for both terrestrial and aquatic environments.

Mobility of a pesticide is a function of how strongly it is adsorbed to soil particles and organic matter, its solubility in water, and its persistence in the environment. Pesticides strongly adsorbed to soil particles, relatively insoluble in water, and not environmentally persistent would be less likely to move across the soil surface into surface waters or to leach through the soil profile and contaminate groundwater. Conversely, pesticides that are not strongly adsorbed to soil particles, are highly water soluble, and are persistent in the environment would have greater potential to move from the application site (off-site movement).

The degree of pesticide adsorption to soil particles and organic matter (Kerle et. al. 1996) is expressed as the soil adsorption coefficient (K_{oc}). The soil adsorption coefficient is measured as micrograms of pesticide per gram of soil (μg/g) that can range from near zero to the thousands. Pesticides with higher Koc values are strongly absorbed to soil and, therefore, would be less subject to movement.

Water solubility describes the amount of pesticide that will dissolve in a known quantity of water. The water solubility of a pesticide is expressed as milligrams of pesticide dissolved in a liter of water (mg/l or ppm). Pesticide with solubility <0.1 ppm are virtually insoluble in water, 100-1000 ppm are moderately soluble, and >10,000 ppm highly soluble (US Geological Survey 2000). As pesticide solubility increases, there would be greater potential for off-site movement.

The Groundwater Ubiquity Score (GUS) is a quantitative screening tool to estimate a pesticide's potential to move in the environment. It utilizes soil persistence and adsorption coefficients in the following formula.

$$GUS = \log_{10} (t_{½}) \times [4 - \log_{10} (K_{oc})]$$

The potential pesticide movement rating would be based upon its GUS value. Pesticides with a GUS <0.1 would considered to have an extremely low potential to move toward groundwater. Values of 1.0-2.0 would be low, 2.0-3.0 would be moderate, 3.0-4.0 would be high, and >4.0 would have a very high potential to move toward groundwater.

Water solubility describes the amount of pesticide dissolving in a specific quantity of water, where it is usually measured as mg/l or parts per million (ppm). Solubility is useful as a comparative measure because pesticides with higher values are more likely to move by run-off or leaching. GUS, water solubility, $t_{½}$, and K_{oc} values are available for selected pesticides from the OSU Extension Pesticide Properties Database at http://npic.orst.edu/ppdmove.htm. Many of the values in this database were derived from the SCS/ARS/CES Pesticide Properties Database for Environmental Decision Making (Wauchope et al. 1992).

Soil properties influence the fate of pesticides in the environment. The following six properties are mostly likely to affect pesticide degradation and the potential for pesticides to move off-site by leaching (vertical movement through the soil) or runoff (lateral movement across the soil surface).

- Permeability is the rate of water movement vertically through the soil. It is affected by soil texture and structure. Coarse textured soils (e.g., high sand content) have a larger pore size and they are generally more permeable than fine textured soils (i.e., high clay content). The more permeable soils would have a greater potential for pesticides to move vertically down through the soil profile. Soil permeability rates (inches/hour) are usually available in county soil survey reports.
- Soil texture describes the relative percentage of sand, silt, and clay. In general, greater clay content with smaller the pore size would lower the likelihood and rate water that would move through the soil profile. Clay also serves to adsorb (bind) pesticides to soil particles. Soils with high clay content would absorb more pesticide than soils with relatively low clay content. In contrast, sandy soils with coarser texture and lower water holding capacity would have a greater potential for water to leach through them.
- Soil structure describes soil aggregation. Soils with a well developed soil structure have looser, more aggregated, structure that would be less likely to be compacted. Both characteristics would allow for less restricted flow of water through the soil profile resulting in greater infiltration.
- Organic matter would be the single most important factor affecting pesticide adsorption in soils. Many pesticides are adsorbed to organic matter which would reduce their rate of downward movement through the soil profile. Also, soils high in organic matter would tend to hold more water, which may make less water available for leaching.
- Soil moisture affects how fast water would move through the soil. If soils are already wet or saturated before rainfall or irrigation, excess moisture would runoff rather than infiltrate into the soil profile. Soil moisture also would influence microbial and chemical activity in soil, which effects pesticide degradation.
- Soil pH would influence chemical reactions that occur in the soil which in turn determines whether or not a pesticide will degrade, rate of degradation, and, in some instances, which degradation products are produced.

Based upon the aforementioned properties, soils most vulnerable to groundwater contamination would be sandy soils with low organic matter. In contrast, the least vulnerable soils would be well-drained clayey soils with high organic matter. Consequently, pesticides with the lowest potential for movement in conjunction with appropriate best management practices (see below) would be used in an IPM framework to treat pests while minimizing effects to non-target biota and protecting environmental quality.

Along with soil properties, the potential for a pesticide to affect water quality through run-off and leaching would consider site-specific environmental and abiotic conditions including rainfall, water table conditions, and topography (Huddleston 1996).

- Water is necessary to separate pesticides from soil. This can occur in two basic ways. Pesticides that are soluble move easily with runoff water. Pesticide-laden soil particles can be dislodged and transported from the application site in runoff. The concentration of pesticides in the surface runoff would be greatest for the first runoff event following treatment. The rainfall intensity and route of water infiltration into soil, to a large extent, determine pesticide concentrations and losses in surface runoff. The timing of the rainfall after application also would have an effect. Rainfall interacts with pesticides at a shallow soil depth (¼ to ½ inch), which is called the mixing zone (Baker and Miller 1999). The pesticide/water mixture in the mixing zone would tend to leach down into the soil or runoff depending upon how quickly the soil surface becomes saturated and how rapidly water can infiltrate into the soil. Leaching would decrease the amount of pesticide available near the soil surface (mixing zone) to runoff during the initial rainfall event following application and subsequent rainfall events.

- Terrain slope would affect the potential for surface runoff and the intensity of runoff. Steeper slopes would have greater potential for runoff following a rainfall event. In contrast, soils that are relatively flat would have little potential for runoff, except during intense rainfall events. In addition, soils in lower areas would be more susceptible to leaching as a result of receiving excessive water from surrounding higher elevations.
- Depth to groundwater would be an important factor affecting the potential for pesticides to leach into groundwater. If the distance from the soil surface to the top of the water table is shallow, pesticides would have less distance to travel to reach groundwater. Shallower water tables that persist for longer periods would be more likely to experience groundwater contamination. Soil survey reports are available for individual counties. These reports provide data in tabular format regarding the water table depths and the months during which it is persists. In some situations, a hard pan exists above the water table that would prevent pesticide contamination from leaching.

7.5 Determining Effects to Air Quality

Pesticides may volatilize from soil and plant surfaces and move from the treated area into the atmosphere. The potential for a pesticide to volatilize is determined by the pesticide's vapor pressure which would be affected by temperature, sorption, soil moisture, and the pesticide's water solubility. Vapor pressure is often expressed in mm Hg. To make these numbers easier to compare, vapor pressure may be expressed in exponent form ($I \times 10^{-7}$), where I represents a vapor pressure index. In general, pesticides with $I<10$ would have a low potential to volatilize; whereas, pesticides with $I>1{,}000$ would have a high potential to volatilize (Oregon State University 1996). Vapor pressure values for pesticides are usually available in the pesticide product MSDS or the USDA Agricultural Research Service (ARS) pesticide database.

7.6 Preparing a Chemical Profile

The following instructions would be used by Service personnel to complete Chemical Profiles for pesticides. Specifically, profiles would be prepared for pesticide active ingredients (e.g., glyphosate, imazapic) that would be contained in one or more trade name products that are registered and labeled with USEPA. All information fields under each category (e.g., Toxicological Endpoints, Environmental Fate) would be completed for a Chemical Profile. If no information is available for a specific field, then "No data is available in references" would be recorded in the profile. Available scientific information would be used to complete Chemical Profiles. Each entry of scientific information would be shown with applicable references.

Completed Chemical Profiles would provide a structured decision-making process utilizing quantitative assessment/screening tools with threshold values (where appropriate) that would be used to evaluate potential biological and other environmental effects to refuge resources. For ecological risk assessments presented in these profiles, the "worst-case scenario" would be evaluated to determine whether a pesticide could be approved for use considering the maximum single application rate specified on pesticide labels for habitat management and croplands/facilities maintenance treatments pertaining to refuges. Where the "worst-case scenario" likely would only result in minor, temporary, and localized effects to listed and non-listed species with appropriate BMPs (see Section 5.0), the proposed pesticide's use in a PUP would have a scientific basis for approval under any application rate specified on the label that is at or below rates evaluated in a Chemical Profile. In some cases, the Chemical Profile would include a lower application rate than the maximum labeled rate in order to protect refuge resources. As necessary, Chemical Profiles would be periodically updated with new scientific information or as pesticides with the same active ingredient are proposed for use on the refuge in PUPs.

Throughout this section, threshold values (to prevent or minimize potential biological and environmental effects) would be clearly identified for specific information presented in a completed Chemical Profile. Comparison with these threshold values provides an explicit scientific basis to approve or disapprove PUPs for habitat management and cropland/facilities maintenance on refuge lands. In general, PUPs would be approved for pesticides with Chemical Profiles where there would be no exceedances of threshold values. However, BMPs are identified for some screening tools that would minimize/eliminate potential effects (exceedance of the threshold value) as a basis for approving PUPs.

Date: Service personnel would record the date when the Chemical Profile is completed or updated. Chemical Profiles (e.g., currently approved pesticide use patterns) would be periodically reviewed and updated, as necessary. The most recent review date would be recorded on a profile to document when it was last updated.

Trade Name(s): Service personnel would accurately and completely record the trade name(s) from the pesticide label, which includes a suffix that describes the formulation (e.g., WP, DG, EC, L, SP, I, II or 64). The suffix often distinguishes a specific product among several pesticides with the same active ingredient. Service personnel would record a trade name for each pesticide product with the same active ingredient.

Common chemical name(s): Service personnel would record the common name(s) listed on the pesticide label or material safety data sheet (MSDS) for an active ingredient. The common name of a pesticide is listed as the active ingredient on the title page of the product label immediately following the trade name, and the MSDS, Section 2: Composition/ Information on Ingredients. A Chemical Profile is completed for each active ingredient.

Pesticide Type: Service personnel would record the type of pesticide for an active ingredient as one of the following: herbicide, dessicant, fungicide, fumigant, growth regulator, insecticide, pisicide, or rodenticide.

EPA Registration Number(s): This number (EPA Reg. No.) appears on the title page of the label and MSDS, Section 1: Chemical Product and Company Description. It is not the EPA Establishment Number that is usually located near it. Service personnel would record the EPA Reg. No. for each trade name product with an active ingredient based upon PUPs.

Pesticide Class: Service personnel would list the general chemical class for the pesticide (active ingredient). For example, malathion is an organophosphate and carbaryl is a carbamate.

CAS (Chemical Abstract Service) Number: This number is often located in the second section (Composition/Information on Ingredients) of the MSDS. The MSDS table listing components usually contains this number immediately prior to or following the % composition.

Other Ingredients: From the most recent MSDS for the proposed pesticide product(s), Service personnel would include any chemicals in the pesticide formulation not listed as an active ingredient that are described as toxic or hazardous, or regulated under the Superfund Amendments and Reauthorization Act (SARA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Toxic Substances Control Act (TSCA), Occupational Safety and Health Administration (OSHA), State Right-to-Know, or other listed authorities. These are usually found in MSDS sections titled "Hazardous Identifications", "Exposure Control/Personal Protection", and "Regulatory Information". If concentrations of other ingredients are available for any compounds identified as toxic or hazardous, then Service personnel would record this information in the Chemical Profile by trade name. MSDS(s) may be obtained from the manufacturer, manufacturer's website or from an on-line database maintained by Crop Data Management Systems, Inc. (see list below).

Toxicological Endpoints

Toxicological endpoint data would be collected for acute and chronic tests with mammals, birds, and fish. Data would be recorded for species available in the scientific literature. If no data are found for a particular taxonomic group, then "No data available is references" would be recorded as the data entry. Throughout the Chemical Profile, references (including toxicological endpoint data) would be cited using parentheses (#) following the recorded data.

Mammalian LD_{50}: For test species in the scientific literature, Service personnel would record available data for oral lethal dose (LD_{50}) in mg/kg-bw (body weight) or ppm-bw. Most common test species in scientific literature are the rat and mouse. The lowest LD_{50} value found for a rat would be used as a toxicological endpoint for dose-based RQ calculations to assess acute risk to mammals (see Table 1 in Section 7.1).

Mammalian LC_{50}: For test species in the scientific literature, Service personnel would record available data for dietary lethal concentration (LC_{50}) as reported (e.g., mg/kg-diet or ppm-diet). Most common test species in scientific literature are the rat and mouse. The lowest LC_{50} value found for a rat would be used as a toxicological endpoint for diet-based RQ calculations to assess acute risk (see Table 1 in Section 7.1).

Mammalian Reproduction: For test species listed in the scientific literature, Service personnel would record the test results (e.g., Lowest Observed Effect Concentration [LOEC], Lowest Observed Effect Level [LOEL], No Observed Adverse Effect Level [NOAEL], No Observed Adverse Effect Concentration [NOAEC]) in mg/kg-bw or mg/kg-diet for reproductive test procedure(s) (e.g., generational studies [preferred], fertility, new born weight). Most common test species available in scientific literature are rats and mice. The lowest NOEC, NOAEC, NOEL, or NOAEL test results found for a rat would be used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table 1 in Section 7.1).

Avian LD_{50}: For test species available in the scientific literature, Service personnel would record values for oral lethal dose (LD_{50}) in mg/kg-bw or ppm-bw. Most common test species available in scientific literature are the bobwhite quail and mallard. The lowest LD_{50} value found for an avian species would be used as a toxicological endpoint for dose-based RQ calculations to assess acute risk (see Table 1 in Section 7.1).

Avian LC_{50}: For test species available in the scientific literature, Service personnel would record values for dietary lethal concentration (LC_{50}) as reported (e.g., mg/kg-diet or ppm-diet). Most common test species available in scientific literature are the bobwhite quail and mallard. The lowest LC_{50} value found for an avian species would be used as a toxicological endpoint for dietary-based RQ calculations to assess acute risk (see Table 1 in Section 7.1).

Avian Reproduction: For test species available in the scientific literature, Service personnel would record test results (e.g., LOEC, LOEL, NOAEC, NOAEL) in mg/kg-bw or mg/kg-diet consumed for reproductive test procedure(s) (e.g., early life cycle, reproductive). Most common test species available in scientific literature are the bobwhite quail and mallard. The lowest NOEC, NOAEC, NOEL, or NOAEL test results found for an avian species would be used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table 1 in Section 7.1).

Fish LC_{50}: For test freshwater or marine species listed in the scientific literature, Service personnel would record a LC_{50} in ppm or mg/L. Most common test species available in the scientific literature are the bluegill, rainbow trout, and fathead minnow (marine). Test results for many game species may also be available. The lowest LC_{50} value found for a freshwater fish species would be used as a toxicological endpoint for RQ calculations to assess acute risk (see Table 1 in Section 7.1).

Fish Early Life Stage (ELS)/Life Cycle: For test freshwater or marine species available in the scientific literature, Service personnel would record test results (e.g., LOEC, NOAEL, NOAEC, LOAEC) in ppm for test procedure(s) (e.g., early life cycle, life cycle). Most common test species available in the scientific literature are bluegill, rainbow trout, and fathead minnow. Test results for other game species may also be available. The lowest test value found for a fish species (preferably freshwater) would be used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table 1 in Section 7.1).

Other: For test invertebrate as well as non-vascular and vascular plant species available in the scientific literature, Service personnel would record $LC_{50,}$ $LD_{50,}$ LOEC, LOEL, NOAEC, NOAEL, or EC_{50} (environmental concentration) values in ppm or mg/L. Most common test invertebrate species available in scientific literature are the honey bee and the water flea (*Daphnia magna*). Green algae (*Selenastrum capricornutum*) and pondweed (*Lemna minor*) are frequently available test species for aquatic non-vascular and vascular plants, respectively.

Ecological Incident Reports: After a site has been treated with pesticide(s), wildlife may be exposed to these chemical(s). When exposure is high relative to the toxicity of the pesticides, wildlife may be killed or visibly harmed (incapacitated). Such events are called ecological incidents. The USEPA maintains a database (Ecological Incident Information System) of ecological incidents. This database stores information extracted from incident reports submitted by various federal and state agencies and non-government organizations. Information included in an incident report is date and location of the incident, type and magnitude of affects observed in various species, use(s) of pesticides known or suspected of contributing to the incident, and results of any chemical residue and cholinesterase activity analyses conducted during the investigation.

Incident reports can play an important role in evaluating the effects of pesticides by supplementing quantitative risk assessments. All incident reports for pesticide(s) with the active ingredient and associated information would be recorded.

Environmental Fate

Water Solubility: Service personnel would record values for water solubility (S_w), which describes the amount of pesticide that dissolves in a known quantity of water. S_w is expressed as mg/L (ppm). Pesticide S_w values would be categorized as one of the following: insoluble <0.1 ppm, moderately soluble = 100 to 1000 ppm, highly soluble >10,000 ppm (US Geological Survey 2000). As pesticide S_w increases, there would be greater potential to degrade water quality through run-off and leaching.

Sw would be used to evaluate potential for bioaccumulation in aquatic species [see **Octanol-Water Partition Coefficient (K_{ow})** below].

Soil Mobility: Service personnel would record available values for soil adsorption coefficient (K_{oc} [μg/g]). It provides a measure of a chemical's mobility and leaching potential in soil. K_{oc} values are directly proportional to organic content, clay content, and surface area of the soil. K_{oc} data for a pesticide may be available for a variety of soil types (e.g., clay, loam, sand).

K_{oc} values would be used in evaluating the potential to degrade groundwater by leaching (see **Potential to Move to Groundwater** below).

Soil Persistence: Service personnel would record values for soil half-life ($t_{½}$), which represents the length of time (days) required for 50% of the deposited pesticide to degrade (completely or partially) in the soil. Based upon the $t_{½}$ value, soil persistence would be categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days (Kerle et. al. 1996).

Threshold for Approving PUPs:

If soil $t_{½}$ ≤100 days, then a PUP would be approved without additional BMPs to protect water quality.
If soil $t_{½}$ >100 days, then a PUP would only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to minimize potential surface run-off and leaching that can degrade water quality:*

- *Do not exceed one application per site per year.*
- *Do not use on coarse-textured soils where the ground water table is <10 feet and average annual precipitation >12 inches.*
- *Do not use on steep slopes if substantial rainfall is expected within 24 hours or ground is saturated.*

Along with K_{oc}, soil $t_{½}$ values would be used in evaluating the potential to degrade groundwater by leaching (see **Potential to Move to Groundwater** below).

Soil Dissipation: Dissipation time (DT_{50}) represents the time required for 50% of the deposited pesticide to degrade and move from a treated site; whereas, soil $t_{½}$ describes the rate for degradation only. As for $t_{½}$, units of dissipation time are usually expressed in days. Field dissipation time would be the preferred data for use to estimate pesticide concentrations in the environment because it is based upon field studies compared to soil $t_{½}$, which is derived in a laboratory. However, soil $t_{½}$ is the most common persistence data available in the published literature. If field dissipation data is not available, soil half-life data would be used in a Chemical Profile. The average or representative half-life value of most important degradation mechanism would be selected for quantitative analysis for both terrestrial and aquatic environments.

Based upon the DT_{50} value, environmental persistence in the soil also would be categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days.

Threshold for Approving PUPs:

If soil DT_{50} ≤100 days, then a PUP would be approved without additional BMPs to protect water quality.
If soil DT_{50} >100 days, then a PUP would only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to minimize potential surface run-off and leaching that can degrade water quality:*

- *Do not exceed one application per site per year.*
- *Do not use on coarse-textured soils where the ground water table is <10 feet and average annual precipitation >12 inches.*
- *Do not use on steep slopes if substantial rainfall is expected within 24 hours or ground is saturated.*

Along with K_{oc}, soil DT_{50} values (preferred over soil $t_{½}$) would be used in evaluating the potential to degrade groundwater by leaching (see **Potential to Move to Groundwater** below), if available.

Aquatic Persistence: Service personnel would record values for aquatic $t_{½}$, which represents the length of time required for 50% of the deposited pesticide to degrade (completely or partially) in water. Based upon the $t_{½}$ value, aquatic persistence would be categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days (Kerle et. al. 1996).

Threshold for Approving PUPs:

If aquatic $t_{½}$ ≤100 days, then a PUP would be approved without additional BMPs to protect water quality.
If aquatic $t_{½}$ >100 days, then a PUP would only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to minimize potential surface run-off and leaching that can degrade water quality:*

- *Do not exceed one application per site per year.*
- *Do not use on coarse-textured soils where the ground water table is <10 feet and average annual precipitation >12 inches.*

- *Do not use on steep slopes if substantial rainfall is expected within 24 hours or ground is saturated.*

Aquatic Dissipation: Dissipation time (DT_{50}) represents the time required for 50% of the deposited pesticide to degrade or move (dissipate); whereas, aquatic $t_{½}$ describes the rate for degradation only. As for $t_{½}$, units of dissipation time are usually expressed in days. Based upon the DT_{50} value, environmental persistence in aquatic habitats also would be categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days.

Threshold for Approving PUPs:

If aquatic DT_{50} ≤100 days, then a PUP would be approved without additional BMPs to protect water quality.
If aquatic DT_{50} >100 days, then a PUP would only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to minimize potential surface run-off and leaching that can degrade water quality:*

- *Do not exceed one application per site per year.*
- *Do not use on coarse-textured soils where the ground water table is <10 feet and average annual precipitation >12 inches.*
- *Do not use on steep slopes if substantial rainfall is expected within 24 hours or ground is saturated.*

Potential to Move to Groundwater: Groundwater Ubiquity Score (GUS) = $\log_{10}$(soil $t_{½}$) x [4 – $\log_{10}(K_{oc})$]. If a DT_{50} value is available, it would be used rather than a $t_{½}$ value to calculate a GUS score. Based upon the GUS value, the potential to move toward groundwater would be recorded as one of the following categories: extremely low potential<1.0, low - 1.0 to 2.0, moderate - 2.0 to 3.0, high - 3.0 to 4.0, or very high>4.0.

Threshold for Approving PUPs:

If GUS ≤4.0, then a PUP would be approved without additional BMPs to protect water quality.
If GUS >4.0, then a PUP would only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to minimize potential surface run-off and leaching that can degrade water quality:*

- *Do not exceed one application per site per year.*
- *Do not use on coarse-textured soils where the ground water table is <10 feet and average annual precipitation >12 inches.*
- *Do not use on steep slopes if substantial rainfall is expected within 24 hours or ground is saturated.*

Volatilization: Pesticides may volatilize (evaporate) from soil and plant surfaces and move off-target into the atmosphere. The potential for a pesticide to volatilize is a function of its vapor pressure that is affected by temperature, sorption, soil moisture, and the pesticide's water solubility. Vapor pressure is often expressed in mm Hg. To make these values easier to compare, vapor pressure would be recorded by Service personnel in exponential form (I x 10^{-7}), where I represents a vapor pressure index. In general, pesticides with I<10 would have low potential to volatilize; whereas, pesticides with I >1,000 would have a high potential to volatilize (Oregon State University 1996). Vapor pressure values for pesticides are usually available in the pesticide product MSDS or the USDA Agricultural Research Service (ARS) pesticide database (see **References**).

Threshold for Approving PUPs:

If I≤1000, then a PUP would be approved without additional BMPs to minimize drift and protect air quality.
If I >1000, then a PUP would only be approved with additional BMPs specifically to minimize drift and protect air quality. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to reduce volatilization and potential to drift and degrade air quality:*

- *Do not treat when wind velocities are <2 or >10 mph with existing or potential inversion conditions.*
- *Apply the large-diameter droplets possible for spray treatments.*
- *Avoid spraying when air temperatures >85^{o}F.*
- *Use the lowest spray height possible above target canopy.*
- *Where identified on the pesticide label, soil incorporate pesticide as soon as possible during or after application.*

Octanol-Water Partition Coefficient (K_{ow}): The octanol-water partition coefficient (K_{ow}) is the concentration of a pesticide in octanol and water at equilibrium at a specific temperature. Because octanol is an organic solvent, it is considered a surrogate for natural organic matter. Therefore, K_{ow} would be used to assess potential for a pesticide to bioaccumulate in tissues of aquatic species (e.g., fish). If K_{ow} >1000 or S_w<1 mg/L AND soil $t_{½}$>30 days, then there would be high potential for a pesticide to bioaccumulate in aquatic species such as fish (US Geological Survey 2000).

Threshold for Approving PUPs:

If there is not a high potential for a pesticide to bioaccumulate in aquatic species, then the PUP would be approved.
If there is a high potential to bioaccumulate in aquatic species (K_{ow}>1000 or S_w<1 mg/L AND soil $t_{½}$>30 days), then the PUP would not approved, except under unusual circumstances where approval would only be granted by the Washington Office.

Bioaccumulation/Bioconcentration: The physiological process where pesticide concentrations in tissue would increase in biota because they are taken and stored at a faster rate than they are metabolized or excreted. The potential for bioaccumulation would be evaluated through bioaccumulation factors (BAFs) or bioconcentration factors (BCFs). Based upon BAF or BCF values, the potential to bioaccumulate would be recorded as one of the following: low – 0 to 300, moderate – 300 to 1000, or high >1000 (Calabrese and Baldwin 1993).

Threshold for Approving PUPs:

If BAF or BCF≤1000, then a PUP would be approved without additional BMPs.

If BAF or BCF>1000, then a PUP would not approved, except under unusual circumstances where approval would only be granted by the Washington Office.

Worst-Case Ecological Risk Assessment

Max Application Rates (acid equivalent): Service personnel would record the highest application rate of an active ingredient (ae basis) for habitat management and cropland/facilities maintenance treatments in this data field of a Chemical Profile. These rates can be found in Table CP.1 under the column heading "Max Product Rate – Single Application (lbs/acre – AI on acid equiv basis)". This table would be prepared for a chemical profile from information specified in labels for trade name products identified in PUPs. If these data are not available in pesticide labels, then write "NS" for "not specified on label" in this table.

EECs: An estimated environmental concentration (ECC) represents potential exposure to fish and wildlife (birds and mammals) from using a pesticide. EECs would be derived by Service personnel using an USEPA screening-level approach (US Environmental Protection Agency 2004). For each max application rate [see description under **Max Application Rates (acid equivalent)**], Service personnel would record 2 EEC values in a Chemical Profile; these would represent the worst-case terrestrial and aquatic exposures for habitat management and croplands/facilities maintenance treatments. For terrestrial and aquatic EEC calculations, see description for data entry under **Presumption of Unacceptable Risk/Risk Quotients**, which is the next field for a Chemical Profile.

Presumption of Unacceptable Risk/Risk Quotients: Service personnel would calculate and record acute and chronic risk quotients (RQs) for birds, mammals, and fish using the provided tabular formats for habitat management and/or cropland/facilities maintenance treatments. RQs recorded in a Chemical Profile would represent the worst-case assessment for ecological risk. See Section 7.2 for discussion regarding the calculations of RQs.

For aquatic assessments associated with habitat management treatments, RQ calculations would be based upon selected acute and chronic toxicological endpoints for fish and the EEC would be derived from Urban and Cook (1986) assuming 100% overspray to an entire 1-foot deep water body using the max application rate (ae basis [see above]).

For aquatic assessments associated with cropland/facilities maintenance treatments, RQ calculations would be done by Service personnel based upon selected acute and chronic toxicological endpoints for fish and an EEC would be derived from the aquatic assessment in AgDRIFT® model version 2.01 under Tier I ground-based application with the following input variables: max application rate (acid basis [see above]), low boom (20 inches), fine to medium/coarse droplet size, 20 swaths, EPA-defined wetland, and 25-foot distance (buffer) from treated area to water.

See Section 7.2.1.2 for more details regarding the calculation of EECs for aquatic habitats for habitat management and cropland/facilities maintenance treatments.

For terrestrial avian and mammalian assessments, RQ calculations would be done by Service personnel based upon dietary exposure, where the "short grass" food item category would represent the worst-case scenario. For terrestrial spray applications associated with habitat management and cropland/facilities maintenance treatments, exposure (EECs and RQs) would be determined using the Kanaga nomogram method through the USEPA's Terrestrial Residue Exposure model (T-REX) version 1.2.3. T-REX input variables would include the following: max application rate (acid basis [see above]) and pesticide half-life (days) in soil to estimate the initial, maximum pesticide residue concentration on general food items for terrestrial vertebrate species in short (<20 cm tall) grass.

For granular pesticide formulations and pesticide-treated seed with a unique route of exposure for terrestrial avian and mammalian wildlife, see Section 7.2.1.1.2 for the procedure that would be used to calculate RQs.

All calculated RQs in both tables would be compared with Levels of Concern (LOCs) established by USEPA (see Table 2 in Section 7.2). If a calculated RQ exceeds an established LOC value (in brackets inside the table), then there would be a potential for an acute or chronic effect (unacceptable risk) to federally listed (T&E) species and nonlisted species. See Section 7.2 for detailed descriptions of acute and chronic RQ calculations and comparison to LOCs to assess risk.

Threshold for approving PUPs:

If RQs≤LOCs, then a PUP would be approved without additional BMPs.
If RQs>LOCs, then a PUP would only be approved with additional BMPs specifically to minimize exposure (ecological risk) to bird, mammal, and/or fish species. One or more BMPs such as the following would be included in the **Specific Best Management Practices (BMPs) section** *to reduce potential risk to non-listed or listed species:*

- *Lower application rate and/or fewer number of applications so RQs≤LOCs*
- *For aquatic assessments (fish) associated with cropland/facilities maintenance, increase the buffer distance beyond 25 feet so RQs≤LOCs.*

Justification for Use: Service personnel would describe the reason for using the pesticide based control of specific pests or groups of pests. In most cases, the pesticide label will provide the appropriate information regarding control of pests to describe in the section.

Specific Best Management Practices (BMPs): Service personnel would record specific BMPs necessary to minimize or eliminate potential effects to non-target species and/or degradation of environmental quality from drift, surface runoff, or leaching. These BMPs would be based upon scientific information documented in previous data fields of a Chemical Profile. Where necessary and feasible, these specific practices would be included in PUPs as a basis for approval.

If there are no specific BMPs that are appropriate, then Service personnel would describe why the potential effects to refuge resources and/or degradation of environmental quality is outweighed by the overall resource benefit(s) from the proposed pesticide use in the BMP section of the PUP. See Section 4.0 of this document for a complete list of BMPs associated with mixing and applying pesticides appropriate for all PUPs with ground-based treatments that would be additive to any necessary, chemical-specific BMPs.

References: Service personnel would record scientific resources used to provide data/information for a chemical profile. Use the number sequence to uniquely reference data in a chemical profile.

The following on-line data resources are readily available for toxicological endpoint and environmental fate data for pesticides:

1. California Product/Label Database. Department of Pesticide Regulation, California Environmental Protection Agency. (http://www.cdpr.ca.gov/docs/label/labelque.htm#regprods)

2. ECOTOX database. Office of Pesticide Programs, US Environmental Protection Agency, Washington, D.C. (http://cfpub.epa.gov/ecotox/)

3. Extension Toxicology Network (EXTOXNET) Pesticide Information Profiles. Cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Cornell University and University of Idaho through Oregon State University, Corvallis, Oregon. (http://extoxnet.orst.edu/pips/ghindex.html)

4. FAO specifications and evaluations for plant protection products. Pesticide Management Unit, Plant Protection Services, Food and Agriculture Organization, United Nations. (http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/)

5. Human health and ecological risk assessments. Pesticide Management and Coordination, Forest Health Protection, US Department of Agriculture, US Forest Service. (http://www.fs.fed.us/foresthealth/pesticide/risk.htm)

6. Pesticide Chemical Fact Sheets. Clemson University Pesticide Information Center. (http://entweb.clemson.edu/pesticid/Document/Labels/factshee.htm)

7. Pesticide Fact Sheets. Published by Information Ventures, Inc. for Bureau of Land Management, Dept. of Interior; Bonneville Power Administration, U.S. Dept. of Energy; and Forest Service, US Department of Agriculture. (http://infoventures.com/e-hlth/pesticide/pest-fac.html)

8. Pesticide Fact Sheets. National Pesticide Information Center. (http://npic.orst.edu/npicfact.htm)

9. Pesticide Fate Database. US Environmental Protection Agency, Washington, D.C. (http://cfpub.epa.gov/pfate/home.cfm).

10. Pesticide product labels and material safety data sheets. Crop Data Management Systems, Inc. (CDMS) (http://www.cdms.net/pfa/LUpdateMsg.asp) or multiple websites maintained by agrichemical companies.

11. Registered Pesticide Products (Oregon database). Oregon Department of Agriculture. (http://www.oda.state.or.us/dbs/pest_products/search.lasso)

12. Regulatory notes. Pest Management Regulatory Agency, Health Canada, Ontario, Canada. (http://www.hc-sc.gc.ca/pmra-arla/)

13. Reptile and Amphibian Toxicology Literature. Canadian Wildlife Service, Environment Canada, Ontario, Canada. (http://www.cws-scf.ec.gc.ca/nwrc-cnrf/ratl/index_e.cfm)

14. Specific Chemical Fact Sheet – New Active Ingredients, Biopesticide Fact Sheet and Registration Fact Sheet. U.S Environmental Protection Agency, Washington, D.C. (http://www.epa.gov/pestidides/factsheets/chemical_fs.htm)

15. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Invasive Species Initiative. The Nature Conservancy. (http://tnsweeds.ucdavis.edu/handbook.html)

16. Wildlife Contaminants Online. US Geological Survey, Department of Interior, Washington, D.C. (http://www.pwrc.usgs.gov/contaminants-online/)

17. One-liner database. 2000. US Environmental Protection Agency, Office of Pesticide Programs, Washington, D.C.

Chemical Profile

Date:			
Trade Name(s):		**Common Chemical Name(s):**	
Pesticide Type:		**EPA Registration Number:**	
Pesticide Class:		**CAS Number:**	
Other Ingredients:			

Toxicological Endpoints

Mammalian LD_{50}:	
Mammalian LC_{50}:	
Mammalian Reproduction:	
Avian LD_{50}:	
Avian LC_{50}:	
Avian Reproduction:	
Fish LC_{50}:	
Fish ELS/Life Cycle:	
Other:	

Ecological Incident Reports

Environmental Fate

Water solubility (S_w):	
Soil Mobility (K_{oc}):	
Soil Persistence ($t_{½}$):	
Soil Dissipation (DT_{50}):	
Aquatic Persistence ($t_{½}$):	
Aquatic Dissipation (DT_{50}):	
Potential to Move to Groundwater (GUS score):	
Volatilization (mm Hg):	
Octanol-Water Partition Coefficient (K_{ow}):	
Bioaccumulation/Biocentration:	**BAF:`** **BCF:**

Worst Case Ecological Risk Assessment

Max Application Rate (ai lbs/acre – ae basis)	**Habitat Management:** **Croplands/Facilities Maintenance:**
EECs	**Terrestrial (Habitat Management):** **Terrestrial (Croplands/Facilities Maintenance):** **Aquatic (Habitat Management):** **Aquatic (Croplands/Facilities Maintenance):**

Habitat Management Treatments:

Presumption of Unacceptable Risk		**Risk Quotient (RQ)**	
		Listed (T&E) Species	**Nonlisted Species**
Acute	Birds	[0.1]	[0.5]
	Mammals	[0.1]	[0.5]
	Fish	[0.05]	[0.5]
Chronic	Birds	[1]	[1]
	Mammals	[1]	[1]
	Fish	[1]	[1]

Cropland/Facilities Maintenance Treatments:

Presumption of Unacceptable Risk		**Risk Quotient (RQ)**	
		Listed (T&E) Species	**Nonlisted Species**
Acute	Birds	[0.1]	[0.5]
	Mammals	[0.1]	[0.5]
	Fish	[0.05]	[0.5]
Chronic	Birds	[1]	[1]
	Mammals	[1]	[1]
	Fish	[1]	[1]

Justification for Use:	
Specific Best Management Practices (BMPs):	
References:	

Table CP.1 Pesticide Name

Trade Name[a]	Treatment Type[b]	Max Product Rate – Single Application (lbs/acre or gal/acre)	Max Product Rate - Single Application (lbs/acre - AI on acid equiv basis)	Max Number of Applications Per Season	Max Product Rate Per Season (lbs/acre/season or gal/acre/season)	Minimum Time Between Applications (Days)

[a]From each label for a pesticide identified in pesticide use proposals (PUPs), Service personnel would record application information associated with possible/known uses on Service lands.
[b]Treatment type: H – habitat management or CF – cropland/facilities maintenance. If a pesticide is labeled for both types of treatments (uses), then record separate data for H and CF applications.

8.0 References

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Appendix H. Statement of Compliance for Implementation of the Hakalau Forest National Wildlife Refuge Comprehensive Conservation Plan

The following Executive orders and legislative acts have been reviewed as they apply to implementation of the Comprehensive Conservation Plan (CCP) for Hakalau Forest National Wildlife Refuge (NWR).

National Environmental Policy Act (1969) (42 U.S.C. 4321 et seq.). The CCP planning process has been conducted in accordance with National Environmental Policy Act implementing procedures, Department of the Interior and U. S. Fish and Wildlife Service procedures, and has been performed in coordination with the affected public. Procedures used to reach this decision meet the requirements of the National Environmental Policy Act and its implementing regulations in 40 CFR Parts 1500-1508. These procedures included the development of a range of alternatives for the CCP; analysis of the likely effects of each alternative; and public involvement throughout the planning process.

An environmental assessment (EA) was prepared that integrated the CCP into the NEPA document and process. The Draft CCP/EA was released for a 30-day public comment period. The affected public was notified of the availability of the Draft CCP/EA through a Federal Register notice, news release to local media outlets, the Service's refuge and refuge planning websites, and a planning update. Copies of the Draft CCP/EA and/or planning update were distributed to an extensive mailing list. Based on public comments received no changes were made to the selected alternative. A summary of comments and Service response was included in Appendix K.

National Historic Preservation Act (1966) (16 U.S. C.470 et seq.). The management of historic, archaeological, and cultural resources of Hakalau Forest NWR complies with the regulations of Section 106 of the National Historic Preservation Act. No historic, archaeological, and cultural resources are known to be affected by the implementation of the CCP based on the criteria of an effect or adverse effect as an undertaking defined in 36 CFR 800.9 and Service Manual 614 FW 2. Should historic properties be identified in the future, the Service will comply with the National Historic Preservation Act if any management actions have the potential to affect any of these properties.

Executive Order 12372. Intergovernmental Review. Coordination and consultation with other affected Federal, State, and County agencies have been completed through personal contact by Service planners, the Refuge manager and supervisors. The Refuge manager determined there are no local or tribal governments (as defined by Executive Order 13175) associated with Hakalau Forest NWR.

Executive Order 12898. Federal Actions to Address Environmental Justice in Minority and Low-Income Populations. All Federal actions must address and identify, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations, low-income populations, and Indian Tribes in the

United States. The CCP was evaluated and no adverse human health or environmental effects were identified for minority or low-income populations, Indian Tribes, or anyone else.

Executive Order 13186. Responsibilities of Federal Agencies to Protect Migratory Birds. This Order directs departments and agencies to take certain actions to further implement the Migratory Bird Treaty Act (MBTA). The CCP is consistent with this Executive Order because management actions are consistent with the provisions of the MBTA and the CCP and NEPA analysis evaluated the effects of such action on MBTA species.

Endangered Species Act (ESA) (16 U.S.C. 1531-1544). This Act provides for the conservation of threatened and endangered species of fish, wildlife, and plants by Federal action and by encouraging the establishment of state programs. It provides for the determination and listing of endangered and threatened species and the designation of critical habitats. Section 7 requires refuge managers to perform consultation before initiating projects which affect or may affect endangered species. The Refuge will conduct consultation under Section 7 of the Endangered Species Act for any Refuge management program actions that have the potential to affect listed species.

Coastal Zone Management Act, Section 307. Section 307(c)(1) of the Coastal Zone Management Act of 1972 amended, requires each Federal agency conducting or supporting activities directly affecting the coastal zone, to conduct or support those activities in a manner that is, to the maximum extent practicable, consistent with approved State coastal management programs. The implementation of the Hakalau Forest National Wildlife Refuge CCP will not have an effect upon land or water use within the purview of the State's management program.

National Wildlife Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. 668dd-668ee). During the CCP process, the Refuge Manger evaluated all existing and proposed Refuge uses at Hakalau Forest NWR. Priority wildlife-dependent uses (hunting, fishing, wildlife observation and photography, environmental education and interpretation) are considered automatically appropriate under Service policy and thus exempt from appropriate uses review. Appropriate Use Findings have been prepared for the following uses: commercial photography, videography, filming or audio recording; commercial tour operation/conservation and education group visits; the University of Hawaiʻi Field station; and research, scientific collecting, and surveys. Compatibility Determinations have been prepared for the following uses: hunting, wildlife observation and photography, commercial photography, videography, filming or audio recording, commercial tour operation/conservation and education group visits, the University of Hawaiʻi Field Station, and research, scientific collecting, and surveys.

Integrated Pest Management (IPM), 517 DM 1 and 569 FW 1. In accordance with 517 DM 1 and 569 FW 1, an integrated pest management (IPM) approach has been adopted to eradicate, control or contain pest and invasive species on the Refuge. In accordance with 517 DM 1, only pesticides registered with the U.S. Environmental Protection Agency (EPA) in full compliance with the Federal Insecticide, Fungicide, and Rodenticide Act and as provided in regulations, orders, or permits issued by the EPA may be applied on lands and waters under Refuge jurisdiction.

Executive Order 11990. Protection of Wetlands. The CCP is consistent with Executive Order 11990 because CCP implementation would protect existing wetland at the Refuge (e.g., *Carex* bogs).

Wilderness Preservation Act of 1964 (Wilderness Act). The Wilderness Act requires the Service to evaluate the suitability of Hakalau Forest NWR for wilderness designation. A Wilderness Review is included as Appendix D to the CCP.

Chief, Division of Planning,
Visitor Services and Communications

9/28/10
Date

Appendix I. Acronyms and Abbreviations

Ac	Acres
ACHP	President's Advisory Council on Historic Preservation
Administration Act	National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd-668ee)
ALUM	State of Hawai'i Agricultural Land Use Maps
AM	Adaptive Management
ATSDR	Agency for Toxic Substances and Disease Registry
BCC	Birds of Conservation Concern
BIDEH	Biological Integrity, Diversity, and Environmental Health
BIISC	Big Island Invasive Species
Complex	Big Island National Wildlife Refuge Complex
BMPs	Best Management Practices
BRD	Biological Resources Discipline
CCP	Comprehensive Conservation Plan
CCS	Challenge Cost Share
CD	Compatibility Determination
CDP	Community Development Plan
CEQ	White House Council on Environmental Quality
CI	Confidence Interval
CWCS	Comprehensive Wildlife Conservation Strategy
Dbh	Diameter at Breast Height
DHHL	Department of Hawaiian Home Lands
DLNR	Department of Land and Natural Resources
DM	Deferred Maintenance
DOA	State of Hawai'i Department of Agriculture
DOFAW	Division of Forestry and Wildlife
DOI	Department of the Interior
DOSP	Division of State Parks
EA	Environmental Assessment
EE	Environmental Education
EIS	Environmental Impact Statement
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ES	Ecological Services
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FIRM	Flood Insurance Rate Map
FOH	Friends of Hakalau Forest National Wildlife Refuge
FONSI	Finding of No Significant Impact
FPD	Frost Protection Devices
Ft	Feet (Foot)
FUMP	Feral Ungulate Management Plan
GHG	Greenhouse Gases
HAVO	Hawai'i Volcanoes National Park
HAWP	Hawai'i Association of Watershed Partnerships

HETF	Hawaiʻi Experimental Tropical Forest
HFU	Hakalau Forest Unit
HPWRA	Hawaiʻi Pacific Weed Risk Assessment
Improvement Act	National Wildlife Refuge System Improvement Act of 1997
I&M	Inventory and Monitoring
In	Inch(es)
IPCC	Intergovernmental Panel on Climate Change
IPIF	Institute of Pacific Islands Forestry
IPM	Integrated Pest Management
ISST	Invasive Species Strike Team
KFU	Kona Forest Unit
LCC	Landscape Conservation Cooperatives
LEIS	Legislative Environmental Impact Statement
LUPAG	Land Use Pattern Allocation Guide
MBTA	Migratory Bird Treaty Act
MBCA	Migratory Bird Conservation Act
Mgd	Million gallons per day
Mi	Mile(s)
MKWA	Mauna Kea Watershed Alliance
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAR	Natural Area Reserve
NEPA	National Environmental Policy Act
NFWF	National Fish and Wildlife Foundation
NGO	Nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPL	National Priorities List
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRDC	Natural Resources Defense Council
NRHP	National Register of Historic Places
NWPS	National Wilderness Preservation System
NWR	National Wildlife Refuge
NWRS	National Wildlife Refuge System
OHA	Office of Hawaiian Affairs
OKP	ʻŌlaʻa-Kīlauea Partnership
PDM	Post Delisting Monitoring
PEP(P)	Plant Extinction Prevention (Program)
PICCC	Pacific Islands Climate Change Cooperative
PIER	Pacific Islands Ecosystem at Risk
PIF	Partners in Flight
PFT	Permanent Full-Time
PTA	U.S. Army Pōhakuloa Training Area
RO	Regional Office
RONS	Refuge Operational Needs System
SAMMS	Service Asset Maintenance and Management System
SCORP	State Comprehensive Outdoor Recreation Plan

SD	Standard Deviation
SE	Standard Error
SGCN	Species of Greatest Conservation Need
SHC	Strategic Habitat Conservation
SOC	Species of Concern
SUP	Special Use Permit
SWG	State Wildlife Grants
T&E	Threatened and Endangered
TBD	To be Determined
TMA	Three Mountain Alliance
TNC	The Nature Conservancy
UH	University of Hawai‘i
USDA	U.S. Department of Agriculture
USDA-APHIS/WS	USDA Animal and Plant Health Inspection Service/Wildlife Services
USFS	U.S. Forest Service
USFWS, FWS, the Service	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VFE	Visitor Facility Enhancement
WSA	Wilderness Study Area

Appendix J. CCP Team Members

The CCP was developed primarily by the core team members. The team sought expert advice and review from other professionals from several different agencies and organizations. Extended team members provided input during reviews. Core and extended team members as well as regional office team members are listed below.

Core Planning Team (*those preparing the plan*)

Name and title (in alphabetical order)	Responsibilities
Ann Bell, Outdoor Recreation Planner, HIPAC NWRC (departed 2009)	Writer/reviewer various CCP components; build and maintain mailing list; visitor services goals and objectives; communication plan; environmental education and interpretation guidance. Assist with outreach efforts and public meetings; review of documents; planning updates; NOI/NOA; news releases; communication plan.
James Glynn, Deputy Refuge Manager, Hakalau Forest NWR	Writer/reviewer various CCP components (historical/cultural, physical facilities, public access and recreation, social and economic; vision statement, goals and objectives, alternatives, compatibility determinations, compliance, purposes, authorities for Hakalau Forest and Kona Unit); Section 7 consultations.
Baron Horiuchi, Horticulturist, Hakalau Forest NWR	Attend meetings, some writings of background information, review of final document related to outplanting strategies, implementation, and budget.
Andy Kikuta, Maintenance Supervisor, Hakalau Forest NWR	Attend meetings, some writing of background information, review of final document related to IPM, weed management, facilities maintenance, ungulate control, and related implementation and budget.
Lance Koch, Wildlife Biologist, Hakalau Forest NWR *replaced,* Jack Jeffrey, Wildlife Biologist, Hakalau Forest NWR (retired 2009)	Writer/reviewer; refuge vision; research/analysis/oversight of: habitats, invasive plants and animals, wildlife; Feral Ungulate Management Plan, Forest Reforestation Plan, Integrated Pest Management Plan, Wildlife Disease Contingency Plan, and Predator Management Plan integration; ESA biological assessment(s); compatibility determinations, Section 7, rare plants and plant communities; compatibility determinations; assistance with production of working GIS maps and graphics; public involvement.
Jim Kraus, Refuge Manager, Hakalau Forest NWR *replaced,* Richard Wass, Refuge Manager, Hakalau Forest NWR (retired 2008)	Supervision; responsible for overall coordination and development of the CCP; decisionmaking; public involvement; planning updates and NOI's; decision file. Writer/reviewer; editor of documents refuge vision; research/analysis/oversight; socioeconomics;

Name and title (in alphabetical order)	Responsibilities
	cultural resources; visitor services and compatibility determinations; compliance with NEPA, ESA, NHPA, etc.; and Federal and State agency, Office of Hawaiian Affairs and partner coordination.
Christine Ogura, Natural Resource Planner, Hawaiian and Pacific Islands NWRC *replaced,* Bill Perry, Refuge Conservation Planner, Hawaiian and Pacific Islands NWRC (departed 2010) *replaced,* Charlie Pelizza, Refuge Conservation Planner, Hawaiian and Pacific Islands NWRC (departed 2008)	Planning team leader responsible for Regional and Honolulu office coordination and process guidance for development of the CCP; process facilitator; public involvement; principal NEPA advisor; writer/reviewer/editor; document format and layout; and assist with refuge purposes, vision statement, and goals, objectives, and strategies development and public involvement.
Don Palawski, Deputy Project Leader, Hawaiian and Pacific Islands NWRC *replaced*, Jerry Leinecke, Deputy Project Leader, Hawaiian and Pacific Islands NWRC (retired 2009)	Supervised planner, reviewed both draft and final documents, assisted with Refuge/Honolulu office coordination and process guidance with the Regional office.

Extended Team (*those who attended periodic planning meetings and reviewed information*)

Name and Title (in alphabetical order)	Responsibilities
Donna Ball, Wildlife Biologist, USFWS - Ecological Services	Reviewer, technical expertise for biological resources.
Laura Beauregard, Natural Resource Planner, Hawaiian and Pacific Islands NWRC	Assisted with planning initiative during vacant natural resource planner period, provided guidance to Refuge staff and new planner, assisted with public meetings.
Sandra Hall, External Affairs, USFWS	Assisted with printing CCP/EA and planning update 3 as well as posting information on the Hakalau website during public comment period.
Lynne Hanzawa, Administrative Officer, Hakalau Forest NWR	Mailings, public meetings, logistical support.
Barbara Maxfield, External Affairs Chief, USFWS	Assist with outreach efforts and public meetings; review of documents; planning updates; NOI/NOA; news releases; communication plan; preparation of documents for printing/distribution.
Pearl Mokuhalii, Office Assistant, Hakalau Forest NWR *replaced* Clara Tsang, Office Automation Clerk, Hakalau Forest NWR (departed 2010)	Mailings, public meetings, assisting with compiling comments.
Barry Stieglitz, Project Leader, Hawaiian and Pacific Islands NWRC	Supervised planner early in the process, reviewed both draft and final documents, assisted with Refuge/Honolulu office coordination and process guidance with the Regional office, decisionmaker.

Regional Office Team (*provided CCP process guidance, technical assistance, and review*)

Name and title (in alphabetical order)	Responsibilities
Carolyn Bohan, Regional Chief NWRS	Major decisions on CCP direction.
Liz Cruz, Geographer/GIS Specialist	GIS advice; GIS data layer development and assistance with production of working maps for CCP/EA and final CCP, planning updates, agency/public involvement.
Joe Engler, Wildlife Biologist	IPM advice, data, and review; assist with development of objectives and strategies.
Nicole Garner, Writer/Editor	Assisted with developing planning update 3, processing public comments.
Mike Green, Wildlife Biologist, Migratory Birds	Advice on birds, applicable goals from regional bird plans.
Ben Harrison, Division Chief Natural and Cultural Resources	CCP Advisor, purposes, wilderness review, policy, CD review.
Chuck Houghten, Chief, Division of Planning, Visitor Service, Transportation	Reviewer; planning workload assistance; coordination with other divisions.
Kay Kier-Haggenjos, Lead Writer/Editor	Editing of CCP related documents, preparation of documents for printing/distribution, planning update format, providing guidance on formatting and template resources and examples, posting related documents on the main planning website.
Kevin Kilbride, Wildlife Biologist, Regional IPM Coordinator	IPM advice, data, and review; assist with development of objectives and strategies for pest management.
Greg Larson, Environmental Planner/Specialist, SWCA	CCP development.
Mike Marxen, Branch Chief, Visitor Services	CCP Advisor, layout graphics design, public use goals and objectives; public involvement assistance, CD review.
Scott McCarthy, Branch Chief, Refuge, Planning	CCP Advisor, reviewer, coordination with other divisions.
Fred Paveglio, Branch Chief, Refuge Biology	CCP Advisor, Conservation targets, Habitat management plan, habitat goals and objectives, CD review.
Anan Raymond, Regional Archaeologist	Cultural resources advice, data, and review.
Patrick Stark, Visual Information Assistant	Assisted with layout and cover design, processed printing orders.
Tiffany Thair, Environmental Planner/Specialist, SWCA	CCP development.
Robyn Thorson, Regional Director	Decision maker, CCP/EA approval.
Amy Wing, Conservation Planner	Land acquisition history, refuge purposes.
Tara Zimmerman, Wildlife Biologist, Migratory Birds	Advice on birds, applicable goals from regional bird plans.
Stephen Zylstra, Regional Landscape Conservation Manager	Provided guidance on addressing climate change in CCP.

Appendix K. Summary of Public Involvement

Public involvement was sought throughout the development of the CCP. Public involvement began in 2009 with the scoping process and publication of our notice of intent. In February 2009, we mailed approximately 150 copies of Planning Update 1 to interested individuals, local conservation and interest groups, research organizations, Native Hawaiian organizations and local, State, and Federal government agencies and elected officials. Planning Update 1 was available at two public open house meetings in March 2009. It was also posted on the Refuge's website (*http://www.fws.gov/hakalauforest/planning.html*) and the Service's Pacific Region refuge planning website (*http://www.fws.gov/pacific/planning/main/docs/HI-PI/docshakalau.htm*). A news release was issued announcing the open house meetings. An interagency scoping meeting was also held July 2009, as well as briefings for government officials such as the Mayor of Hawai'i County.

In Planning Update 1, we described the CCP planning process; Refuge purposes; draft wildlife, habitat, and public use goals; and preliminary issues to be considered in the CCP. In Planning Update 2 (made available in October 2009 and similarly circulated as the first update) we summarized the comments we received and listed primary management issues we used to draft alternatives and refine draft goals and objectives. We also included draft vision statements for both units.

In the last stage of CCP development, Planning Update 3, which announced the Draft CCP/EA availability during the public comment period and summarized the alternatives, was circulated similarly to previous planning updates. In addition, the public comment period was announced through a news release, holding a public open house meeting in Hilo on August 25, 2010, posting the draft document on both the Hakalau planning website and main Pacific Region refuge planning website, notice of availability in the Federal Register, and email and related list-serve announcements.

Public Scoping Sessions

The public scoping period for this CCP opened February 25, 2009, and ended March 27, 2009. Two public meetings were held, in Hilo and Captain Cook, Hawai'i, on March 3, 2009, and March 4, 2009, respectively. At the meetings, Refuge staff explained the CCP planning process; the Refuge purposes, vision, and management; and preliminary management issues, concerns, and opportunities. Refuge staff also answered questions from attendees and received written comments. Twelve private citizens and representatives from various organizations attended the meetings and commented on the issues and opportunities we presented. Six written responses were received from individuals or organizations during scoping. The comments we received addressed broad or long-range issues and very specific or detailed strategies that could be used to achieve biological or public use objectives. Summaries of the issues identified and Service responses in Planning Update 2 follow.

How can we best protect endangered forest birds and the nēnē?
The primary purpose of the Refuge is protection of endangered species. We manage Refuge resources to ensure high-quality habitat is available for endangered species, especially forest birds. Drawing on 20 years of Refuge management experience at the HFU, we have included objectives and strategies in the Draft CCP/EA for maintaining and enhancing native habitat communities to provide the life-history needs of Hakalau Forest NWR's endangered species.

How can we best protect montane wet koa/ʻōhiʻa forest, montane dry koa/ʻōhiʻa/māmane forest, lava tubes, and lava tube skylights?
These habitat types are key to the survival of endangered species. Refuge management objectives and strategies will be designed to protect these habitat types, and where appropriate, restore areas to high-quality habitat. We describe alternatives for managing these important resources in Chapter 2.

What opportunities exist for expanding environmental education through outreach and onsite programs?
Refuge staff have worked with ʻImi Pono no ka ʻĀina on environmental education opportunities onsite and offsite in local schools. Through the CCP planning process, we have identified additional partnerships or opportunities to expand upon the work that is already in place (e.g., through the Friends of Hakalau Forest Refuge).

How can we best prepare for, manage, and prevent the spread of wildfires?
There is concern, especially from adjacent landowners, that a wildfire could be ignited on the Refuge and then spread onto private land. The Refuge currently coordinates with the County of Hawaiʻi to provide wildland fire fighting capabilities. We are also concerned about the potential for wildfire as habitat restoration efforts are implemented. Within the past year, a fire adjacent to the HFU came close to spreading onto Refuge lands. Close coordination with the County, other agencies, and adjacent landowners is essential to ensure an efficient response to fire threats. As part of the Draft CCP/EA, Refuge staff will review options for creating firebreaks and obtaining the equipment and personnel required to meet firefighting needs at both units.

How can we keep refuge visitors and others (e.g. contractors, Service staff) from trespassing on adjacent lands?
The KFU is currently closed to the public. At both units, a number of contractors and Refuge staff use the easements for accessing the Refuge. We continue to impress upon all individuals who access the areas the importance of using only the authorized and in some cases court-ordered easements. Where appropriate, trespass incidents will be referred to Service law enforcement.

Is acquiring additional easements for accessing the Kona Forest Unit feasible?
The existing easement includes difficult access from the Mamalahoa Highway, steep slopes, and multiple gates. At this point, no additional access or easement opportunities have been identified. We will continue to explore options if they arise.

What Native Hawaiian gathering activities occur on the Refuge?
To date, there have been very few access requests for gathering activities. As part of the CCP, Refuge staff plan to review the process for granting Special Use Permits for gathering activities.

Can we maintain public access to the historic Kaunene Trail?
We have reviewed options for access to the trail. At this time access, safety, and resource management needs preclude maintenance and public access to the trail. Over time, we could revisit opportunities to reopen the Kaunene Trail.

Do the Refuge units meet the minimum requirements for a wilderness designation nomination?
A wilderness review, as required by Service policy, has been conducted as part of the CCP planning process and is included as Appendix D.

Is there the potential to protect habitat for endangered forest birds through additional land acquisition or conservation easements?
At each unit we will consider opportunities for Refuge boundary expansion on a case-by-case basis, and in accordance with Service policy. The Refuge is working with nongovernment conservation organizations (NGOs) that are familiar with private lands in the vicinity of existing refuge units in evaluating any feasible acquisition opportunities that may arise. Currently, two tracts of land with high-quality habitat within the HFU's approved acquisition boundary have not been acquired and are being managed by an agency partner. All of the land within the acquisition boundary for the KFU has been acquired. We encourage landowners with high-quality habitat for forest birds to manage their lands for conservation. In addition, Refuge staff will work with Regional staff to develop a land conservation plan as outlined in objectives 1e and 3e in Chapter 2.

How can we better manage the Kona Forest Unit's ungulate populations?
Refuge staff are in the process of administering a contract to build a perimeter fence around the unit and two interior fences that would create three management areas within the unit. Options and opportunities for ungulate management, including removal, are included as part of the management of the KFU in the preferred alternative.

How will climate change impact the Refuge?
The Refuge's two units are unique in the Hawaiian Islands because of the range of elevations that occur on Refuge lands. Through the CCP planning process we will evaluate the effectiveness, impacts, and benefits of providing wildlife habitats at a variety of elevations, temperatures, and rainfall regimes, so that wildlife can move freely between them as conditions are altered through climate change processes and management responses.

Interagency Scoping

On July 1, 2009, Refuge and Hawaiian and Pacific Islands staff members met with some of our agency partners to discuss planning for Hakalau Forest NWR. Individuals from the DLNR, DHHL, USGS-BRD, and USFS attended the meeting. Refuge staff provided an overview of the planning process and current management of the Refuge. The following list of issues was developed based upon feedback received from these individuals.

- Desire by partners to see staff and a satellite office in the vicinity of the KFU;
- Potential for some joint planning with NPS at Kahuku;
- Interest in developing some sort of "Partnership Boundary" that could include Three Mountain Alliance, Mauna Kea Watershed Alliance, Wai'ea;
- Need for strong management partnerships at KFU;
- Climate Change
  - Issues that will likely become larger in the context of climate change include avian malaria, the need for corridors to connect habitat fragments;
  - Quote - "This is one of Hawai'i's great opportunities to deal with climate change";
  - The Plan should look for opportunities to connect the subalpine habitat with wet-lower elevation habitats;
- On adjacent lands, DHHL is considering māmane restoration, bird corridors, koa restoration, and gorse control. [Since this meeting DHHL's 'Āina Mauna Legacy Program more completely outlines specific plans for adjacent areas.];

- Endangered plants are an important piece of the habitats that are being restored. We should specify actions and species;
- There should be more exploration into carbon sequestration. Previous efforts did not get off the ground, but there is an emerging market for "boutique" carbon that could serve Hakalau well;
- Research
  - There is a need for research into habitat and species responses to adaptive management to help make adjustments over time;
  - There is a greater need for monitoring than for pure research;
  - Consider developing a Research Management Plan with a formal subcommittee;
  - Need a way to filter research requests;
- Additional enforcement should be present at both units;
- Education/Outreach
  - Consider expanding the open house to twice per year;
  - Develop an airport kiosk;
  - Host an annual "low-budget" research symposium: potential ideas include poster sessions, keynote speakers, in conjunction with other events that may be occurring on island;
- Hakalau nēnē appear to be a migratory subpopulation that could provide an additional avenue for education about management at Hakalau;
- Develop a bibliography of Hakalau research; and
- Review and use the Hawai‘i Volcanoes National Park ungulate control Environmental Impact Statement (EIS).

Forest Bird Workshop

The Service held a workshop with partner agencies, renowned forest bird researchers, and statisticians in Hilo October 8-10, 2008, to expand a review of the current status of the Hawai‘i ‘ākepa and other endangered Hawaiian forest birds at the Refuge for development of options for management alternatives for the CCP.

The Service has received contradictory information over the population status of the endangered Hawai‘i ‘ākepa in a portion of the Refuge, a major stronghold of the species, over the last several years. The Regional Director obtained the assistance of the USGS' Dr. J. Michael Scott in conducting a review of available information on the Hawai‘i ‘ākepa, and this workshop was an extension of the review.

The agenda was focused on the endangered Hawaiian forest birds found at the Refuge. It was anticipated that although the workshop focused specifically on the Refuge, much of the information shared would be applicable to these species throughout their ranges and to the broader Mauna Kea and Hawai‘i Island ecosystems or forest bird survey methodology in general.

The workshop purposes and objectives were:
1. Identify and prioritize management needs and activities, including research, at Hakalau Forest NWR to recover endangered Hawaiian forest birds;
2. Incorporate identified needs and activities in the Hakalau Forest 15-year CCP; and
3. Extrapolate Hakalau-specific information to the broader Mauna Kea area and other geographic areas and bird species and suites of birds as appropriate.

A number of suggestions came out of the workshop. The suggestions are listed below. The rankings for each of the lists are based upon voting by workshop participants. The complete forest bird workshop summary is included as Appendix E.

Immediate Threats to Hawaiian Forest Birds at Hakalau Forest NWR

1. Ungulates;
2. Lack of Habitat;
3. Invasive Plants;
4. Predation;
5. Data Insufficient to Meet Management Needs;
6. Parasites; and
7. Interspecific Competition.

Management Actions (Priority Ranking by Workshop Participants)

1. *Grazers/browsers (Habitat destruction/relative to mosquito production) (High)
   - Fence construction, maintenance, and removal of animals;
   - See Research Priorities;
2. Habitat Restoration (High)
   - Revegetation of pasture land;
   - Improve ‘ōhi‘a densities;
3. Invasive plants (High)
   - Continue invasive species control (e.g., blackberry, banana poka, gorse);
   - Prevent and eliminate incipient weeds;
   - See Research Priorities;
4. Monitoring and Data Needs (High)
   - See Research priorities;
   - Delivery of technical information;
5. Predation (Medium)
   - See Research priorities;
6. Parasites (Low)
   - Incipient invasive parasites, true population counts, delouse birds;
7. Interspecific competition (Low)
   - See Research priorities;
   - Identify ectoparasites/mites.

Research Priorities (Priority Ranked by Workshop Participants)

1. Monitoring and Data: Expand point counts/banding data (combined primary counter training, consider use of a B-Bird (Breeding Biology Research and Monitoring Database) system (*http://www.umt.edu/bbird/info.htm*), and threat surveillance);
2. Predation: Investigate effects of rats on forest birds; rodent population index;
3. Invasive Plants: Develop effective biocontrols;
4. *Grazers/Browsers: Predator proof fencing;
5. Invasive Plants: Develop more efficient control methods and registration of herbicides;
5. Determine the effects of global climate change at the Refuge; Develop more effective cat control techniques;
6. Determine effects of ectoparasites on non-endangered bird populations; and
6. Experimental control of Japanese white-eyes.

*Caveat: Activities to construct an ungulate-proof fence and a predator-proof fence caused some confusion. Dr. Scott obtained consensus that these activities could be combined with a third separate but related activity of removing ungulates.

Public Comment Period

In the last stage of CCP development, Planning Update 3, which announced the Draft CCP/EA availability during the public open comment period (August 16-September 15, 2010) and summarized the alternatives, was circulated similarly to previous planning updates (which included mailings to national organizations). In addition, announcement of the public open comment period was made through a news release distributed within Hawai‘i and on the mainland; holding a public open house meeting in Hilo on August 25, 2010; posting the draft document on both the Hakalau planning website and main Refuge RO planning website; notice of availability in the Federal Register as well as the Environmental Notice (State Office of Environmental Quality Control); and email and related list-serve announcements. In addition, where meetings were already scheduled with partner agencies and organizations (e.g., Friends of Hakalau Forest NWR board meeting, quarterly Three Mountain Alliance meeting) during the public comment period, updates of the Draft CCP/EA were provided.

Public Comments on the Draft CCP/EA and Service Responses

This section addresses comments that were received on the Hakalau Forest National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Assessment (Draft CCP/EA, August 2010) during the official public comment period from August 16-September 15, 2010. A total of 19 comments were received via letter, email, or at the public meeting. All comments are categorized (i.e., management strategies, research and monitoring, public use, historic resources, climate change, refuge capacity, and adequacy of document), summarized, and listed with our responses below. Editorial comments have been considered in the development of the final CCP.

Table K-1. Draft CCP/EA Respondents

Respondent	Representing	City/State
Larry Wayne Jose		Keauhou, Hawai‘i
Daniel Rubinoff, Ph.D., Associate Professor, University of Hawai‘i		Honolulu, Hawai‘i
Lorraine Ellison		Kea‘au, Hawai‘i
Patricia Richardson		Hilo, Hawai‘i
Jean Pbulic		Florham Park, New Jersey
Patrick Conant		Volcano, Hawai‘i
Leonard A. Freed, Ph.D., and Rebecca L. Cann, Ph.D., University of Hawai‘i		Honolulu, Hawai‘i
Stephen Stearns, Ph.D., Professor, Yale University		New Haven, Connecticut
Mark Fox, Director of External Affairs	The Nature Conservancy, Hawai‘i Program	Honolulu, Hawai‘i

Respondent	Representing	City/State
Richard Hoeflinger, President	Big Island Gun Dogs	Keaʻau, Hawaiʻi
Matt Hoeflinger, Hunting Committee Chair and Wayne Blyth, Chairman	Mauna Kea Recreational Users Group	Hilo, Hawaiʻi
Gordon Tribble, Director	Pacific Island Ecosystems Research Center, USGS	Honolulu, Hawai'i
Chris Farmer, Ph.D., Science Coordinator for Endangered Hawaiian Birds	American Bird Conservancy	Hawaiʻi National Park, Hawaiʻi
Richard C. Wass, President	Friends of Hakalau Forest National Wildlife Refuge	Hilo, Hawaiʻi
Gustav Bodner, Graduate Student, University of Hawaiʻi		Honolulu, Hawaiʻi
Walter D. Koenig, Ph.D., Cornell Laboratory of Ornithology		Ithaca, New York
Cathy M. Lowder		Hilo, Hawaiʻi
Annie Marshall, Ph.D.	Nēnē Recovery Action Group	Honolulu, Hawaiʻi
BJ Leithead Todd, Planning Director	County of Hawaiʻi Planning Department	Hilo, Hawaiʻi
Kaulana H.R. Park, Chairman Hawaiian Homes Commission	Department of Hawaiian Home Lands	Honolulu, Hawaiʻi

Management Strategies

Alternatives
Several commenters specifically expressed their support for implementation of Alternative B, as described in the Draft CCP/EA. Commenters stated Alternative B was preferable because it includes the most acreage of reforestation and restoration across all forest types; large inventory, research, and assessment components; and increased opportunities for outreach, volunteers, and environmental education; and because it would best maintain biodiversity. One commenter stated that Alternative B could be strengthened by including the best management strategies available.

Response: Alternative B, identified as our preferred alternative in the Draft CCP/EA, has been incorporated into this final CCP. Based on more specific comments below, the management objectives and strategies have been clarified to improve the final plan.

Biodiversity:
A few commenters felt we should have placed more emphasis on conserving biological diversity rather than on protecting forest birds. Comments requested that we highlight additional species that may be just as endangered and important as they could be critical to ecosystem functioning. For example, insects may respond more quickly to positive and negative changes, but no allowance was made for understanding this. Another stated an effort to assess broader biodiversity would be a good idea to help the Service understand how thing are changing in both restored and native habitats. One commenter suggested expanding the Refuge goals to include the conservation of biological diversity.

Response: The National Wildlife Refuge System Improvement Act of 1997 directs the Service to ensure that the biological integrity, diversity, and environmental health of the Refuge System are maintained for the benefit of present and future generations of Americans. The Service's policy (601 FW 3) also provides guidance on consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges, and associated ecosystems that represent biological diversity on each refuge. In response to the public comments, we have expanded our discussion of biological integrity, diversity, and environmental health in Chapter 4 of the final CCP. Though the Refuge was established for the purposes of listed species protection, the establishment language also incorporates the ecosystems and habitats which support these species. Consequently, additional species will benefit from this approach. The Service recognizes that biodiversity in an integral part of the overall health of a functioning ecosystem.

<u>Ungulate Removal:</u>
Commenters both opposed and supported removal of ungulates from the Refuge. Those opposed to removal felt the animals deserve to be here as part of what the Hawaiians brought; that removal of ungulates could lead to more grasses and an increase in fire danger; and that it is impossible to remove all ungulates. Those in support of removing ungulates indicated it is a critical action if native habitats are to be restored and endangered forest birds and other species are to survive into the future.

Response: Our goal is to restore and protect the native forests within the Refuge, which is in direct opposition to maintaining ungulates. The final CCP continues to call for the removal of all ungulates from both Units of the Refuge.

One commenter asked to review evidence that "removal of the larger more aggressive pigs could result in population increases through ingress by additional pigs that use smaller territories and reproductive response in the feral pig population."

Response: Since pigs are capable of rapid population growth, we have added language to clarify this statement that very high levels of annual removal are required from managed areas to suppress and retain the pig population to a near zero level.

One commenter asked for a better description of the differences between alternatives, particularly as it relates to ungulate control; another asked that the Refuge's Feral Ungulate Management Plan (FUMP) be included in an appendix since it is referenced throughout the document in multiple places.

Response: The fencing scheme for Alternative A depicted on Map 6 was developed as part of the 1995 Feral Ungulate Management Plan. Based on a recent review of this scheme, we determined that it would be more effective to reduce the number of internal fenced units and align the fences parallel to certain natural elevation contours. This revised fencing scheme is part of the management regime in Alternatives B (Map 7) and C (Map 8). We have revised the CCP to explain this new approach to creating internal fenced units to promote ungulate eradication. The CCP has superseded the FUMP, and we will produce several stepdown management plans (see Appendix C) that tier from the CCP, including an Inventory and Monitoring Plan that would include ungulate management. However, any interested party is welcome to obtain a copy of the original FUMP document from the Refuge upon request.

One commenter supports the use of aerial drops of toxic baits for ungulate control wherever they are safe for native species, as is being done successfully in New Zealand.

Response: The aerial distribution of toxins is being considered Statewide, and we will continue working with our conservation partners to evaluate its usefulness in Hawai'i. We support and implement the concepts and procedures of Integrated Pest Management (as outlined in Appendix G) to control or eradicate invasive species on national wildlife refuges.

Fencing:
The internal fencing identified in Alternative B was supported as a good way to manage wild pigs. One commenter recommended removing feral ungulates immediately after fence installation as they can cause more damage if trapped in one smaller area.

Response: Our goal is to immediately initiate ungulate removal after a management unit is fenced, but the schedule will be dictated by the availability of funding. We agree the action of complete enclosure of a unit should not occur until funding is available for immediate ungulate removal upon fence completion.

Nēnē Management:
One commenter stated that conflicts with nēnē and forest restoration will occur because the original Hakalau vegetation was not suitable for nēnē. He asked that we clarify how we plan to transition out of nēnē management in forested areas and whether expansion of nēnē efforts on adjacent lands above the Refuge might be possible. Another commenter suggested, to avoid conflict with restoration areas, moving breeding habitat to lower elevations and/or in areas where restoration is more problematic within the Refuge. Another person suggested no areas be altered for grasslands.

Response: We agree that originally, no grasslands would have existed at the HFU. However, the existing grasslands created by years of cattle grazing do provide good habitat for this endangered species. Within the timeframe of this CCP (15 years), we do not expect complete reforestation of the HFU to occur. Thus we have chosen to continue to manage portions of this Unit for the recovery of nēnē and will seek a balance between the needs of various listed species on the Refuge. We will continue to work with our neighbors and partners to benefit native species, but have no control over the lands beyond our boundaries.

Two commenters suggested combining the nēnē habitat management proposals in Alternatives B and C in the final CCP, thus protecting both breeding and foraging sites. Another commenter stated creation of additional nēnē habitat may lead to increased predation as nēnē densities increase. Another commenter expressed concern that nēnē develop behavioral problems when around humans and should not be near structures to avoid habitat imprinting that occurs. She suggested that current as well as future nesting and foraging areas be moved away from human infrastructure and areas where human/nēnē interactions would be minimal.

Response: We have chosen to maintain the strategies for nēnē under Alternative B (the selected alternative) until we can evaluate how much foraging habitat is needed, our capacity to manage it (through mowing), and research into the predator and human/nēnē interaction and habitat imprinting issues. Once these issues are more fully understood, we will determine an appropriate acreage and location for additional nēnē habitat. The final CCP calls for adaptive management as factors change on the Refuge.

Invasive Weed Control:
One commenter supported the inclusion of biocontrol in all three alternatives as an important tool for controlling weeds (e.g., naio thrips in Kona could be a threat to naio trees at the Refuge).

Response: We appreciate your support and agree that biocontrol can be an effective tool as part of an Integrated Pest Management program. It is further discussed in Appendix G of the final CCP.

Fire Management:
One commenter stated wildfire response should include development of interagency protocols, early detection, maintenance of water sources, and mobilization of equipment and firefighters.

Response: A strategy under Alternative B (the selected alternative) for habitats in both units calls for the development of a fire prevention program, which will address the issues identified by the commenter. Additionally, the Refuge has fire management plans, and we are a member of the interagency Big Island Wildfire Coordinating Group, which also incorporates the issues above.

Forest Bird Management:
A commenter stated that ʻiʻiwi and ʻapapane do not live above 4,100 ft as they migrate to lower elevations during summer.

Response: We have clarified this information in the final CCP.

Another commenter said avian diseases and parasites should be emphasized as one of the top priority threats to all forest birds, including the Hawaiʻi ʻelepaio.

Response: We have clarified the text as requested.

Research and Monitoring

Two commenters expressed concern that the plan is an attempt to prioritize the management needs and activities for the next 15 years without a full discussion of avian population trends. They believe conclusions cited in the plan about forest bird recovery are untrue because they are based on flawed analysis and models, and that management actions are being proposed without fully understanding population trends. They stated that increased scrutiny needs to be given to ʻākepa in light of its significant declines and that control of Japanese white-eyes should be at the core of adaptive management as they are limiting the food supply for native birds. They further stated that university scientists conducting research independent of agency bias have the potential to contribute significantly to the mission of the Refuge, and that these benefits outweigh any perceived disadvantages.

Another commenter asked that we give weight to the research of Drs. Lenny Freed and Rebecca Cann on the decline of native honeycreepers in this part of Hawaiʻi due to introduced forest birds and stated the Refuge needs to make decisions based on the best available science. An additional commenter suggested allowing an independent expert bird ecologist to conduct a study on the impact of white-eye competition on native birds at Hakalau, suggesting that funding could be arranged from other sources so as not to interfere with Refuge priorities.

Response: We have based our forest bird research and management priorities on those recommended by the experts convened for the Forest Bird Workshop in October 2008 (see Appendix E. Forest Bird Workshop). We agree that research on the demography, life history, carrying capacity, and competition for native forest birds is very important to the Refuge, and we have included it as a project in Appendix C Plan Implementation. We also evaluated the compatibility of research, scientific collecting, and surveys in Appendix B and found "[r]esearch on Hakalau Forest NWR is inherently valuable to the Service, since it is intended to expand the knowledge base of those who are given the responsibility of managing the resources found within the Refuge." We welcome suggestions for seeking non-Refuge funding to support such research.

One comment letter indicated that the research proposal process, from evaluation and feedback to timetables for research and reporting, should be as transparent as possible.

Response: We have included extensive information about the research proposal process within Appendix B. Appropriate Uses and Compatibility Determinations, under the Research, Scientific Collecting, and Surveys compatibility determination, including formats for proposals, annual progress reports, and Memoranda of Understanding for curatorial services. The compatibility determination outlines the proposal process, as well as reporting requirements and stipulations to ensure permitted research conforms to Service regulations and policies and will be performed in a manner that will not impact Refuge resources.

One commenter asked that the alternatives description have an additional paragraph dealing with research and monitoring.

Response: The final CCP does not include alternatives, thus we have not added this text. However, research and monitoring are fully described in several locations within the CCP, including in Chapter 2 and Appendices B and C.

One commenter stated the Refuge should monitor for ungulate presence to optimize effectiveness of fencing and ungulate removal.

Response: We agree that a long-term concerted effort is required as part of overall ungulate management. We plan to continue ungulate surveys as frequently as practicable to monitor their population status and will utilize available resources to take actions necessary to eliminate ungulates from newly fenced units and prevent the ingress of ungulates into existing restored and protected forest habitats. This aspect of ungulate management has been clarified in Chapter 2 under general guidelines, ungulate-proof boundary fencing and sequence of management actions.

Public Use

<u>Hunting:</u>
Several commenters addressed the issue of public hunting on Hakalau Forest NWR, both in favor and opposed. Those in favor stated that hunting provides sustenance for local people, is part of Hawai‘i family lifestyles, is effective in reducing pig numbers, and can be accomplished without impacting other natural resources. Those opposed stated that hunters are less than 3 percent of the American public and should not be allowed to monopolize the sites so that the majority of Americans cannot safely use them, that public hunting is not effective at controlling pigs because 70 percent of

the pig population must be removed annually to effect control, and that the potential damage to recovered habitat and the risk of new weed introductions is too great.

Response: The Service recognizes its strong legal encouragement to offer public hunting on national wildlife refuges when this recreational use can be conducted in a manner that is compatible with the purpose(s) for which the refuge was established. Based on the compatibility determination found in Appendix B, we have determined that public hunting is not compatible with the purposes of the Refuge. Use of public recreational hunting as a tool to meet the overall goals of the Refuge's ungulate control program was not successful in the past. Reduction and ultimately eradication of ungulates is necessary to achieve the required level of protection and eliminate disturbance to endangered species. Recreational hunting is unlikely to achieve the desired goal of reducing pig populations in managed units by >70 percent annually, in order to assure control objectives are achieved where more efficient methods are available (Hess et al.2006). Additionally, keeping ungulate populations at levels required to provide public recreational hunting is not compatible with the Refuge's purposes of protecting listed species and the habitats they rely on.

We believe it is most efficient and effective to control ungulates through staff efforts and/or by contract. Bids for such contracts would be solicited from the public and would not necessarily preclude a contractor from using the services and expertise of local hunting groups to complete the work. Such contracts would have strict stipulations to prevent negative impacts on native species as well as be required to obtain liability insurance, be permitted to carry a firearm, have gone through the State's Hunter Education Program and carry a State hunting license/permit, and any other stipulations identified in the contract solicitation.

One commenter indicated public hunting is addressed only for pig hunting, avoiding other island game species.

Response: We agree. We modified our hunting compatibility determination to reflect that hunting of game birds is not compatible because the flight paths of the endangered nēnē and wild turkeys overlap.

One commenter felt the discussion of hunting in the Draft CCP/EA offered abundant speculation and opinion, and little that is factually accurate. Others stated there is no substantiated evidence of hunters purposefully pursuing game into impenetrable vegetation or cutting or pulling endangered plants, and it is speculative to say public hunting has negative impacts on such resources. Another asked if other public uses are allowed in the area would not have the same impacts as hunters.

Response: We have reviewed the language included within our hunting compatibility determination to ensure it is more objective and accurate. Unlike other public use opportunities, such as wildlife photography and bird watching, which occur on identified roads or paths to keep people from negatively impacting Refuge resources, hunting is not an activity that has similar infrastructure in place to protect resources and guide the user. Hunting is a pursuit of a wild animal that can go anywhere and the hunter follows. This unguided pathway through Refuge habitat could inadvertently impact native vegetation and restoration efforts as well as disturb habitat for native species.

Additional concerns about impact to Refuge resources are the inadvertent spread of nonnative weed species through Refuge habitats. Given the many other hunting opportunities on the rest of the island, it is unknown what invasive plant species seeds or other reproductive plant medium may be *attached to clothing or equipment. The cost of controlling invasive weeds in remote areas is high, and it is easier to prevent the establishment of nonnative plants than control them after the fact.*

Wildlife Observation, Photography, Interpretation, and Environmental Education:
Two commenters supported additional visitor uses within the Refuge. One asked to open the Pua ʻĀkala tract to the public once a month for birding, wildlife photography, and other compatible uses; to develop a wildlife observation platform in the vicinity of Pua ʻĀkala cabin and Maulua; and to advertise and host a monthly onsite environmental education event. Another suggested opening the KFU to the public for guided interpretation, nature study, and photography.

Response: Based on staffing limitations and concerns about additional impacts to endangered forest birds and plants, we have determined a small-scale wildlife observation and photography program with strict stipulations is appropriate only in the Upper Maulua Unit of the HFU (See Appendix B). The final CCP also calls for the development of a Visitor Services Plan in the coming years, and proposals to expand visitor programs may be reevaluated at that time as well as when additional funding is available to support visitor services positions.

One commenter stated that outreach is key to gaining public support, especially for restoring ʻalalā at the KFU.

Response: We agree that outreach is important to gain public support for maintaining and recovering all native species and for management activities at Hakalau Forest NWR. We will seek further opportunities with other Hawaiʻi refuges, the State, nongovernmental organizations, schools, and the Friends of Hakalau Forest NWR to expand our outreach efforts, as discussed under Objective 7.4.

Historic Resources

One commenter asked who would manage Pua ʻĀkala cabin if it is listed on the National Register of Historic Places and how it would be managed.

Response: We have clarified in the final CCP that the cabin would remain under the management of the Fish and Wildlife Service if it is designated as historic and that it would be managed in accordance with guidelines from the National Registry and the Secretary of the Interior's Standards for Historic Preservation.

Climate Change

Two commenters addressed the issue of climate change on the Refuge, one stating that outplanting species that were present many years ago is impractical and wasteful due to climate change, and the other encouraging the Refuge to consider other components of Hawaiian biota threatened by climate change (not just forest birds) in assessing future land acquisition.

Response: We have added substantial text to the final CCP (Chapter 3) regarding climate change. The Service is supporting the development of regional Landscape Conservation Cooperatives that will integrate local climate models with models of climate change responses by species, habitats, and ecosystems. Cooperatives will collectively plan and design appropriate conservation actions at a landscape scale, monitor responses to climate change, and assess the effectiveness of management *strategies. The local version of these Landscape Conservation Cooperatives is the Pacific Islands Climate Change Cooperative (PICCC), headquartered in Honolulu, Hawai'i, but working across the Pacific. By working with PICCC, the Refuge will identify additional mitigation measures for climate change.*

Refuge Capacity

Several commenters either expressed concern that the Service has not had the funding and staffing necessary to manage the Refuge at the current level or expressed support for expanding Refuge staffing to implement the CCP. Some particularly supported filling the positions for a park ranger/volunteer coordinator, fire fuels specialist, and office assistant.

Response: As indicated in Appendix C. Plan Implementation, Hakalau Forest NWR recognizes the need for additional staffing for current management operations as well as to implement the final CCP. Position priorities will be determined as funding becomes available and based on skills needed at that time.

Adequacy of Document

One commenter stated there is little explanation of how the various management target areas were determined for the different forest objectives and asked that we clarify how they are currently managed and what needs to be done for each of the targeted areas.

Response: Management targets were established based on evaluation of the vegetation type maps found in the Draft CCP/EA. A new appendix (L) was created to summarize past and current management actions. We recognize that more detailed planning would be beneficial in carrying out management actions identified in the CCP. The Service planning process provides for the development of "stepdown plans" to facilitate this additional planning need (see Appendix C). We will be preparing an Inventory and Monitoring Plan which will assist managers in implementing habitat protection, maintenance, and restoration strategies. Additionally, as the Service implements its new Inventory and Monitoring approach, we will be fine tuning our habitat related management targets and actions annually through the new habitat database system.

One commenter felt availability of the draft plan for public review was not adequately publicized within the other 49 States.

Response: Our efforts to seek public involvement in the planning process are outlined earlier in this Appendix. Although we recognize each national wildlife refuge belongs to all Americans, typically those nearest to the site are most interested in commenting on its management. We published a notice of availability in the Federal Register, mailed numerous planning updates to nonlocal entities such as national organizations, and distributed a news release throughout the Pacific Region. Information also has been available on various Service websites.

One commenter supported development of an environmental impact statement rather than an environmental assessment.

Response: As indicated in the Finding of No Significant Impact, the Service believes that implementing Alternative B as the CCP for management of Hakalau Forest NWR is not a major

Federal action that would significantly affect the quality of the human environment within the meaning of section 102(2) (c) of the National Environmental Policy Act of 1969. Accordingly, the Service is not required to prepare an environmental impact statement.

Appendix L. Summary of Past and Current Management

When Hakalau Forest National Wildlife Refuge was created in 1985 to protect native forest habitat for endangered animals and plants, the initial lands acquired with the help of the Nature Conservancy had been used for cattle ranching, some of which had also been logged. As such, the condition of the native forest had been degraded by 100 years of cattle grazing, with about 5,000 acres of upper elevation forest (mostly above 6,000 ft) converted into open woodland and pasture dominated by introduced grasses (though most of the Refuge still had closed canopy forest, with the most intact areas in the lower elevations). Under the closed canopy forest, certain sections of the understory had been disturbed by cattle, pigs, and rats. The mesic koa/ʻōhiʻa and koa/māmane forests were the most severely degraded. Listed species that were found at the time included *Phyllostegia racemosa* and *Clermontia lindseyana*. The first initial management actions implemented by the Refuge included surveys (forest bird, native plant, weed, ungulate), construction of ungulate proof fences, ungulate removal, weed control, and reforestation (outplanting of koa) and reforestation research focused on techniques (mainly with assistance of the USFS-Institute of Pacific Islands Forestry (IPIF)). Due to the remote location of the Refuge, a cabin and storage building as well as water catchment systems had to be constructed to support Refuge operations. The last cattle permitted to graze at the Refuge were removed in 1996. Over the years, other parcels of the Refuge (Pua ʻĀkala, Middle Papaikou, Middle Hakalau, and units B-F) were acquired so that today, HFU is 32,730 acres.

In 1997, an additional 5,300 acres was purchased from the Les Marks Estate in South Kona, bringing the total Refuge acreage up to 38,030 acres. This unit was established specifically for the endangered ʻalalā, as well as other listed species. Vegetation at the lower portions, around the 2,000-foot elevation, was dominated by a mixture of introduced and native trees, shrubs, and grasses. These included guava (*Psidium guajava*), strawberry guava (*Psidium cattleianum*), silky oak (*Grevillea robusta*), and Christmas berry (*Schinus terebinthifolius*), and ʻōhiʻa (*Metrosideros polymorpha*) was the most common native tree. Above the 2,500-foot elevation, introduced trees and shrubs become less prevalent, and the forest community was dominated by an overstory of ʻōhiʻa trees and an understory of native trees, shrubs, and hapuʻu tree ferns (*Cibotium* spp.). Between the 3,000-6,000 foot elevations, a diverse native forest community was found. This forest type is characterized by an overstory comprised of a mixture of koa (*Acacia koa*) and ʻōhiʻa trees and an understory of native shrubs and hapuʻu. Cattle grazing had created pastures in some of these upper elevations. Above the 6,000-foot elevation, the native forest was characterized by a mixed māmane-sandalwood (*Sophora chrysophylla*-*Santalum ellipticum*) and koa or ʻōhiʻa dryland natural communities with ground cover of nonnative grasses and native shrubs. Listed species found included the ʻōpeʻapeʻa, Hawaiʻi ʻākepa, the Hawaiʻi creeper, the ʻakiapōlāʻau, and the ʻio. Initial refuge management of this unit included securing road access, surveys (forest bird, native plant, weed, ungulate), and establishing a field camp.

Current Refuge management for both units (Hakalau Forest Unit and Kona Forest Unit) revolves around maintaining and constructing new fencing, controlling pest species (plants and animals), native forest restoration, reforestation, and threatened and endangered species management. In addition, the Refuge contains structures and facilities that existed before the original acquisition. The Refuge has built its own facilities to support management. All require maintenance, including a candidate historic structure (Pua ʻĀkala Cabin). Chapter 5 provides additional information on Refuge facilities.

For the Hakalau Forest Unit, eight internal management units exist, consisting of 14,150 fenced acres. There are 45 miles of ungulate proof fencing established, including both perimeter and internal fences (Figure 2-1). Middle Honohina (1) is roughly 550 acres, Shipman (2) 5,000 acres, Lower Honohina (3) 1,800 acres, Upper Maulua (4) 2,000 acres, Upper Honohina (5) 1,000 acres, Middle Hakalau (6) 1,500 acres, Middle Papaikou (7) 1,800 acres, and Pua ʻĀkala (8) 500 acres. Middle and Lower Maulua and Lower Honohina consist of closed canopy forest with relatively intact understory. Middle Honohina, which has been pig free for the longest time period (since 1989), also consists of closed canopy forest as are units B, C, E, and F.

A majority of restoration and reforestation work has been conducted within Pua ʻĀkala, Shipman, and Upper Honohina, with over 400,000 native plants (mainly koa) outplanted since 1987 in order to create additional native forest habitat in formerly grazed and degraded areas (see before and after photographs below). Most recent restoration management has focused on using other native plants to build up the understory now that koa canopy coverage has been established. Preparation of land for outplanting includes grass control to reduce competition by using mechanical (dozer) as well as hand control (it has been documented that pasture grasses as well as lack of seed, soil conditions, and harsh climate (frost) in open grasslands can inhibit natural forest regeneration). In addition, listed plants have also been outplanted in these areas including *Clermontia pyrularia, Clermontia lindseyana, Clermontia peleana, Cyanea shipmanii, Phyllostegia racemosa,* and *Pyllostegia velutina* and *Ranunculus hawaiiensis*. Native habitat vegetation in each unit can be seen in Figure 4-2, with Middle Papaikou, Middle Hakalau, Lower Honohina, Middle Maulua and units A-F containing the most intact native forests on the Refuge.

Intermittent streams can be found in upper elevation units 1-8, while lower elevations have perennial streams (Figure 4-2). Additional aquatic habitats include *Carex* bogs found in montane wet ʻōhiʻa/uluhe forest. Some hydrology research has been conducted. However, very little management (other than gorse removal in the upper units) has been done for these aquatic habitats.

The invasive weeds of most concern are: (1) gorse, which is found most heavily in open pasture areas at Pua ʻākala, with smaller populations in Shipman and Upper Honohina, and (2) Florida blackberry, which can be found in all units above 5,000 ft. Pua ʻĀkala also has a heavy English holly infestation, with some smaller populations in Shipman and Upper Honohina. All three units of Honohina and the two upper units of Maulua also have banana poka. *Hotenia davidiana* has the highest concentration in Middle Honohina and the upper portions of the Lower Honohina. The highest concentration of nonnatives is found at the higher elevations above 5,000 ft. All invasive weeds that currently exist at HFU are in a monitoring, control, or maintenance stage of management, with a focus on both chemical and mechanical control. Florida blackberry control activities are conducted May-October and gorse control focused on in winter months; while English holly is year-round. Volunteers assist with banana poka control.

Listed species management includes both flora and fauna. Listed animal species of most concern can be found in the following units with Pua ʻĀkala and Shipman having the highest concentration of listed species:

- ʻAkiapōlāʻau can be found in all units above 4,500 ft elevation;
- Hawaiʻi ʻākepa can be found in all units above 4,500 ft elevation with the greatest densities in the Shipman and Pua ʻĀkala units;
- Hawaiʻi creeper can be found in all units above 4,500 ft elevation;

- ʻŌʻū had two unconfirmed detections in the late 1990s in the lower Honohina tract;
- ʻIo can be found in all units;
- Nēnē can be found at Pua ʻĀkala and Shipman;
- Koloa maoli can be found in stock ponds in the upper units; and
- ʻŌpeʻapeʻa can be found in all units.

The Plant Extinction Prevention (PEP) Program for Hawaiʻi Island has been collecting seeds for PEP listed species. Seeds *of Phyllostegia racemosa* were collected from plants in the Maulua tract in years past are being grown at the Volcano Rare Plant facility, and seeds from these plants are being propagated. Other examples are *Asplenium schizophyllum* (collected one founder - lower Honohina (unit 3)) and *Trematolobelia grandifolia* (collected one founder in unit 6). Outplantings of PEP plants onto Refuge lands includes seedlings of *Clermontia peleana* in unit 7, unit 6, and in Maulua. All other PEP plant outplantings were conducted in the Maulua tract, including *Clermontia pyrularia*, *Clermontia lindseyana* and *Cyanea shipmanii.* The listed *Cyanea shipmanii* (3,896 acres of critical habitat are identified at HFU) as well as *Phyllostegia racemosa* (over 2,317 acres of critical habitat are identified at HFU) can be found at Pua ʻĀkala. Critical habitat can also be found for *Clermenonita peleana* and *Clermontia lindseyana* (over 2,000 acres).

Surveys for forest birds occurred every year since 1987 (Figure 4-5). Additional surveys include ʻōpeʻapeʻa (in Pua ʻĀkala and Upper Maulua), invasive plants occasionally (which follow the forest bird transects), and ungulates on forest bird transects annually until 2005.

Species research includes ʻōpeʻapeʻa, nēnē, invertebrates, pollination, listed plants and animals, forest structure and species diversity, and restoration. Most research occurs in units 2, 4, 5 and 8 and some research occurs in units 1, 3, 6, and 7.

Fire (fuel) breaks and gates are also maintained, along with internal dirt/gravel roads for management purposes in units 2, 4, 5 and 8 (Figure 5-2). Wildland fire history at the Refuge is minimal. The Refuge sustained its first fire in 2002 in the Maulua unit. Its cause is undetermined. Most of the fires occur outside the Refuge and are human caused. Several have burned right up to Refuge fences, but were stopped by the fuel breaks.

Fences are an integral part of ungulate management. Forty-five miles of fence are inspected/repaired once a month (when staffed) to prevent new animals from entering control units. Several methods are employed to control pigs and cattle. These include hunting, trapping, snaring, and driving. Normally a combination of methods is used to eradicate the animals in an area. These units are sized to efficiently remove animals over a given period of time. As an example, a 1,500 acre unit will be snared at a rate of one snare per acre. This will facilitate control within 5 years. Middle Papaikou has 1,700 snares and Middle Hakalau has 1,600 snares. Lower Honohina has 1,000 snares but also has active baiting and trapping as well. Monitoring of fences for ungulate ingress will be an on-going activity.

For the Kona Forest Unit (Figure 2-2), a perimeter as well as internal fenceline has been cleared in preparation for building 17 miles of ungulate proof fencing, anticipated to be completed within 2 years. Three management units within KFU will exist once the fencing is completed. The PEP Program for Hawaiʻi Island has been similarly collecting seeds for PEP listed species at this unit and propagating them at the Volcano Rare Plant Facility. These include *Asplenium peruvianum var.*

insulare (several founders, not considered PEP anymore), *Sicyos macrophylla* (one founder); *Sanicula sandwicensis* (three founders); *Cyanea marksii* (one founder); *Cyanea stichtophylla* (two founders); *Phyllostegia ambigua* (one founder); *Phyllostegia* spp. (one founder); *Stenogyne macrantha* (one founder); *Rubus macraei* (one founder); and *Fragaria chiloensis* ssp. *sandwicensis* (three founders). No outplantings have occurred at KFU because it has not been fenced. Plants that were collected and matured to outplanting sizes have been outplanted in State Natural Area Reserve fenced exclosures in nearby south Kona. Other PEP species occur on lands adjacent to the Kona Forest Unit and have been collected for future outplantings in the KFU once it is protected by fencing and animals have been removed.

The KFU is also considered potential habitat for listed *Cyanea hamatiflora carlsonii* and is critical habitat for listed *Drosophila*. Four bird transects have also been established and bird surveys are conducted intermittently. The U.S. Geological Survey has been conducting basic cave reconnaissance related to lava tubes and skylights. Additional surveys that have been made of the area include archaeological, rare plant, ‘io, and weed surveys. There is also an access road easement on private lands from the highway to the Refuge that requires periodic repairs (Figure 5-3). Though no aquatic habitats occur at KFU, the area is considered a groundwater recharge area and critical for this drought prone region of the island.

The current budget (FY2010) for Hakalau Forest NWR is $1,168,098. This budget funds seven full time staff members (refuge manager, deputy refuge manager, maintenance supervisor, maintenance worker leader, wildlife biologist, horticulturalist, and administrative officer) as well as all operational needs. An additional six staff (field crew and administrative support positions) are all funded through soft monies (non-base funding).

The following two tables are a chronological description of the acquisition history listing dates, tract numbers, acreage, expiration dates as applicable, and any specific relevant comments.

Table L-1. Refuge Acquisition History for Hakalau Forest NWR.

Date Acquired	Legal Document	Tract #	Acreage	Comments	Expiration Date
10/28/1985	Easement	14R	19.45	From: The Nature Conservancy Cost: $0.00 cost included with Tract 14.	unknown
10/29/1985	Fee Title	10	4,994.00	From: The Nature Conservancy Cost: $2,800,000.00 Signed 10/21/85. All metallic minerals to the State of Hawai‘i.	n/a
10/29/1985	Fee Title	14	3,300.00	From: The Nature Conservancy Cost: $1,000,000.00 A road easement consisting of 19.45 (Tract 14R) was also acquired in the same deed signed 10/21/85. all minerals and metallic mines to State of Hawai‘i.	n/a

Date Acquired	Legal Document	Tract #	Acreage	Comments	Expiration Date
06/05/1986	Easement	11-1R	1.05	From: The Nature Conservancy Cost: $0.00 The price for easements 11R and 11R1 were included with Tract 11 and 11A.	unknown
06/05/1986	Easement	11R	3.17	From: The Nature Conservancy Cost: $0.00 The price for easements 11R and 11R1 were included with Tract 11 and 11A. Road, utilities, access trails for ancient Hawaiian use or custom. All mineral and metallic mines to State of Hawai‘i.	unknown
06/06/1986	Fee Title	11a	2,523.78	From: The Nature Conservancy Cost: $849,017.00 Tracts 112R and 11R-1 are included in this cost. Signed 6/5/86.	n/a
06/06/1986	Fee Title	11	717.54	From: The Nature Conservancy Cost: $240,983.00 All minerals and metallic mines to State of Hawai‘i. Roads, utilities, access trails for ancient Hawaiian use or custom. Tracts 11R and 11R-1 are included in this cost. Signed 6/5/86.	n/a
09/24/1986	Easement	13-1R	1.65	From: Hawaiian Home Lands Cost: $900.00 Nonexclusive, perpetual road easement, including right to trim vegetation and right of entry upon easement area and adjoining land of Hawaiian Home lands for maintenance of FWS jeep trail-term 6/1/86.	perpetual
12/31/1986	Fee Title	16	1,542.50	From: The Nature Conservancy Cost: $1,064,325.00 signed 12/29/86.	n/a
12/11/1987	Fee Title	14a	1,977.82	From: The Nature Conservancy Cost: $550,000.00 Mineral and metallic mines to State of Hawai‘i. Hilo Forest Reserve easement. Perpetual license dated 10/31/78 for purposed of surplus water signed 10/5/87.	n/a

Date Acquired	Legal Document	Tract #	Acreage	Comments	Expiration Date
12/14/1988	Fee Title	15	400.00	From: The Nature Conservancy Cost: $360,000 Mineral and metallic mines to State of Hawaii. Signed 12/2/88 Sutton.	n/a
01/27/1993	Fee Title	11b	1,033.94	From: The Nature Conservancy Cost: $1,033.94 No deed signed date given. Liluokalani.	n/a
09/14/1994	Fee Title	12	15,715.54	From: World Union Cost: $10,000,000.00 Mineral and metallic mines to State of Hawai‘i. Deed signed 7/22/94.	n/a
04/12/1995	Fee Title	17	500.00	From: W.H. Shipman LTD. Cost: $500,000 Deed signed 4/6/95.	n/a

Table L-2. Refuge Acquisition History for Kona Forest Unit.

Date Acquired	Legal Document	Tract #	Acreage	Comments	Expiration Date
10/01/1997	Fee Title	20	5,300.00	From: Les Marks Trust Cost: $7,780,000.00 Road and utility easements. Native tenant rights. Other authorities are DT authority 1888 & 1931.	n/a
03/30/2005	Easement	21-1R	4.00	From: Les Marks Trust Cost: $20,000.00 Grant of Nonexclusive easement document. Monetary purchase and settlement agreement.	unknown
03/30/2005	Easement	21-2R	13.00	From: Les Marks Trust Cost: $40,000.00 Grant of Nonexclusive easement document. Monetary purchase and settlement agreement.	unknown

Figure L-1. 1993 pre-reforestation and restoration efforts (photo courtesy of Jack Jeffrey).

2007 post-reforestation and restoration effort (photo courtesy of Jack Jeffrey).

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National Wildlife Refuge System Information
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