U.S. Fish & Wildlife Service

Hanalei National Wildlife Refuge

Draft Wetlands Management and Waterbird Conservation Plan

DRAFT WETLANDS MANAGEMENT AND WATERBIRD CONSERVATION PLAN

Hanalei National Wildlife Refuge

HAWAI'I

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ABBREVIATIONS

AHWP annual habitat work plan

AMVA American Veterinary Medical Association

APHIS Animal Plant Health Inspection Service

ASAE American Society of Agricultural Engineers

ATV all-terrain vehicle

AUF appropriate use findings

BIDEH Biological Integrity, Diversity, and Environmental Health

BLM Bureau of Land Management

BMP best management practices

CAA Cooperative Agriculture Agreement

CCP Comprehensive Conservation Plan

CD Compatibility Determinations

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act

CFR Code of Federal Regulations

cfs cubic feet per second

COLA cost of living adjustment

CWA Clean Water Act

DLNR Department of Land and Natural Resources

dWMWCP Draft Wetlands Management and Waterbird Conservation Plan

DM Department Manual

DO dissolved oxygen

DOFAW Division of Forestry and Wildlife

DOI U.S. Department of the Interior

EA Environmental Assessment

ECDC Eagle County Development Corporation

EO Executive Order

EPA U.S. Environmental Protection Agency

ERA Ecological Risk Assessment

ES Ecological Services

ESA Endangered Species Act of 1973

FEMA Federal Emergency Management Agency

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act

FW U.S. Fish and Wildlife Service Manual

gad gallons per acre per day

GMC genetically modified crops

HACCP Hazard Analysis and Critical Control Points

HAR Hawai‘i Administrative Rules

HDOH Hawai‘i State Department of Health

HMP Habitat Management Plan

HUC Hydrologic Unit Code

I&M Inventory and Monitoring

IMP Inventory and Monitoring Plan

IPM Integrated Pest Management

ISST Invasive Species Strike Team

JV Joint Venture

KISC Kaua‘i Invasive Species Committee

KNWRC or Complex Kaua‘i National Wildlife Refuge Complex

KTGA Kaua‘i Taro Grower’s Association

LCC Landscape Conservation Cooperative

MBTA Migratory Bird Treaty Act of 1918

MC management capacity

mgd million gallons per day

NAWCA North American Wetlands Conservation Act

NEPA National Environmental Policy Act

NHPA National Historic Preservation Act of 1966

NOAA National Oceanic and Atmospheric Administration

NRCS Natural Resouce Conservation Service

NTHP National Trust for Historic Preservation

NWR or Refuge Hanalei National Wildlife Refuge

NWRS or Refuge System National Wildlife Refuge System

ORP oxidation/reduction potential

OSHA Occupational Safety and Health Administration

PPE personal protective equipment

PUP Pesticide Use Proposal

PVC polyvinyl chloride

QMUA Quarterly Management Unit Assessments

RCRA Resource Conservation and Recovery Act of 1973

Refuge Administration Act National Wildlife Refuge System Administration Act of 1966

Refuge Improvement Act National Wildlife Refuge System Improvement Act of 1997

RHPO Regional Historic Preservation Officer

RM Refuge Manual

ROC Resources of Concern

RONS Refuge Operational Needs System

SAMMS Service Asset Maintenance Management

SHPD State Historic Preservation Division

SLH Session Laws of Hawaii

SOS Save-Our-Shearwaters

SQuiRTs NOAA Screening Quick Reference Tables

SUP Special Use Permit

SWAP State Wildlife Action Plan

TBD To Be Determined

TCSA Toxic Substances Control Act

TMDL Total Maximum Daily Load

U.S. United States

U.S.C. United States Code

USACE U.S. Army Corps of Engineers

USDA United States Department of Agriculture

USFS U.S. Forest Service

USFWS or Service U.S. Fish and Wildlife Service

USGS United States Geological Survey

WMWCP Wetlands Management and Waterbird Conservation Plan

WRB Water Resources Branch

EXECUTIVE SUMMARY

This Wetlands Management and Waterbird Conservation Plan (WMWCP) describes the processes and procedures needed to achieve Hanalei National Wildlife Refuge's (NWR or Refuge) management objectives, including those related to threatened and endangered Hawaiian waterbird conservation, for approximately 480 acres of rotational managed wetland (moist-soil) units, lo'i kalo (wetland taro fields), ditches and dikes, fallow, riparian habitat, and associated uplands. The WMWCP is being prepared to facilitate compliance with applicable laws, regulations, and policies, including the revised U.S. Fish and Wildlife Service (USFWS or Service) policy on Cooperative Agricultural Use (620 U.S. Fish and Wildife Service Manual [FW] 2). To comply with the Service's Appropriate Refuge Uses (603 FW 1) and Compatibility (603 FW 2) policies, appropriate use findings (AUFs) and compatibility determinations (CDs) for kalo (taro, *Colocasia esculenta*) farming, livestock grazing, and research and scientific collections were prepared and included as appendices to this plan. In accordance with the National Environmental Policy Act (NEPA), an environmental assessment (EA) was concurrently prepared to disclose the effects of alternatives associated with this plan. The plan, AUFs, and CDs may be modified between the draft and final depending upon comments received.

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

Hanalei National Wildlife Refuge (NWR or Refuge) is managed by the U.S. Fish and Wildlife Service (USFWS or Service) as part of the National Wildlife Refuge System (NWRS or Refuge System). The Refuge, located in northern Kaua‘i in Hanalei Valley (Figure 1-1), contains one of the first protected wetlands in the State of Hawai‘i. The Refuge was established in 1972 under the authority of the Endangered Species Conservation Act of 1969 (16 United States Code [U.S.C.] 668aa; Statute 275) to aid in the recovery of threatened and endangered species through the preservation and management of habitat. The approved refuge acquisition boundary (defined as the area within which the Service may acquire lands from willing sellers) totals 934 acres. Currently, 917 acres are owned in fee title and managed by the Service.

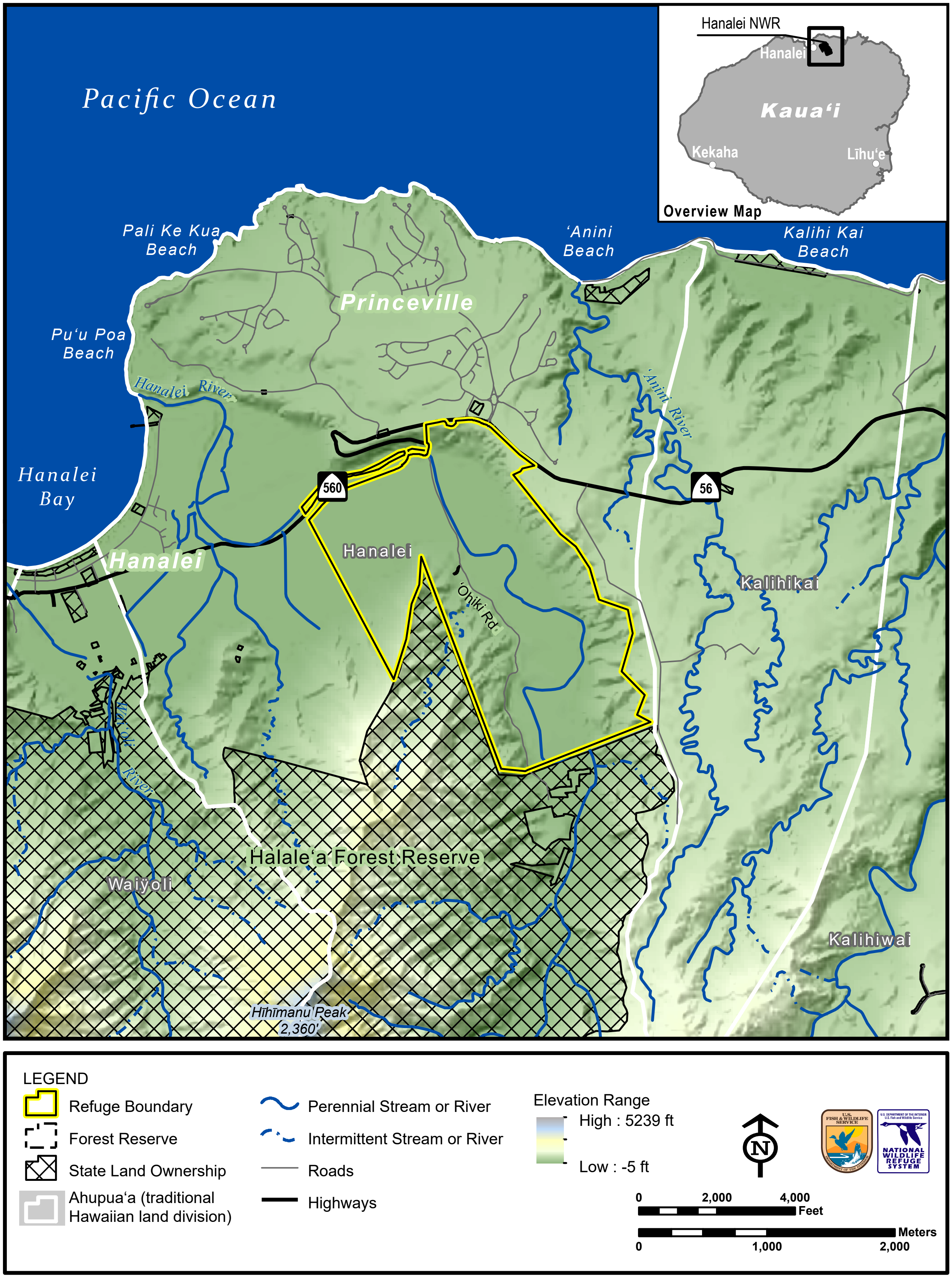
The Refuge is in a relatively flat river valley ranging in elevation from 20 to 40 feet above sea level and includes some steep wooded hillsides reaching up to 1,600 feet. A portion of the Hanalei River, which is a designated American Heritage River, runs through the Refuge.

Following the Refuge's establishment purpose, management focuses on the conservation of federally listed species, with a particular emphasis on the endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*). In total, the Refuge supports four endangered birds including the koloa maoli, ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*), ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*), and ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); and the threatened nēnē (Hawaiian goose, *Branta sandvicensis*)[1]. Hanalei NWR is one of two Refuges in the state where habitat managed to support all of the life history needs for these five federally listed Hawaiian waterbirds is available year-round. In addition, the Refuge is one of the only places where the threat of hybridization of koloa maoli with feral mallards (*Anas platyrhynchos*) can be managed and nonhybridized, pure koloa maoli can thrive. The Refuge also provides habitat for the endangered ‘ōpe‘ape‘a (Hawaiian hoary bat, *Lasiurus cinereus semotus*) and other native species, including migratory waterfowl and shorebirds.

Lowland areas of the Refuge are managed in a mosaic of wetland habitats, including rotational managed wetland (moist-soil) units (also referred to in this document as wetland management units) and kalo (taro, *Colocasia esculenta*) farms. The resulting agroecological system provides a variety of societal benefits (ecological, cultural, aesthetic, and historical). In addition to providing essential habitat for plants and animals and providing an ideal place to farm traditional wet agriculture crops such as kalo, wetlands serve as ‘landscape filters’ that improve water quality of connected rivers and offshore waters. The plant communities and soil within wetlands also serve as carbon sinks, helping to moderate global climate change. Wetlands help to dissipate the energy of surface water flow during periods of heavy rainfall by temporarily retaining water, slowing downstream flows, and attenuating downstream flooding. Wetlands are also important water retention areas, which can restore groundwater and its flow.

[1] Throughout the document, the term "threatened and endangered waterbirds" will be used to refer collectively to these five species.

Figure 1-1. Local area, Hanalei NWR



Map Date: 7/1/2019 File: 11-067-1.mxd
Data: USFWS 2019, Hawaii Office of Planning 2009

USFWS R1 Refuge Inventory and Monitoring Branch

Kalo farming on the Refuge is a cooperative venture, with substantial involvement from both the Service and individual farmers. This type of flooded agriculture is conducted by farmers in support of a biological objective for managing shallow-water habitat to satisfy life history requirements of threatened and endangered waterbirds.

Hanalei NWR currently permits kalo farming as a Refuge management economic activity through Special Use Permits (SUPs) on approximately 160 acres (not including houses and storage areas). Kalo farming existed prior to and at the time of the establishment of the Refuge and is culturally and economically important both to the State of Hawaiʻi and local communities. Kalo itself is a staple food and highly valued plant in the Hawaiian culture. Current farming on Hanalei NWR represents a substantial portion of kalo acreage and production statewide, estimated at 40–60 percent (Gutscher-Chutz 2011; NASS 2012; Cho, Yamakawa, and Hollyer 2007).

1.2 Scope and Rationale

The Wetlands Management and Waterbird Conservation Plan (WMWCP) describes the processes and procedures needed to achieve the Refuge's management objectives for approximately 480 acres of rotational managed wetland units, loʻi kalo (wetland taro fields), ditches and dikes, fallow, riparian habitat, and associated uplands. The definition of a waterbird for the purpose of this plan follows from Sawyer (1926): "A water bird is any species of bird primarily and anatomically adapted to live continuously where aquatic conditions predominate." The WMWCP is being prepared to facilitate compliance with applicable laws, regulations, and policies, including the revised Service policy on Cooperative Agricultural Use (620 U.S. Fish and Wildlife Service Manual [FW] 2). To comply with the Service's Appropriate Refuge Uses (603 FW 1) and Compatibility (603 FW 2) policies, appropriate use findings (AUFs) and compatibility determinations (CDs) for kalo farming, livestock grazing, and research and scientific collections were prepared and included as appendices to this plan. In accordance with the National Environmental Policy Act (NEPA), an environmental assessment (EA) was concurrently prepared to disclose the effects of alternatives associated with this plan. We are requesting public comments on this draft plan, draft AUFs, draft CDs, and EA. The WMWCP, AUFs, and CDs may be modified between the draft and final depending upon comments received.

The goals, objectives, and strategies described in this plan will be re-examined as part of the Comprehensive Conservation Plan (CCP), a 15-year plan that provides management direction for all Refuge programs and managed lands, which is currently being developed. Information from this WMWCP will be revised as appropriate and incorporated into the CCP.

1.3 Legal Mandates

1.3.1 Refuge Purpose

The purpose(s) for which a refuge was established or acquired is of key importance in refuge planning. Purposes must form the foundation for management decisions. The purpose(s) of 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. Unless the establishing law, order, or other document indicates otherwise, purposes dealing with the conservation, management, and restoration of fish, wildlife, and plants, and the habitats on which they depend take precedence over other purposes in the management and administration of any unit. When a conflict exists between the Refuge System mission and the specific purpose(s) of an individual refuge, the refuge purpose(s) supersede the mission (601 FW 1).

Hanalei NWR was established in 1972 through the acquisition of lands from Eagle County Development Corporation (ECDC). The purpose of Hanalei NWR 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; Endangered Species Act of 1973). The establishment authority for this Refuge originated from the Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa; Stat. 275).

1.3.2 National Wildlife Refuge System

For consistency across the Refuge System, there are a number of laws, policies, and directives that guide our management. Key concepts and guidance of the Refuge System are derived from the National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), as amended, including by the National Wildlife Refuge System Improvement Act of 1997 (Refuge Improvement Act); Title 50 of the Code of Federal Regulations (CFR); and the FW. The Refuge Administration Act is implemented through regulations covering the Refuge System, published in Title 50, Subchapter C of the CFR. These regulations govern general administration of units of the Refuge System.

In addition, the Service has developed or revised numerous policies and Director's orders to reflect the mandates and intent of the Improvement Act. Some of these key policies include Biological Integrity, Diversity, and Environmental Health (BIDEH; 601 FW 3); Compatibility (603 FW 2); Refuge System Mission, Goals, and Purposes (601 FW 1); Appropriate Refuge Uses (603 FW 1); Cooperative Agricultural Use (620 FW 2); Inventory and Monitoring (701 FW 2); and the Director's Order for Coordination and Cooperative Work with State/Territorial Fish and Wildlife Agency Representatives on Management of the Refuge System. These policies and others in draft form or under development can be found at http://refuges.fws.gov/policymakers/nwrpolicies.html.

Cooperative Agricultural Use

In August 2017, the Service finalized the revised Cooperative Agricultural Use policy, which outlines objectives for the use of cooperative agriculture on Refuge System lands and provides an open, transparent, and competitive process for awarding cooperative agriculture agreements (CAAs) on refuges in compliance with the Department of the Interior (DOI) policy on procurement contracts, grant and cooperative agreements (505 Department Manual [DM] 2). Additional federal laws providing authorities for this policy include the Federal Grant and Cooperative Agreement Act (31 U.S.C. 6301–6308), Fish and Wildlife Coordination Act (16 U.S.C. 661–667e), Migratory Bird Conservation Act (16 U.S.C. 715), Refuge Administration Act (16 U.S.C. 668dd), Refuge Revenue Sharing Act (16 U.S.C. 715s), and Refuge System regulations on economic uses and cooperative land management (50 CFR 29.1–29.2). Per policy, cooperative agriculture is when a person or entity uses agricultural practices on Refuge System lands in support of objectives for target species or their associated habitats that represent the biological outcomes the Service desires, and there is substantial involvement between the Service and the person or entity. Our policy is to use cooperative agriculture as a habitat management tool only in situations where we cannot meet our resource management objectives through maintenance, management or mimicking of natural ecosystem processes or functions.

All agricultural uses on Hanalei NWR which are appropriate and compatible; in compliance with legal requirements for federal actions (e.g., NEPA; National Historic Preservation Act of 1966 [NHPA] Section 106; ESA Section 7); specified in a current management plan for the refuge; and cooperative must be entered into a CAA through an open and competitive process. CAAs may last up to a maximum of five years. This WMWCP, along with associated compliance documents (e.g., EA and CDs) will fulfill the prerequisites for initiating an open and competitive process for selecting and awarding CAAs.

The updated process for awarding CAAs will include the following:

- The Service will provide the public with a notice of cooperative agricultural opportunities. This will include publication of a Notice of Funding Opportunity on Grants.gov, notification on a national Service website (https://www.fws.gov/refuges/whm/cooperativeAgriculture.html) and local outreach. The notice will include details on the cooperative agricultural opportunity such as the objective criteria that will be used to rank and score applications.
- Applicants will apply directly to the Kaua'i NWR Complex using the application guidance provided in the CAA prospectus.
- The Kaua'i NWR Complex Project Leader, along with a selection panel, will score and rank all applicants and notify each applicant regarding whether they were awarded the CAA and the reasoning for the panel's decision. Unsuccessful applicants have the right to appeal the decision in accordance with 50 CFR 25.45.
- Once the CAA has been awarded, the cooperator and the Service will work together to finalize the terms and conditions of the CAA, including a plan of operations.

1.3.3 Other Laws and Mandates

Many other federal laws, Executive Orders, Service policies, and international treaties govern the Service and Refuge System. Examples include the Migratory Bird Treaty Act of 1918 (MBTA), Refuge Recreation Act of 1962, NHPA, and the ESA. For additional information on laws and other mandates, a list and brief description of federal laws of interest to the Service can be found in the Laws Digest at http://www.fws.gov/laws/Lawsdigest.html.

1.4 Relationship to Other Plans

When developing this WMWCP, the Service considered the goals and objectives of existing national, regional, state, and ecosystem plans and/or assessments. The Service intends to be consistent with existing plans, as much as possible, and assist in meeting their conservation goals and objectives. If there are conflicts between these various sources and Refuge management, conflicts would be resolved in favor of and in priority order of consistency with Refuge purpose, System mission, and other plans. This section summarizes some of the key wildlife- and habitat-related plans reviewed by the planning team while developing this WMWCP.

1.4.1 Refuge Plans

The following Hanalei NWR plans, reports, or environmental assessments were reviewed:

- Archaeological Investigations of Hanalei NWR (Shapiro and Shapiro 1995);

- Environmental Assessment and Finding of No Significant Impact for the Wetland Enhancement of Units A, B, and C at Hanalei NWR (USFWS 2004c);
- Hawaiian Wetland Refuge Wildlife and Habitat Management Review (Paveglio et al. 1999)
- Wildland Fire Management Plan (USFWS 2004b);
- Internal Draft Annual Habitat Management Plan (HMP, USFWS 2007);
- Complex-wide Invasive Species Management Plan (USFWS 2008);
- Draft Quarterly Unit Assessment Protocol (USFWS 2010a); and
- Draft Waterbird Monitoring Plan (USFWS 2010b).

1.4.2 Other Plans and Assessments

The following plans were reviewed and determined to be consistent with the Refuge purpose; System mission; and management goals, objectives, and strategies described in this plan:

Recovery Plan for Hawaiian Waterbirds, Second Revision (USFWS 2011e). The goal of the recovery program is to restore and maintain multiple self-sustaining populations of Hawaiian waterbirds (i.e., koloa maoli, ʻalae keʻokeʻo, ʻalae ʻula, and aeʻo) statewide within their historic ranges. The recovery of these waterbirds focuses on the following objectives:

- Increasing population numbers to statewide baseline levels (consistently stable or increasing with a minimum of 2,000 birds for each species);
- Establishing multiple, self-sustaining breeding populations throughout each species' historic range;
- Establishing and protecting a network of both core and supporting wetlands that are managed as habitat suitable for waterbirds, including the maintenance of appropriate hydrological conditions and control of invasive nonnative plants;
- For all four species, eliminating or controlling the threats posed by introduced predators, avian diseases, and contaminants; and
- For the koloa maoli, removing the threat of hybridization with feral mallards.

Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose (**Branta sandvicensis*****) (USFWS 2004a).*** Of the five or so endemic goose species described from the Hawaiian Islands, only the nēnē has survived to the present day. The nēnē was declared a federally endangered species in 1967. It was considered one of the most endangered geese in the world and was the second most endangered waterfowl in the United States (U.S.). The implementation of recovery actions for nēnē has reduced the risk of extinction for the species, leading to the species being reclassified from endangered to threatened, effective January 21, 2020.

The Service's recovery plan aims to restore and maintain multiple self-sustaining nēnē populations on Hawaiʻi, Maui Nui (Maui, Molokaʻi, Lānaʻi, Kahoʻolawe), and Kauaʻi. Additionally, threats to the nēnē 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 the islands resulting in the species no longer meeting the definition of endangered or threatened under the ESA. The recovery of the nēnē focuses on the following objectives:

- Identify and protect nēnē habitat, focusing on the identification and protection of sufficient habitat to sustain target population levels;

- Manage habitat and existing populations for sustainable productivity and survival complemented by monitoring changes in distribution and abundance;
- Control alien predators, which addresses control of introduced mammals to enhance nēnē populations;
- Continue captive propagation program, which describes techniques and priorities for the captive propagation and release of nēnē into the wild;
- Establish additional nēnē populations, which focuses on partnerships with private landowners;
- Address conflicts between nēnē and human activities, which includes potential management and relocation of nēnē in unsuitable areas;
- 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;
- Provide a public education and information program, which describes important outreach and education activities; and
- Validate recovery actions, which call for formalizing the Nēnē Recovery Action Group and evaluating management and research projects to determine if recovery objectives have been met.

Hawai'i's State Wildlife Action Plan (DLNR 2015). The U.S. Congress mandated each state and territory to develop a comprehensive wildlife conservation plan in order to continue to receive State Wildlife Grants, which assist states with wildlife management. Hawai'i's state wildlife action plan (SWAP) reviews the status 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 provides management recommendations for their continued conservation. Hawai'i's Species of Greatest Conservation Need include all native terrestrial animals, 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. This list includes a terrestrial mammal (1), birds (78), terrestrial invertebrates (approximately 5,000), freshwater fishes (5), freshwater invertebrates (12), anchialine pond-associated fauna (20), marine mammals (26), marine reptiles (6), marine fishes (151), marine invertebrates (197), and flora (over 756).

Pacific Coast Joint Venture Strategic Plan for Wetland Conservation in Hawai'i (Henry 2005). The mission of the Hawai'i Wetland Joint Venture, a subset of the Pacific Coast Joint Venture, is to protect, restore, increase, and enhance all types of wetlands, riparian habitat, and associated uplands throughout the Hawaiian Islands through partnerships for the benefit of birds, other wildlife, people, and the Hawaiian culture. This strategic plan is intended to guide partners in collaborative efforts that protect the best and most important wetlands first, with an eye toward long-term habitat sustainability and site adaptability in the face of climate change.

Koloa Maoli Communication and Outreach Plan (Sato 2009). This plan provides a framework for localized (Kaua'i/Ni'ihau) and statewide educational campaigns to build public support for removing the threat of feral mallards and mallard-koloa maoli hybrids, strengthening public policies, and restoring/managing primary habitats to benefit a suite of native Hawaiian and migratory waterbirds.

Recovery Plan for the Kaua'i Plant Cluster (USFWS 1995). The Service's recovery plan covers 37 plant taxa, 34 of which are federally listed as endangered and three listed as threatened. The recovery actions identified in the plan include protecting current populations, controlling threats, and monitoring; expanding current populations; conducting research essential to conservation of the species; establishing new populations as needed to reach recovery objectives; validating and revising recovery objectives; and devising and implementing a public education program.

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. There is a general lack of historic and current data on this subspecies and its present status is not well understood. The Service’s recovery objective is delisting from the ESA, with the interim goals of determining present population status and downlisting to threatened status. Distribution and abundance of ‘ōpe‘ape‘a 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.

U.S. Pacific Islands Regional Shorebird Conservation Plan (Engilis and Naughton 2004). Conservation and restoration of shorebird habitats is essential for the protection of endangered and declining shorebird populations. Wetlands, beach strand, coastal forests, and mangrove habitats are particularly vulnerable on Pacific islands due to increasing development pressures and already limited acreage. Monitoring and research needs include assessment of population sizes and trends; assessment of the timing and abundance of birds at key wintering and migration stopover sites; assessment of habitat use and requirements at wintering and migration areas; exploration of the geographic linkages between wintering, stopover, and breeding areas; and evaluation of habitat restoration and management techniques to meet the needs of resident and migratory species. Education and public outreach are critical components of this plan. Resource management agencies of federal, territorial, commonwealth, and state governments will need to work together with military agencies, nongovernmental organizations, and the scientific community. On a larger scale, coordination at the international level will be key to the conservation of vulnerable species, both migratory and resident.

CHAPTER 2. MANAGEMENT CONTEXT

2.1 LOCATION

The 917-acre Hanalei NWR in Kaua‘i County is situated near Hanalei Town and is located within the Hanalei ahupua‘a (watershed), in the Halele‘a moku ‘aina (district), extending 1.5 miles south of the Hanalei River and 0.5 miles west of the Hanalei Bridge. Approximately 90 percent of the forested watershed is undeveloped, including the state-managed Halelea Natural Area Reserve. The Refuge occupies 1.5 square miles of the watershed in the lower valley (Kubo and Henderson 2005).

Not including reservoirs, irrigation and flood control ditches, golf course water features, streams, ephemeral springs and basins, or sewer treatment ponds, the current extent of coastal plain wetlands in the main Hawaiian Islands is approximately 15,474 acres. Over 31 percent of coastal wetlands have been lost (Kosaka 1990) and the majority that remain are degraded by altered hydrology, invasive species, human encroachment, and contaminants. Of the coastal plain wetlands, roughly 8,690 acres are identified core (5,820 acres) or supporting areas (2,869 acres) important for the recovery of waterbirds (USFWS 2011e). Hanalei NWR is considered a core wetland area and is the largest wetland complex on Kaua‘i.

2.2 PHYSICAL ENVIRONMENT

2.2.1 CLIMATE, AIR TEMPERATURE, AND PRECIPITATION

Climatic conditions on the island of Kaua‘i are dominated by northeasterly tradewinds approximately 70 percent of the year. Tradewinds bring warm, tropical, moisture-laden air to Kaua‘i. As a result of the steep topography, the northern and eastern (windward) sides of Kaua‘i record heavier rainfall than the drier south and west (leeward) sides. Traditionally, only two seasons were recognized in Hawai‘i: kau—the warm season occurring from May to October that is characterized by northeast winds and an overhead sun, and ho‘oilo—the cold season, occurring from October to April and characterized by cooler temperatures, rain, variable winds, and a lower sun (Juvik and Juvik 1998; Siemers 2009).

The nearest climate/weather station to the Hanalei NWR is the National Weather Service CO-OP Princeville Ranch station (#518165) located within a mile northeast of the Refuge. The period of record dates from 1939 to the present. Monthly climate normals have been compiled for the period from 1981–2010 (Table 2-1). High and low average temperatures do not exhibit much variability over the course of the year, with about 7 degrees Fahrenheit (°F) separating January minimums from August/September maximums. About 57 percent of the rain typically falls during the six months between November and April, the remaining 43 percent between May and October (WRCC 2017).

TABLE 2-1. MONTHLY NORMALS (1981–2010) FOR PRINCEVILLE RANCH 1117, HI (WRCC 2017)

Month	*Precipitation (inches)*	*Minimum Temperature (°F)*	*Mean Temperature (°F)*	*Maximum Temperature (°F)*
January	6.91	62.0	70.1	78.2
February	6.22	62.2	70.4	78.6
March	7.00	62.7	70.6	78.5
April	6.20	64.3	72.2	80.1
May	5.11	66.1	73.7	81.3
June	4.39	67.9	76.1	84.2
July	5.77	68.1	76.7	85.3
August	5.70	69.0	77.1	85.2
September	5.68	69.0	77.2	85.3
October	6.63	68.1	75.7	83.4
November	10.04	66.6	73.5	80.4
December	8.11	64.0	71.2	78.5
Annual	77.76	65.8	73.7	81.6

A study examining air temperature trends over 88 years (1919–2006) based on measurements from 21 temperature stations within Hawaiʻi showed a long-term increase in temperature and an accelerated rate of increase in the last few decades (0.08°F/decade for the full record versus about 0.3°F/decade since 1975) (Giambelluca, Diaz, and Luke 2008). In general, warming trends are lower for summer (May–October) and higher for winter (November–April), compared with the annual trends.

Median annual precipitation measured at the Princeville Ranch station is nearly 80 inches, and rarely below 60 inches (Table 2-2). Direct precipitation on 229 acres of wetlands and loʻi kalo gives an input of 1,500 acre-feet of water annually (Pilson 2017).

TABLE 2-2. ANNUAL* PRECIPITATION IN INCHES (1939–2015) FOR PRINCEVILLE RANCH CO-OP (#518165) SUMMARY STATISTICS

10^{th} Percentile	*25^{th} Percentile*	*Median*	*75^{th} Percentile*	*90^{th} Percentile*	*Standard Deviation*
59.6	70.5	79.7	92.0	101.4	16.7
* Based on Water Year: October 1 to September 30					

Over the last century, both rainfall and baseflow in streams across Hawaiʻi have decreased and Hawaiʻi has experienced more prolonged dry spells in the recent past (1980–2011) as compared to 1950–1970 (Chu and Chen 2005; Chu, Chen, and Schroeder 2010). Lack of rain could lower the amount of freshwater lens recharge and decrease available water supplies.

2.2.2 HYDROLOGY

Watershed Context

The Hanalei River subwatershed (hydrologic unit code [HUC] 200700000103) is 33.1 square miles and encompasses the Hanalei River as well as four additional streams that drain into Hanalei Bay. The Hanalei River drainage is the largest component of the subwatershed and covers 23.6 square miles. Heavy precipitation (over 400 inches annually) dominates the upper reaches of the subwatershed on Mount Waiʻaleʻale; lower-lying coastal areas receive about 100 inches of rain per year. The river begins in the Halelea Forest Reserve and travels 15.7 miles to Hanalei Bay through a mixture of forest and shrub-scrub landscape. A portion of the flow from the Hanalei River is diverted into rotational managed wetland (moist-soil) units and loʻi kalo on the Refuge. The Hanalei Estuary begins about 3.5 miles upstream of the river's entrance into the bay. Urban development associated with the town of Hanalei dominates this reach of the river.

Rivers, Streams, and Creeks

The perennial Hanalei River is the only major stream in the vicinity of Hanalei NWR; it travels approximately 3.1 miles through the Refuge (Figure 2-1). In 1998, the river was designated as an American Heritage River by Executive Order (EO) 13061. This designation fosters cooperative, community-based efforts for its preservation.

This river has the greatest average discharge of any river or stream on Kauaʻi (HDBEDT 2009). This could be the reason why water diversion of the river for sugarcane plantations began in the early 1900s. In 1925, the Kaʻāpoko Tunnel was constructed to bring water from the Hanalei River to Wailua. A year later, the Hanalei Tunnel was built to bring water to Līhuʻe. Around 1991, water diversions from the upper Hanalei River basin to the Wailua side of the island for sugar irrigation ended. Today, the only major water diversion from the Hanalei River is the Service's intake for wetland management units and kalo farms managed for threatened and endangered waterbirds, much of which is re-directed back out to the River after passing through the Refuge.

From the U.S. Geological Survey (USGS) Hanalei River gauging station (#16110300) located upstream of the Refuge, median daily flow calculated for water years 1993–2015 ranged between 90–250 cubic feet per second (cfs); however, peak daily flows >1,000 cfs occurred during all months except June. There is a trend toward slightly higher (~50–75 cfs) streamflow in winter compared to summer months. Interannual variation in flow is generally within a range of 100 cfs. As expected from its setting within a very wet watershed, the Hanalei River is characterized by good flow volumes throughout the year and from year to year. Monthly and yearly average discharge generally exceeds 150 cfs (mean for both: 212 cfs), and on 60 percent of days, mean flow is above 100 cfs (USGS 2017; summarized by Pilson 2017).

In contrast to daily, monthly, or annual statistics, instantaneous peak flows provide a sense of the magnitude of flows a river is capable of generating. The USGS has calculated that the Hanalei River has a peak flood discharge of 14,500 cfs about every two years and a peak flood discharge of 28,100 cfs every 10 years (Oki, Rosa, and Yeung 2010). The flow of this river is extremely flashy in nature because of high rainfall, short travel distances, steep slopes, and high topography inland from the Refuge toward the headwaters of the river. Flow magnitudes can change ten-fold over a few hours (Berg, McGurk, and Calhoun 1997).

Given the amount of water that falls on high terrain and runoff associated with steep slopes, the Hanalei River is capable of producing substantial floods in the valley during prolonged rains. The river begins to back up at several meanders that have developed heavy vegetation (e.g., hau bush [*Hibiscus tiliaceus*]), which impedes flow, and portions of the Refuge become flooded.

Floods are part of the natural cycle and can distribute large amounts of water and suspended river sediment over vast areas. This sediment helps replenish valuable topsoil components to lands and can keep the elevation of a land mass above sea level. Floods can also recharge ground water, make soil more fertile, and provide nutrients in which it is deficient. Additionally, wetlands provide the ability to capture, hold, and attenuate flood waters, nutrients, and the erosive properties of moving water. Freshwater floods in particular play an important role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biodiversity.

The lower Hanalei River typically overflows onto its floodplain several times a year, whereas most streams flood, on average, once every 2–3 years. Flood events can last from two hours to two days in duration (Matt Rosener 2011, pers. comm.). The Federal Emergency Management Agency (FEMA) National Flood Insurance Program prepared Flood Insurance Rate Maps that depict flood hazard areas throughout the state. Almost the entire Hanalei coastal plain is included within the 100-year flood inundation boundaries (Figure 2-2). Most of the area within the Refuge adjacent to the river channel is also designated as floodway where no development is allowed that may affect flood elevations. A Flood Insurance Study for the lower 4.4-mile reach of the river was conducted by FEMA which described the periodic flooding of Kūhiō Highway and damage to beachfront houses and agricultural properties due to riverine and tsunami-induced flooding. The study identified several features of the Hanalei River floodplain that aggravate riverine flooding, such as the sandbar at the river's mouth and thick tree growth encroaching on the riverbank. During high flood discharges, the dune on which most of the residences of Hanalei are built causes greater flood stages as a result of construction on the floodplain at the mouth of the river (Moffatt and Nichol 2007).

The highest instantaneous peak flow in the full record was 44,600 cfs on November 3, 1995. However, even larger floods occurred in 2009 and 2018, the latter cited as the largest documented flood. During the 2018 flood, the gauges stopped recording at around 32,700 cfs when they broke due to the intensity of the flood. The storm in 2018 showed recorded rainfall of 49.69 inches in just 24 hours between April 14 and 15 at the nearby Waipa location.

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Before (left) and after (right) photos of Hanalei NWR during 2009 heavy rains and flooding.

Figure 2-1. Water flow and infrastructure, Hanalei NWR

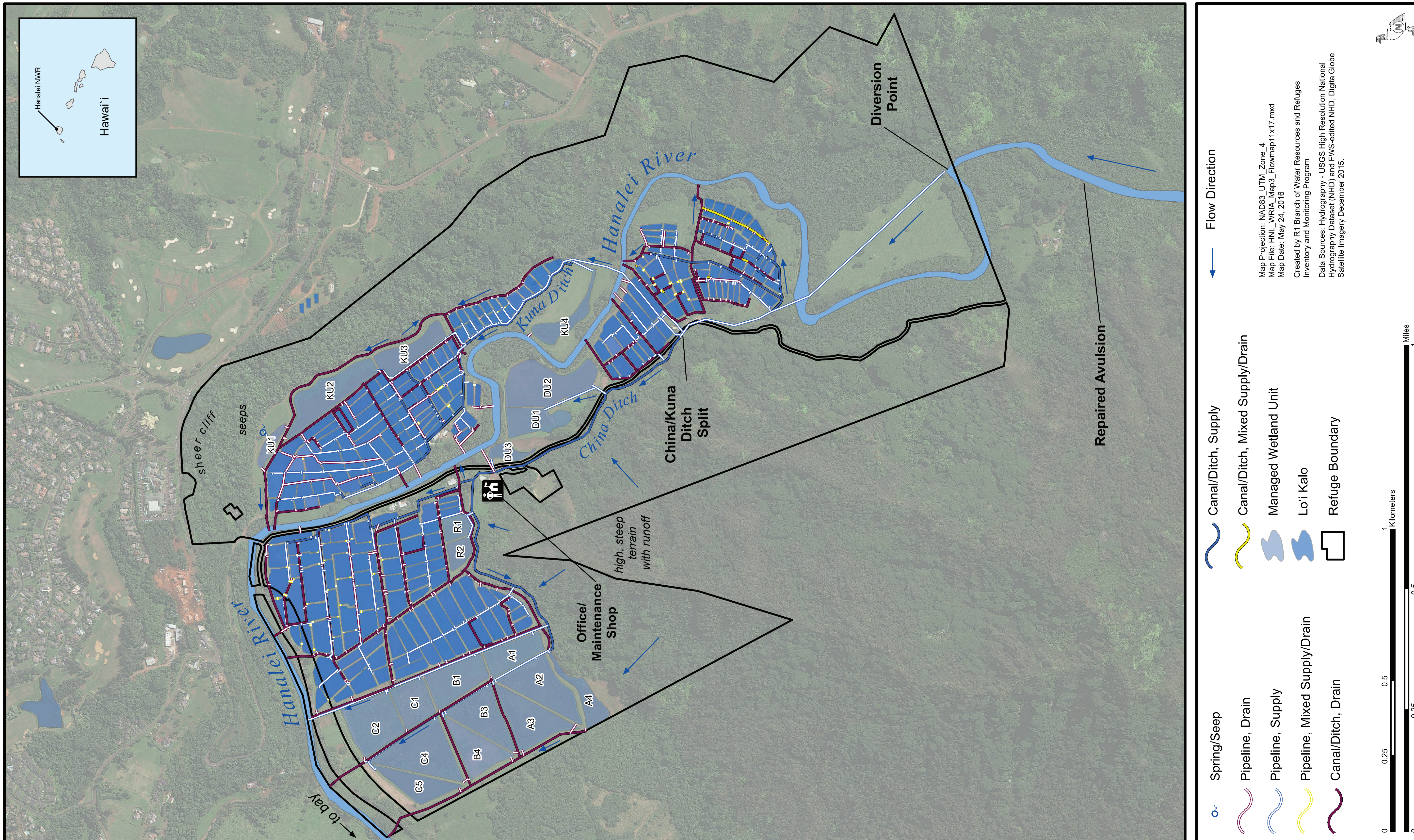

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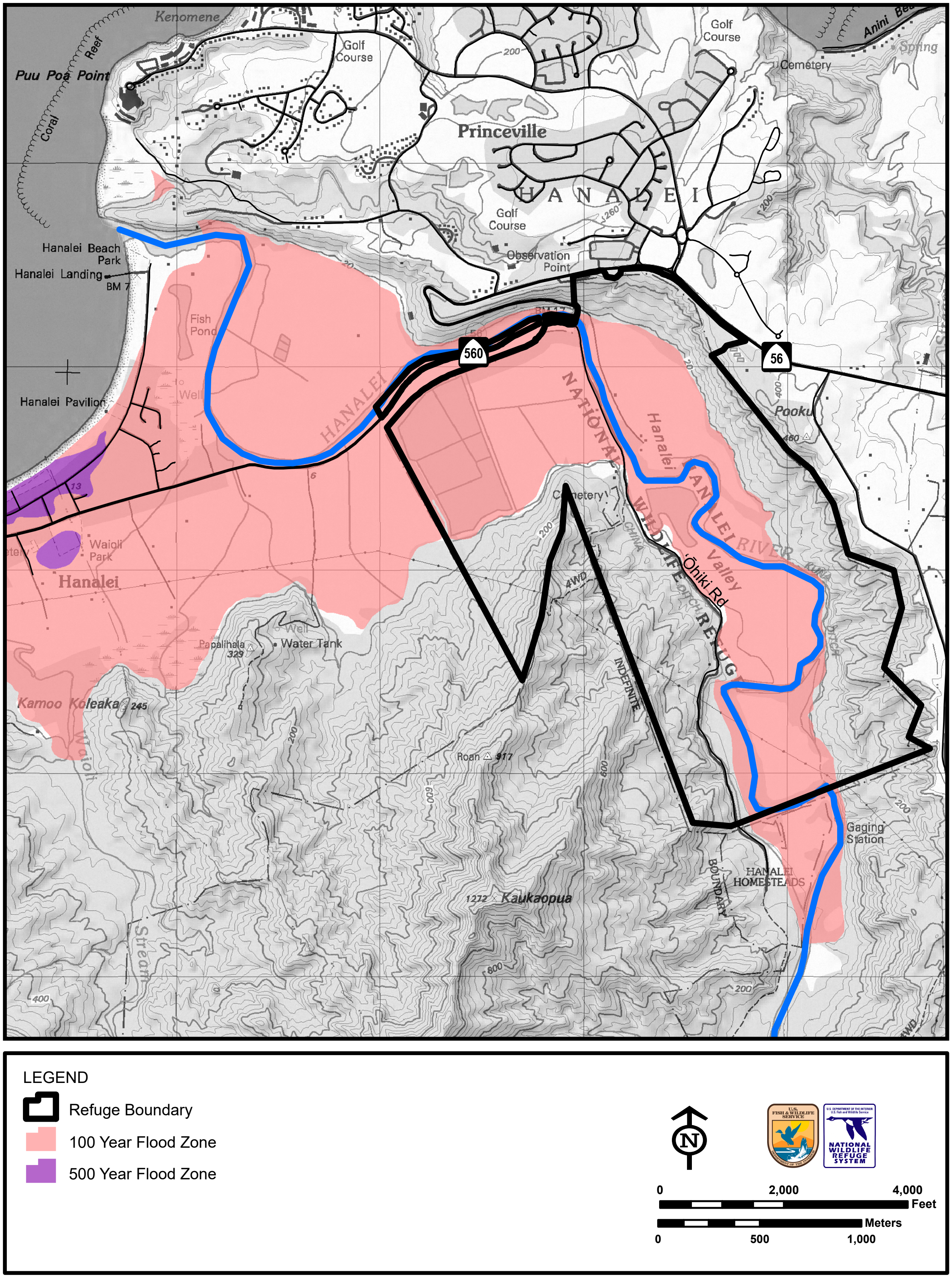
Figure 2-2. FEMA flood zones, Hanalei NWR



Map Date: 7/1/2019 File: 11-070-1.mxd
Data Source: FEMA, USFWS 2019
USFWS R1 Refuge Inventory and Monitoring Branch

The U.S. Army Corps of Engineers (USACE) analyzed the flooding issues in the valley in *Flood Plain Re-analysis of Hanalei River, Island of Kaua'i* (USACE 1999). This analysis was conducted to determine impacts that a private, elevated roadway/berm and Service rotational managed wetland units (impoundments or ponds) A–D have had on the Hanalei River 100-year floodplain. This project was initiated, in part, because of the November 3, 1995 flood.

The analysis concluded that collectively the Service ponds and the roadway/berm constructed by a separate private landowner had increased the 100-year flood height to a maximum of 2.12 feet at Section 102+36 (the upstream side of the Service's ABC ponds). However, the study does not take into account the ponds acting as part of the floodplain (rather than as an encroachment); does not look at the whole floodplain to take into account the lo'i kalo, other ponds, and access roads; and the modeling results are for a flow (58,000 cfs) that is much higher than the highest measured flow in the record (which occurred on November 3, 1995, at that time). This record measured 44,600 cfs, but all other peak flows from 1962 to 2009 have been 26,600 cfs or less, about half of what was modeled.

Canals, Drainage Ditches, and Pipelines

As a result of agricultural infrastructure, the Refuge has a multitude of ditches and pipes to facilitate water delivery and drainage (Figure 2-1). The diversions from the Hanalei River supply all the water to flood lo'i kalo and rotational managed wetland units on the Refuge. Water from the River flows into a 48-inch concrete pipeline that empties into China Ditch northwest of a bend in the river. A natural clay bank with many river rocks across it keeps the opening to the pipeline submerged and a gate valve at the diversion intake controls the flow into the pipeline. Once water enters China Ditch it is diverted to lo'i kalo, rotational managed wetland units, or spills back to the Hanalei River. Flow from China Ditch is controlled primarily by gate valves and also has some stop-log structures or open polyvinyl chloride (PVC) pipes. The primary diversion from China Ditch is to the east side of the Hanalei River into Kuna Ditch.

The existing diversion structure is a manhole structure just within the boundary of the Refuge. Refuge water, with a design flow of 50 cfs, enters a 48-inch pipe that runs northwesterly until it intersects the river again. The water is then conveyed under the river by a 48-inch diameter inverted siphon, which discharges the water into a 48-inch pipeline that feeds multiple lateral Refuge pipelines.

The Hanalei River has historically been a reliable water source for the Hanalei NWR and its kalo farmers; however, in 1995 a breach formed upstream of the Refuge's water intake structure outside of the Refuge boundary, on State of Hawai'i land. Large-scale storm events caused varying volumes of water to bypass the Refuge's intake structure by transporting large amounts of river rock downstream. A large flood eroded this new bypass channel that conveyed about one-half of the total river flow to a point below the existing diversion area. High flow storm events in the Hanalei River led to repeated widening of the river bank breach, allowing more and more of the Hanalei River to flow away from its original channel, predominantly toward the breach channel.

During the 2011 Hawai'i State Legislative session, $1,000,000 was appropriated under the Budget Act (Act 164, Session Laws of Hawaii [SLH] 2011, Item No. D-3) to plan, design, and construct upgrades, repairs, and reinforcements to the Hanalei River breach. The funding was appropriated to the Hawaii Department of Land and Natural Resources (DLNR) for building a dam to maintain adequate flows to the Refuge. All improvements were made on DLNR land in 2015. In November 2017, two large flood events caused further damage to the breach channel repair site as well as the infrastructure and bank surrounding the main irrigation intake for the Refuge. During the April 2018 record rainfall event, the Hanalei River jumped its banks through both a previously repaired breach and a new breach immediately downstream. The old repair was effectively eliminated by flood waters. Through both the old and new breach, the river is largely bypassing the Refuge's water supply intake, which supplies all kalo farms on the Refuge as well as providing water for the rotational managed wetlands that are crucial for recovery of the threatened and endangered waterbirds. Emergency corrective action to keep water in the main river channel was led by the Kauaʻi Taro Grower's Association (KTGA) and the State of Hawaiʻi, as this damage occurred off-Refuge. In addition, the intake and head wall on the Refuge were extensively compromised by the flood and will require substantial effort to re-stabilize and design a longer-term solution and location. The Refuge will continue to coordinate with DLNR, other agencies, and kalo farmers to achieve Refuge objectives related to protecting the environmental integrity of the Hanalei River and providing a stable water supply for wetland management and kalo production on Hanalei NWR.

In total, there are 14.2 miles of ditches on the Refuge. There are approximately 15 miles of pipe on the Refuge, with a portion of that owned and maintained by kalo farmers. Much of the pipe infrastructure is rudimentary, consisting of PVC piping and open "box" distribution junctions where flow is controlled by tilting an open elbow pipe until the outlet level is below the head of water in the system. Given the open-air nature of many of the junctions (to facilitate debris removal), the pressure head within certain units can be very low.

Moist-Soil Wetlands and Loʻi Kalo

Management of wetlands on the Refuge is divided into two broad categories: rotational managed wetland units and loʻi kalo. Moist-soil management techniques (e.g., Fredrickson and Taylor 1982) adapted to the tropical climate of Kauaʻi are used within managed wetland units. There are currently 20 managed wetland units on the Refuge, encompassing 86 acres of intensively managed habitat (excluding dikes and ditches) to promote recovery for threatened and endangered waterbirds.

Loʻi kalo make up a large proportion of the lowland acreage on the Refuge, and are managed to produce kalo throughout the year, with wet and dry fallows interspersed throughout. The main kalo cultivar currently grown at the Refuge has a 12–16 month cycle from planting to harvest. Each lo'i is then wet fallowed for at least 30 days and dry fallowed for 0–6 months. Most loʻi are small, averaging about a half-acre, but some are as large as several acres. At any given time, on average approximately 76–79 percent of loʻi are in kalo production, 10–13 percent are in dry fallow, and 11 percent in wet fallow (Gee 2007; DJL Economic Consulting 2019). There is currently a total kalo farming footprint of 160 acres (i.e., including dikes, ditches, and canals).

Groundwater

Kuna Spring emerges from the toe of the valley wall and is collected in a small depression before being distributed to wetland unit KU1. Service hydrologists have estimated its flow rate as being close to the evaporative rates, so it is not practical for diversion to supply other wetlands (Fred Wurster 2009, unpublished field notes). Other springs have been noted by the Refuge staff along the toe slope of the cliff along the eastern edge of the Refuge.

Infrastructure

For its size, the Refuge has a large amount of water control infrastructure due to the large number of constructed wetlands and lo‘i where consistent inflows of fresh water are required to maintain good water quality. Water management structures are divided between supply and drain systems. On the supply system side, there are ditches that supply water to each unit independently of the drain ditch; supply pipelines such as from the intake to the China Ditch and the Kuna Ditch; supply valves; a main supply valve which is a large gate valve and intake box with metal grating to keep large debris out; diversion gate valves to divert water in different directions; individual supply valves at each pond (butterfly valves); and diversion boxes, which are large cement boxes with boards inside to divert water in different directions. Refuge rotational managed wetland units usually have valved supply pipes and a boardstop structure to facilitate staggered drawdown for moist-soil and wetland native plant production. Lo‘i supply pipes were traditionally unvalved but are slowly being converted over to valve systems with better drainage and circulation to help alleviate wildlife diseases such as avian botulism. On the drain system side, there are water control structures (cement “drain” boxes installed at each pond that have grooves to insert “tongue and groove” boards for varying water levels and a hole on the other side to attach a drain pipe); drain pipelines that usually run from the individual water control structures at each pond to the drain ditch; drain ditches that drain each pond and carry water to the Hanalei River (independent from the supply ditch); and sediment control structures, which are cement U-shaped structures placed in the drain ditch with grooves for “tongue and groove” boards designed to slow water down so that sediment falls out. Drainage pipes for lo‘i are either uncovered to drain or rotated to a set drainage elevation. Table 2-3 summarizes Refuge-owned water control infrastructure, excluding dikes.

TABLE 2-3. HANALEI NWR-OWNED WATER CONTROL INFRASTRUCTURE

Wetland Infrastructure Type	*Count*
Valved inflow pipes	21
Boardstop drains	21
Screwgates	4
Fish screens	2

Kalo farmers are responsible for maintaining their own water infrastructure pipes; however, the Refuge staff has assisted with water delivery and infrastructure improvement projects to improve water quality in response to avian botulism outbreaks. Drainage ditch cleaning responsibilities are addressed in Chapter 4 and in Appendix B, Compatibility Determinations.

USFWS

Valves and monitoring devices provide water control needed for waterbird management.

USFWS

Cement drain boxes with wooden slats inserted and grooved boards are used to control water levels.

Monitoring

Hydrologic monitoring at Hanalei has been sporadic over the years. Prior to becoming a refuge, the USGS operated a gauge between 1912 and 1918 on China Ditch, the principal irrigation diversion to what is now Refuge land. In the mid-1980s, the Service's Water Resources Branch (WRB) installed flow meters at culverts on China Ditch and the first lateral diversion off the ditch. These were checked regularly for about one year and then removed. In 1993, WRB staff installed a monitoring site on China Ditch; however, the site was not maintained or monitored long-term.

From 1994 to 1996, the Service contracted with the U.S. Forest Service to quantify water used by lo'i kalo and wetland impoundments (Table 2-4). At the time, there were > 220 acres of lo'i kalo and managed wetlands. Most sampling occurred on the northern end of the Refuge where pressure head in the ditch system is lower. It was estimated lo'i kalo need inflows between 39,249 and 91,100 gallons per acre per day (gad) (0.06 cfs/acre and 0.14 cfs/acre, respectively) and wetland impoundments need 36,469 to 134,000 gad (0.06 cfs/acre and 0.21 cfs/acre, respectively). Average inflows for wetland kalo were 87,483 gad (0.14 cfs/acre) and 46,179 gad (0.07 cfs/acre) for wetland impoundments. Inflow estimates do not necessarily reflect the actual consumptive use of water on the Hanalei Refuge because nearly 65 percent of inflows pass through the lo'i kalo or impoundments and eventually return to the Hanalei River. The study also found that the inflows to the lo'i kalo and managed wetlands vary dramatically between each, as well as within each individual lo'i kalo and managed wetland over time. Consumptive use for the Refuge as a whole was estimated at over 5 million gallons per day (mgd). This rate of water use is about four percent of the long-term average daily river flow, but becomes 25 percent of extremely low flows, and about 10 percent of the lowest month-long flow levels recorded during the study (Berg, McGurk, and Calhoun 1997).

TABLE 2-4. ESTIMATED MEAN, MINIMUM, AND MAXIMUM INFLOWS FOR LOʻI KALO AND MANAGED WETLAND IMPOUNDMENT ACRES

Refuge Units	*Acres*	*Mean (cfs) Inflow*	*Min (cfs) Inflow*	*Max (cfs) Inflow*
All wetland impoundments	74	5.3	4.2	15
All loʻi kalo	184	25	11	26
Total (entire Refuge)	**258**	**30**	**15**	**41**
Impoundment (Kuna side)	0.0	0	0	0
Total Kuna side (all kalo)	**56**	**7.6**	**3.4**	**7.9**
Impoundment (China side)	74	5.3	4.2	15
Loʻi kalo (China side)	128	17	7.8	18
Total China side	**202**	**23**	**12**	**33**

Water use estimates from Berg, McGurk, and Calhoun (1997). All values are in cfs and do not consider whether land is out of production.

Flow measurements taken by the WRB staff in 2003–2004, when there were 184 acres of loʻi kalo and 74 acres of managed wetlands, and 2015–2017, which approximates the current condition, indicate that water flow/usage is higher at the southern or upstream end of the Refuge (service rates: 0.30 cfs/acre at Spencer diversion vs. 0.11 cfs/acre at Koga diversion). Possibly related to the more limited water supply in the northern part of the Refuge, water levels are shallower, fluctuate more, and are more often dry in the northeast loʻi kalo, compared to the southeast loʻi kalo. Overall findings from the December 2003–November 2004 study concluded that average surface water flow in the China Ditch/Kuna Ditch system was 34 cfs and ranged from 23 to 43 cfs; flows in the ditch mirrored flows in the Hanalei River; inflow requirements for existing uses average 30 cfs and range from 15 to 41 cfs (less than the capacity of the 50 cfs water delivery system); and that the water delivery system is capable of supplying water for existing needs. If more wetlands were created, the ditch system or water use practices would have to be modified to improve water availability (USFWS 2005b). Existing water availability is sufficient for Refuge use; however, a water budget would provide additional information.

As referenced in Chapter 4, water delivery infrastructure improvements are ongoing, to increase efficiency, and improve flushing ability and water quality. For example, the average rate of water delivery measured at 0.11 cfs/acre at China Ditch near the Refuge office (serves the northwest loʻi kalo; and ABC and R wetlands) and 0.09 cfs/acre at Kuna Ditch below the flume (serves the northeast loʻi kalo and Kuna wetlands) before ditch cleaning in April 2015 increased to 0.14 cfs/acre and 0.11 cfs/acre, respectively, after ditch cleaning. Additionally, the average rate of water delivery measured at the Koga culvert (serves some of the northeast loʻi kalo) increased from 0.18 cfs/acre to 0.19 cfs/acre due to irrigation system (pipeline) improvements performed in August 2015.

Piezometers installed in three loʻi kalo in the southeast, northeast, and northwest areas in March–April 2015 showed no consistent differences in groundwater levels or hydraulic gradients among these areas.

2.2.3 Topography and Bathymetry

Located on Kaua'i's north shore, Hanalei Valley extends from Mount Wai'ale'ale (elevation 5,148 feet) to the sea. The valley itself is rather long and narrow and the upper areas are steep. The first eight miles of the valley floor ascend to an elevation of 590 feet. In the remaining three miles, the elevation increases steeply up to the summit of Mount Wai'ale'ale. The valley is 2–3 miles wide, with a drainage area of about 23 square miles (Timbol 1977). A majority of Hanalei NWR resides on the floor of the valley. The area of interest for this plan, the northwest section of the Refuge, is an open flat alluvial plain that extends west toward Hanalei Bay from the north end of the valley.

2.2.4 Soils

In Hanalei Valley, erosion and sediment deposition are ongoing. Soils on the Hanalei Refuge fall predominantly in the Hanalei soil series (Foote et al. 1972; NRCS 2017). These silty clays and silty loams underlie most of the wetlands and lo'i and they are characterized by poor drainage and moderate permeability. They have been forming in alluvium deposited by the Hanalei River in this low gradient and meandering section of the river.

Soils cores in the northwest portion of the Hanalei NWR revealed that there is a coarser (i.e., sand) element to soils to the northwest of the ABC unit, which is indicative of former shoreline(s) when the sea level was higher (Chadd Smith 2017, pers. comm.). From here, there is a gradient toward finer textured soils to the southeast. Wetland configuration was modified in 2005–2007 to preserve textural homogeneity (and consequently drainage characteristics and plant species) and simplify management. The geomorphology of the Hanalei River also impacts soil texture with coarser, gravelly textures dominating point bars along the river and finer silts found in floodplain where settling occurs.

Hanalei Valley has a history of agriculture dating back at least one thousand years or more, including rice, kalo, 'awa, wauke, ranching, sugar, and coffee. These uses may have altered the original soils by affecting structure, composition, biota, nutrient supply, and other characteristics.

2.2.5 Fire

Unlike the continental U.S. where fire can play a large role in ecosystem function and species adaptations, fire is a relatively infrequent disturbance regime in Hawaiian ecosystems. The two primary sources of natural fires are lava flows and lightning strikes (Mueller-Dombois and Lamoureux 1967; Mueller-Dombois 1981; Smith and Tunison 1992). Most ecologists agree that natural fire has not played a significant ecological or evolutionary role in most Hawaiian ecosystems. Most native vegetation is not conducive to fire spread, producing low fuel loads and/or litter of relatively low flammability. When fires did occur, they probably did not spread quickly or extensively due to the patchiness inherent in native habitats. While fires certainly occurred, they were not a formative force in the distribution or type of vegetation found in native Hawaiian habitats.

However, early Polynesians used fire to clear much of the native forests of Hawai'i for agricultural purposes. Most of the vegetation at Hanalei NWR is dense tropical foliage which has a very slow rate of fire spread, although pest species, such as California grass (*Urochloa mutica*) and Guinea grass (*Megathyrsus maximus*), have taken over large areas of the Refuge and have increased the potential for fires.

As is the case in most Hawaiian wetlands, the vegetation on and adjacent to the Refuge grows year-round. The combination of high humidity, high precipitation, and a preponderance of moist vegetation on the Refuge make the threat of wildfire slight. The Refuge supports a diverse mixture of vegetation and open water which would help confine a fire. Conversely, a week of constant dry weather, significant amount of dead, accumulated grass stems, and strong winds could increase chances of wildfire onsite.

The only known wildland fire at Hanalei NWR occurred around 1979 in the wooded slopes on the west side of the Hanalei River. There are no records of any fires on the valley floor of Hanalei NWR. An occasional brush pile was burned at Hanalei NWR in the late 1970s during an unseasonably dry period.

The Refuge has a Wildland Fire Management Plan that was completed in 2004 (USFWS 2004b) and is updated regularly. Small-scale prescribed burns might be occasionally necessary as a method of disposal of woody debris. Prescribed burns would also require individual burn prescriptions. A Hawaiʻi State Department of Health (HDOH) burn permit may also be necessary for each prescribed burn to minimize effects on air quality. The prescribed fire season is expected to be from September to February. Conditions for the permit would exclude specified time periods ("no-burn" days) as broadcast by the National Weather Service.

2.2.6 Environmental Contaminants

The Hanalei Valley, both pre- and post-Refuge designation, has been used for agriculture. No records or evidence has been found of large industrial use or habitation. Potential contamination would most likely be related to past or present farming pesticide practices.

A 1999 investigation into the impacts of a molluscicide (copper sulfate) applied to combat the invasive apple snail (*Pomacea canaliculata*) found elevated levels of metals in sediments on the Refuge (Woodward and Hopper 2002); these levels were often in excess of National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRTs) Threshold Effect Levels (Buchman 1999). Heavy metals of concern included copper, manganese, chromium and nickel. However, because of the volcanic origin of the Hawaiian Islands, Hawaiian soils and sediments tend to have higher concentrations of heavy metals than the continental U.S. and the SQuiRT guidance may not be an appropriate assessment tool to evaluate risk to native fauna (see Halbig et al. 1985 and McMurtry, Wiltshire, and Kauahikaua 1995 for soil/sediment concentrations of heavy metals at several sites in the Hawaiian Islands). Copper concentrations were highest at sites immediately downstream of pesticide application, and higher at a reference site where copper sulfate had been applied for many years. The investigation also found low diversity and numbers of benthic (i.e., at or in the bottom of a body of water) and infaunal (i.e., in the sediment or substrate of a body of water) organisms in loʻi kalo, but differences between sites were not quantifiable because densities were too low. Copper sulfate is no longer allowed for use on loʻi kalo on the Refuge.

All sediment samples were also analyzed for a suite of organochlorine contaminants to further document any background contamination within the Refuge. There was no detectable organochlorine contamination in any of the samples. The method detection limits were high and frequently exceeded the SQuiRT threshold effects levels for freshwater sediments. The detection limits did not exceed the upper effects threshold levels except for total polychlorinated biphenyls.

A survey of persistent organic contaminants and elements in the water, sediment, and biota of the Hanalei River in 2001 found the contaminants at only undetectable or very low levels, below U.S. Environmental Protection Agency (EPA) probable adverse effects levels for aquatic organisms (Orazio et al. 2007). This suggests that upriver practices are not contributing contamination to the Refuge.

2.2.7 WATER QUALITY

A state is required to identify waters that do not meet that state's water quality standards under Section 303(d) of the Clean Water Act (CWA). These waters are considered "water quality limited" and placed on the state's 303(d) impaired waters list. Section 303(d) requires the state to develop total maximum daily loads (TMDLs) for impaired waterbodies. The TMDLs are the amount of each pollutant a waterbody can receive and not exceed water quality standards. Water quality standards in the Water Quality Management Plan for the State of Hawai'i (Hawai'i Administrative Rules [HAR] §11-54) include designated uses, numeric and narrative criteria, and antidegradation policies and procedures. State waters are classified as either inland waters or marine waters with specific water quality criteria for streams, estuaries, embayments, open coastal waters and oceanic waters. Hawai'i's water quality standard categories are further refined by inclusion of a wet or dry season criterion, defined either by calendar date (for inland waters) or by levels of freshwater input (for embayments and open coastal waters). Depending upon the waterbody class, parameters evaluated under the State's water quality standards can include a combination of the following: toxic pollutants, nutrients, suspended solids, turbidity, *Enterococci*, pH, dissolved oxygen, temperature, specific conductance, chlorophyll a, salinity, oxidation, biochemical oxygen demand, and pathogens (fecal coliform or *Salmonella* sp.).

Data collected over many years and used in the TMDL process have shown frequent exceedances of water quality standards for bacteria and turbidity and occasional exceedances for nutrients (nitrogen and phosphorus) (e.g., Berg 1995; Berg, McGurk, and Calhoun 1997; Berg 2007) within waterbodies associated with Hanalei NWR. The TMDLs were developed for the Hanalei Bay Watershed in two phases—the first for streams and estuaries (Tetra Tech and HDOH 2008) and the second for the embayment (Tetra Tech and HDOH 2011). The Phase 1 TMDL report identified Hanalei NWR as one of multiple sources in the watershed contributing sediment and nutrients to Hanalei Bay, and recommended cesspool closure, upgrading septic systems, ungulate fencing and management, stream restoration, trail stabilization, road management, and education to reduce fertilizer and sediment inputs to the river. Two biotic integrity indices suggest habitat in the upper Hanalei River is in good condition and the lower portion is moderately impaired (Tetra Tech and HDOH 2008). For the 2018 303(d) reporting cycle, the waterbodies associated with Hanalei NWR, including those downstream in the bay, listed as impaired are shown in Table 2-5.

TABLE 2-5. WATERBODIES ASSOCIATED WITH HANALEI NWR LISTED AS 303(D) IMPAIRED (HDOH 2018)

Waterbody (in order of increasing distance from the Refuge)	*Wet/dry season*	*Pollutants impaired for (on 303(d) list)*	*TMDL priority**
Hanalei River	Dry	*Enterococci*, total phosphorus	TMDLs approved in 2008 for *Enterococci*, turbidity, and total suspended solids; needs TMDL for nutrients (low priority)
Hanalei River	Wet	*Enterococci*	TMDLs approved in 2008 for *Enterococci*, turbidity, and total suspended solids
Hanalei Bay upstream of Dolphin	N/A	Turbidity	TMDLs approved in 2008 for *Enterococci* and turbidity
Hanalei River (End of Weke Road)	N/A	*Enterococci*, total phosphorus, turbidity, ammonium	TMDLs approved in 2008 for *Enterococci* and turbidity; needs TMDL for nutrients (low priority)
Hanalei Bay (Landing)	Wet	*Enterococci*, turbidity	TMDLs approved in 2012 for *Enterococci* and turbidity
Hanalei Bay Mooring Station	Wet	*Enterococci*	
Hanalei Bay (Pavilion)	Wet	Turbidity	
Hanalei Bay (Waioli Beach)	Wet	Turbidity	

*TMDL priority from HDOH (2018).

Though dated, a study was done in 1997 at the Refuge looking at hydrology and land use effects. The conclusion of this study was that kalo farming and impoundment operations affect water quality of the Hanalei River (Berg, McGurk, and Calhoun 1997). The most visually obvious effect is the sediment plume generated from kalo farming, but the amount of sediment produced may be trivial in comparison to the sediment generated naturally during flood events. The potentially large amounts of sediment generated during flood events can be attributed to the extremely high precipitation, steep topography, and short travel distances for the water flow within the Hanalei basin. Sediment generated from kalo farming, however, is a more consistent input to the river throughout the year compared to that from episodic flood events. Additionally, since sediment from kalo farming is the product of a Refuge use, this input can be managed with implementation of best management practices (BMPs).

The 1997 report also highlighted other water quality effects such as increasing specific conductivity and nutrient loads in the reaches of the river receiving return water from the lo‘i kalo and impoundments and a doubling of suspended sediment load (from two to four pounds/acre/day) between sampling locations above land management operations and at the lower boundary of the Refuge. The report noted that close proximity of many of the lo‘i kalo to the river may preclude options to reduce lo‘i kalo-induced sediment as those sediments that settle before reaching the river or are trapped in sediment basins may be re-mobilized during flood flows. Detectable levels of herbicide were not found in any samples, even those collected soon after herbicide application. Water leaving the individual lo‘i kalo and impoundments was 3–5ºF warmer than inflow waters, but the researchers believed dilution of these warmed waters by the much greater volume of cool water in the river negated significant warming of the river’s water (Berg, McGurk, and Calhoun 1997).

In addition, bank erosion can produce sediment that can be suspended. Suspended sediment monitoring has been conducted at Hanalei River. The Hanalei Basin data averaged a 3-year suspended sediment yield of 1,360 tons/year/square mile (Stock and Tribble 2010). The processes that provide fine sediments to Hanalei Bay are not fully understood. However, possibilities include (1) storm-triggered landslides and debris flow; (2) overland flow from areas impacted by feral pigs; (3) erosion of fine deposits from stream banks; (4) decreased trapping of fine sediment in floodplain; and (5) entrainment of floodplain deposits (Stock and Tribble 2010). Increasing nutrient loads were recorded in the reaches of the Hanalei River receiving return water from lo‘i kalo and waterbird impoundments within the Refuge (Berg 1995). Fertilizers are not added to rotational managed wetland units.

It is important to distinguish between natural and anthropogenic, pathogenic and non-pathogenic, and manageable and non-manageable sources of pollutants and their pathways within the watershed. Boehm (2010; cited in Sustainable Resources Group International Inc. 2012) collected and analyzed water quality data to determine the sources and fluxes of bacteria and nutrients in several surface waterbodies around the Hanalei Bay Watershed. The results showed that although the relative concentrations of nutrients and bacteria were much higher in the waters of the three smaller watersheds draining into the bay (Wai‘oli, Waipā, and Waikoko), the Hanalei River contributed the largest amount of these pollutants to the bay (64 percent of the bay’s dissolved inorganic nitrogen and 80 percent of phosphate). Fecal bacteria tested were *E. coli* and *Enterococci*, with the Hanalei River delivering 60 percent and 50 percent of the bay’s total respectively. A positive correlation was found between these parameters and urbanized or cultivated areas and a negative correlation with forested areas. A contribution of these pollutants to surface water bodies via groundwater seepage is suspected, but this has yet to be confirmed by research. The study also used genetic methods to test samples containing fecal contamination for the source species (human, pig, or ruminant). The study results indicate that many areas have occasional influxes of human fecal contamination, which is suspected to come from cesspools and other sewage related issues. Another observation was a higher amount of fecal indicator bacteria in samples with pig markers, suggesting that pigs are the major source of fecal indicator bacteria in Hanalei Bay. Additional sampling was conducted during kayak trips on the Hanalei River and in the Refuge. In the river, 29 out of 49 samples (60 percent) were above State of Hawai‘i standards for *Enterococci*. Some water samples from the river contained bacteria levels that were ten times higher than the standard. Riverbank sediments were also examined. Since *Enterococci* can naturally occur in Hawaiian soils, it is important to be aware that during high precipitation time periods, large amounts of non-sewage related *Enterococci* could be washed into the bay. The riverbank sediments sampled contained extremely high levels, some up to 100 times higher than water levels. This could cause a huge influx of bacteria into the water during wet weather events when riverbanks are eroded. River water and sediment samples were also tested for DNA markers, which showed that fecal material came from human and pig sources. Samples were also taken in the Refuge from drainage ditches, lo‘i kalo, and managed wetlands. These results indicated high concentrations of bacteria in the water and sediment of drainage ditches. In the lo‘i kalo, there were relatively low concentrations in both water and sediment. In the managed wetlands, low concentrations were recorded in the sediment, but high concentrations were in the water, where birds are frequently found (ibid.).

While herbicides and pesticides have not been detected in the amounts of any concern in the river, there is concern that nutrients from the fertilizers used by kalo farmers in the Refuge and cultivated lands throughout the watershed may be contributing to the elevated nutrient levels found in the receiving Hanalei Estuary and suspected of adversely affecting coral reefs in downstream Hanalei Bay. Based on sampling within Hanalei Bay, two studies suggest that agricultural runoff is the primary source of nitrogen in the bay (Derse et al. 2007; Knee et al. 2008). The State of Hawaiʻi's Coral Reef Local Action Strategy for addressing land-based pollution threats to coral reefs (EPA et al. 2004) has identified the Hanalei watershed, including runoff from kalo farming, as one of three potential areas that are the sources for elevated nutrient input.

The Service's WRB continuously monitored field water quality parameters (temperature, conductivity, pH, dissolved oxygen [DO], and oxidation/reduction potential [ORP]) in areas of the Refuge for various periods from 2015 to 2017. Monitoring was done in loʻi selected randomly from the northeast and southeast kalo farms and in rotational managed wetland units from all areas of the Refuge; loʻi kalo within the northwest part of the Refuge were not monitored. Inflows to these areas had lower temperature, conductivity, and turbidity and higher pH, DO and ORP. Comparing managed wetlands to loʻi kalo, temperatures were either the same or slightly warmer in the wetlands. DO was low in wetlands but not nearly as low as in loʻi kalo and the upper range of concentrations was higher in wetlands. pH in the wetlands was slightly acidic (6.0–7.0) and similar to the loʻi kalo. ORP was always positive. Conductivity was slightly lower in the wetlands compared to the loʻi kalo but in general, conductivity was very low everywhere on the refuge so this difference may not be significant. There were occasional higher spikes in conductivity observed in the loʻi kalo in the northeast.

Comparing field water quality parameters in the loʻi kalo in the northeast versus the southeast, the differences were usually small or non-existent. For most sampling periods, water temperatures were slightly cooler in the northeast versus the southeast (contrary to what was expected). Conductivity was slightly lower and pH was usually slightly higher in the southeast. DO concentrations were low in both areas but usually higher in the southeast, with the exception of summer 2015, when they were lower. There was a lot of variability in field water quality parameters, especially DO and pH, at the scale of the individual loʻi kalo (comparing one loʻi kalo to another from the same area or farmer). This variability was so great that it is hard to generalize about comparisons between areas or farmers.

Comparisons of field water quality parameters between recently fertilized versus unfertilized loʻi kalo were inconclusive. One might expect that fertilization, and the drawdowns that accompany them, would lead to consistent differences in DO and pH but this was not observed. In the summer 2015, we observed no differences in DO or pH in recently fertilized lo'i kalo compared to lo'i kalo that had not been fertilized recently. In the winter 2016, we observed lower pH and DO in recently fertilized lo'i kalo in the northeast. In the summer 2017, we monitored the same lo'i kalo before and after they were fertilized and observed an increase in DO following fertilization and drawdown, but little change in pH.

The Service's WRB also conducted nutrient sampling from July to September 2015 and from January to March 2016 in the same areas as described above. Concentrations of total nitrogen, total phosphorus, and ammonia nitrogen were lowest in the inflows and higher in the loʻi kalo compared to managed wetland units. Bioavailable nitrogen was in the form of ammonia nitrogen at all sites; nitrate nitrogen was non-detectable in all samples. Considering all samples from both seasons combined, total nitrogen, total phosphorus, and ammonia nitrogen concentrations were highest in the northeast loʻi kalo. Occasionally, there were very high concentrations of ammonia nitrogen in the northeast loʻi kalo; Similar nutrient spikes were not observed in the southeast loʻi kalo or managed wetlands. There was almost no ammonia nitrogen in the managed wetlands. Finally, there was no statistical difference in nutrient concentrations between summer and winter in the northeast loʻi kalo. All the other areas showed much lower nutrient concentrations in the winter compared to the summer. Nutrient concentrations appear to be very high in the northeast loʻi kalo throughout the year.

In winter 2016, the WRB also sampled the Hanalei River upstream and downstream of the Refuge for total nitrogen, total phosphorus, ammonia nitrogen, and nitrate nitrogen. Samples were collected weekly for eight weeks. Nitrogen was almost always non-detectable at both sites. Phosphorus was slightly higher downstream. It was mostly non-detectable upstream and at low concentrations downstream. Samples were not collected during the summer, when nutrient concentrations are known to be higher and river flows lower.

Currently, kalo farmers typically use conventional, chemical fertilizers year-round. The estimated fertilizer use by kalo farmers permitted by the Refuge range from 25 to 1,000 lbs per acre per year, as reported by the farmers. Analysis of the nitrogen cycle in kalo ponds suggests that the conventional fertilization methods applied throughout most of the loʻi kalo is prone to loss and runoff over time, and that use of slow-release or organic fertilizers applied to the subsoil prior to planting would allow for more efficient use of the fertilizer by kalo and thus less runoff over time (Deenik, Penton, and Bruland 2013). Based on a study conducted in 2011–2012 (Deenik et al. 2013), the use of slow-release or organic fertilizers provided a long-term reservoir of plant-available nitrogen in the root zone for kalo and reduced nitrogen export to the river system. By comparison, the use of conventional fertilizers did not store applied nitrogen in the soil, but rather showed an increased export of nitrogen to the river. A partial cost-benefit analysis showed that slow-release fertilizer had the highest mean return with the lowest variability across three different farm sites. In other words, Deenik et al. (2013) concluded that the environmental benefit (reduced nitrogen input into the river) of using slow-release fertilizer does not come at a cost to the farmer since yields remained stable and net returns to the farmer were equal to or greater than the current practice. However, future research is needed to confirm these findings, as new, more efficient and appropriate products are available now.

Additional water quality concerns related to kalo farming are the prevalence of wet tilling and other soil disturbance during kalo production, which can cause turbid water to flow back into the river. Results from water quality monitoring conducted during spring (March–April) and summer (June–September) 2015, winter (January–March) 2016 in randomly selected managed wetland units and loʻi kalo in the northeast and southeast indicated differences between water quality in managed wetland units and loʻi kalo (Feddern 2016). The largest differences were DO and ORP, both of which were lower in loʻi kalo than in the managed wetland units. Additionally, a strong correlation between low DO and low ORP was observed suggesting anoxic conditions contribute to negative ORP and thus higher avian botulism risk (Feddern 2015b). In both loʻi kalo and managed wetlands, summer DO was lower than winter DO. DO saturation and concentrations in the northeast loʻi kalo in winter were greatly lower than southeast loʻi kalo.

Additional observations were made regarding algal and plant abundance in loʻi compared to managed wetlands. In some loʻi, large mats of *Azolla filiculoides* (a nitrogen-fixing aquatic fern) and algae were present, while in other loʻi and managed wetlands *Azolla* was absent and algal abundance was minimal. *Azolla* grows best in high-phosphorus conditions and at depths of 0.5 to 0.833 feet (Uchida et al. 2008). Based on this information it was hypothesized fertilization in loʻi kalo causes *Azolla* and algal blooms in response to nutrient inputs. It is likely plant and algae die-offs follow these blooms as nutrients are consumed and loʻi water depth decreases (water drawdowns typically follow kalo fertilization).

Some farmers have expressed concern that the high density of waterbirds may be contributing to nutrient loading in the river and bay. Research suggests resident birds foraging locally would not result in external loadings of the system, as with birds that forage in fields and then roost in wetlands

(Post et al. 1998; Hahn, Bauer, and Klassen 2007). Further monitoring of the nutrient cycle is necessary to assess the relative contribution of nutrients from all potential sources and to better quantify the system inputs from birds, flooding, and other naturally occurring factors versus introduced inputs from farming, management, invasive species, or other non-naturally occurring sources. This monitoring should also include groundwater monitoring, as Knee et al. (2008) determined a significant amount of nitrogen entered the bay from subsurface flows. Because the Refuge was established to conserve threatened and endangered species which are endemic to the area, and has mandates to manage for BIDEH, the Service will work with partners to focus on management of introduced sediment and nutrient inputs versus those of natural origin.

In 2014, water temperature loggers were deployed within mixed-supply (i.e., fresh and drain water) and fresh-supply water lines in the northeast lo‘i kalo. This experiment showed that the average water temperature was higher and more variable in mixed-supply lines, compared to fresh-supply lines. In addition, this experiment showed that average water temperature increased within a mixed pipeline as the number of lo‘i draining into the system increased, but average water temperature does not increase in a similar way in an adjacent fresh pipeline. Overall, the results illustrated how changes to water quality could be cumulative along a mixed-supply line (Cosgrove 2014).

In 2015, following the conversion of two mixed-supply systems to fresh-supply systems, water temperature loggers were again deployed in the northeast lo‘i kalo to determine the impact of the infrastructure improvements. Based on these data, the infrastructural improvements, particularly the open to closed system conversion, significantly decreased water temperature in fresh water pipelines and drain pipelines on the Refuge (Feddern 2015a).

Algal sampling on the Refuge (December 2014 and June 2015) identified several genera of cyanobacteria in Refuge wetlands and lo‘i (Sherwood and Conklin 2015). Some cyanobacterial blooms in lo‘i kalo actively produce toxins (microcystins) (Egelhoff, Conklin, and Sherwood 2016).

The Refuge works with organizations such as the Hanalei Watershed Hui, EPA, NRCS, and HDOH to address water quality issues. For example, in 2009 four residential cesspools were upgraded to septic systems. Due to the potential for nutrients to enter the Hanalei River via drain water from the Refuge, investigations are being designed to quantify possible nutrient input to the Hanalei River and methods of controlling or minimizing this release. The Refuge also participates in studies and workshops such as the 2007 Hanalei Watershed Workshop to continue to better understand the Refuge’s role in larger watershed management issues and integrate with such initiatives. Other ongoing water quality efforts include HDOH monitoring streams (nutrient and sediment) that drain into Hanalei Bay, bacterial source tracking, and pharmaceutical monitoring.

2.3 Wetland Habitat Descriptions and Management Units

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands usually have at least one of the following qualities: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979). Wetlands are legally protected because of their high societal (e.g., recreational fishing and hunting, flood buffers, sediment and nutrients filters) and ecological (e.g., aquifer recharge, global nutrient cycling, native wildlife habitat) values.

Wetland cycles and processes vary in complexity. For habitat, abiotic conditions of wetlands, such as soils, hydrology, geomorphology, and water chemistry, largely determine biotic conditions. The resulting plant community greatly influences the distribution, abundance, and species composition of invertebrates and vertebrates. Over time, the biotic communities, in turn, affect the abiotic conditions of a wetland by altering the hydrology, soil and water chemistry, and other processes (Mitsch and Gosselink 2000).

Traditional land management in Hawaiʻi occurred under a system of land divisions known as ahupuaʻa. Similar to the concept of watersheds, ahupuaʻa focused on utilization and distribution of water with its boundaries, as determined by valleys or ridges, and extended from the mountains into the sea, ensuring the variety of resources necessary for its residents. Prior to the arrival of British explorer Captain James Cook in 1778, the Hawaiian landscape consisted of a mosaic of natural habitats and farming areas, including immense wetland agricultural terrace systems. The Hawaiian Islands have ecosystems with fixed terrestrial boundaries and being unable to expand their area, Native Hawaiians intensified their agricultural systems and integrated them with the islands' ecosystems. This resulted in a wide variety of agricultural systems making use of the full range of natural habitats, with specialized methods for managing water and nutrients. Native Hawaiian farmers used the ecosystem services provided by natural systems to develop soil fertility and other conditions conducive to crop growth. Water and nutrient flows and topography connected irrigated agricultural fields and nearshore fishponds within a cohesive ahupuaʻa (traditional land management system that extends from the mountains to the sea) and land tenure system (Kagawa-Viviani et al. 2018).

Following European contact, native vegetation communities and traditional Native Hawaiian agricultural systems were converted and supplanted by other uses. Natural wetland habitats such as lowland marshes, swamps, mudflats, and bogs were either lost or degraded by altered hydrology, invasive plants and animals, human encroachment or disturbance, land use change, and contaminants. Additionally, the amount of anthropogenic wetlands on the landscape, including loʻi kalo and fishponds, decreased due to urban development or conversion to other types of agriculture. For example, commercial sugarcane plantations steadily consumed agricultural lands, resulting in large amounts of surface and ground water being diverted from streams, kalo, and fishpond systems. Wetland kalo acreage declined from ~50,000 acres to ~30,000 acres by the end of the 19th century (Kagawa-Viviani et al. 2018). By 1939, approximately 1,200 acres remained in wetland kalo and commercial acreage has hovered around 400 acres since 1965 (ibid.).

Prior to historical and substantial human-related changes for kalo and rice production, the Hanalei Valley consisted of a braided river system with a mosaic of riverine, riparian, and seasonal freshwater marshlands. Following Polynesian colonization, land use history within the Valley can be categorized in the following manner (Shapiro and Shapiro 1995):

- Pre-contact (pre-1770s): kalo and breadfruit agriculture supported by ʻauwai (stone-lined water ditches) and loʻi by Native Hawaiians; evidence for irrigated kalo cultivation within the Hanalei Valley dates back as far as A.D. 610±95 (Schilt 1980);
- Early Western contact (1770–1848): kalo supported by ʻauwai and loʻi by Native Hawaiians and Caucasians;
- Missionaries, agricultural experiments (1830s–1860s): coffee, sugar, cattle, silk production supported by fencing, tree plantings, and early roads built by Caucasians and Chinese (though these failed due to the wet climate and poor soil condition);

- Agricultural stabilization (1860s–1890s): sugar, sugar mills, and rice supported by plantations, ornamental planting, expanded road system, ferries, early bridges by Chinese, Japanese, Caucasians;
- Agricultural transition (1890s–1930s): rice and kalo supported by wetland agriculture, fields and patches, and bridges by Chinese, Japanese;
- Consolidation (1930s–1960s): kalo and some rice supported by loss of rice mills, abandoned lo‘i kalo, ‘auwai stabilization by Japanese, Chinese; and
- Increased mechanization (1960s–1980s): increasing tourism, the Refuge, and kalo farms supported by increased field sizes, mechanization, ‘auwai improvements by Native Hawaiians, Japanese-Americans, and Caucasians.

Due to historical land use and more current Refuge management decisions, the portion of the Hanalei Valley located within the present-day Refuge includes areas managed to restore or mimic natural ecosystem processes or functions and agricultural or cultivated wetlands managed in cooperation with local farmers. Wetland habitats within the scope of this plan and described within the following sections include: (1) rotational managed emergent wetlands, (2) dikes and ditches, (3) kalo farms, (4) riverine, and (5) riparian. The Service recognizes that this mosaic of wetland habitats provides a variety of ecological and societal benefits (e.g., cultural, historical, and economical).

In the Hawaiian Islands, wetlands provide critical stopover or wintering habitat for migratory waterfowl and shorebirds from both Asia and the Americas and is necessary for the persistence of five of six resident endemic waterbirds that are federally listed as threatened or endangered. Waterbirds use small habitat patches for certain life functions. Collectively, these habitat patches loosely define the range of a waterbird (e.g., multiple sites within a large wetland complex or multiple wetlands). “Functional habitat units for nesting, resting, feeding, roosting, molting, migration, stopovers, and wintering are essential for completion of the annual life cycle and, therefore, must be considered equally important….” (Weller 1999).

Declines in Hawaiian and migratory waterbird populations parallel losses of wetland habitat. Historical declines in koloa maoli populations, one of our high priority species, are related to the cumulative effects of introduced mammalian predators and loss of large coastal wetland habitats including Waikīkī and Ka‘elepulu marshes on O‘ahu and Mānā Swamp on Kaua‘i (Engilis, Uyehara, and Giffin 2002). Prior to its drainage in 1923, Mānā Swamp was reported to support 400 koloa maoli per square mile. The legal bag limit was 25 ducks per day during a 4-month hunting season (Swedberg 1967).

Given the overall loss or modification of wetland habitat (both natural and anthropogenic) at the landscape-scale since at least the 1850s, protecting and managing remaining wetland habitat to meet as many of the life history requirements of threatened and endangered Hawaiian waterbirds as possible is a prudent strategy. Also, given the substantially altered ‘natural’ conditions that exist in the 21st century, these wetland units require intensive management to create conditions that support Hawaiian waterbird life history requirements.

2.3.1 Rotational Managed Emergent Wetlands

Hanalei NWR contains approximately 86 total acres of rotational managed wetland units, not including dikes and ditches. To restore the functions of wetland wildlife habitat, staff currently use a technique known as moist-soil management which involves the manipulation of soils, hydrology, and vegetation to mimic the natural dynamics of seasonally flooded wetlands (Fredrickson and Taylor

1982). Prior to about 2004, wetland habitat management mainly consisted of mowing and flooding California grass, a highly invasive plant that offers little habitat value. Currently, techniques such as mowing, grinding, disking, tilling, and water level management are used to control undesirable species and provide suitable habitat structure so that threatened and endangered waterbirds can have the opportunity to reproduce successfully at rates that will meet population recovery goals. Practical techniques for restoring heavily modified, lowland Hawaiian wetlands to native plant-dominated communities are currently unavailable. Moist-soil management techniques are known to considerably improve the nutritional quality of plant and animal foods available to wetland birds, and subsequently body condition, survival, and recruitment (Fredrickson and Taylor 1982; Brasher, Steckel, and Gates 2007).

We manage for a mix of native and naturalized plants that naturally occur in the seed bank, are beneficial to wildlife, and are likely to provide for all of the life history needs of ‘alae ‘ula and ae‘o, and most of the life history needs of koloa maoli. Malachowski and Dugger (2018) identified 41 unique plant species in rotational managed wetlands, including 7 that were indigenous to Hawai‘i. Lesser fimbristylis (*Fimbristylis littoralis*) was common in most rotational managed wetland units, but cover was highest in early-successional wetlands. These moist-soil plant species provide high seed production and important nutrient sources (e.g., carbohydrates and protein; DesRochers et al. 2009; DesRochers, McWilliams, and Reed 2010). They are among the species targeted by wetland management at Hanalei NWR (Chadd Smith 2018, pers. comm.). Birds were often observed dabbling seeds from the water surface from plants, such as kāmole (Mexican primrose-willow, *Ludwigia octovalvis*) and flatsedges (*Cyperus spp*.). They were also observed nibbling the seeds, leaves, and inflorescences from plants such as, Mexican primrose-willow, Javanese flatsedge (*Cyperus javanicus*), manyspike flatsedge (*Cyperus polystachyos*), lesser fimbristylis, forked fimbry (*Fimbristylis dichotoma*), rock bulrush (*Schoenoplectus juncoides*), barnyard grass (*Echinochloa crus-galli*), and crowngrasses (*Paspalum spp*.).

Information on the basic ecology of plants and animals of Hawaiian wetlands is lacking and the year-round growing season combined with year-round breeding of multiple threatened and endangered species presents special management challenges and opportunities. Our wetlands management program is still under development; thus, treatments are adapted as information is acquired on the plant, invertebrate, and bird responses to manipulations and will be improved upon based on new information resulting from monitoring and other scientific research.

For more information on rotational managed wetland habitat, see Chapter 4 and Appendix C, Management of Rotational Managed Wetland (Moist-Soil) Units.

2.3.2 Dikes and Ditches

Dikes are used to impound or transport water and are dominated by various grasses and sedges. Although the importance of dikes in meeting the life history needs of wetland birds is uncertain, dikes may provide opportunities for ‘alae ke‘oke‘o and ‘alae ‘ula to establish pair bonds. Koloa maoli use dikes for resting (Malachowski and Dugger 2018). Dikes are elevated and often provide good visibility, which possibly aids in predator detection, and quick access to escape cover.

Dikes provide forage for grazers like nēnē, ‘alae ‘ula, and ‘alae ke‘oke‘o. ‘Alae ‘ula forage on California grass shorter than four inches tall, which is a good source of protein and carbohydrates (DesRochers et al. 2009). The forage value of other existing dike grasses is unknown. However, in mid-elevation Hawai‘i Island, nēnē selected forage with high water and protein content such as the young shoots of a Kikuyu grass-Spanish clover grassland, preferred sward-forming (turf-like growth) over bunch grasses, and short grasses (4–6 inches) over tall grasses (Woog and Black 2001). Maintaining dikes with low to intermediate growing grasses and leafy forbs also helps to control pest plants and reduces concealment cover for introduced predators.

Ditches are used to transport water from waterways to wetlands management units and lo‘i kalo and are dominated by herbaceous plants with patches of woody vegetation and bare ground. Vegetated ditches supporting macroinvertebrates provide supplemental foraging and breeding habitat for ‘alae ‘ula and koloa maoli. Enhancement of ditches may provide additional forage and nesting cover for ‘alae ‘ula and koloa maoli (Gee 2007). Vegetated ditch banks also help to trap sediment and nutrients reducing Hanalei River inputs. Thus, we use mowing, brush-cutting, and herbicide to maintain free-flowing waterways, control pest species, and enhance wildlife habitat.

2.3.3 Kalo Farms

Kalo is a member of the Philodendron family (Araceae) farmed in upland or wetland conditions for its corm and leaves. Cultivation at Hanalei NWR is in flooded patches similar to rice paddies. Kalo cultivation is an agricultural tradition of the Native Hawaiian people and considered an important component of the ahupua‘a. In 1980, there were an estimated 124 acres of kalo on Hanalei NWR (Byrd and Zeillemaker 1981). Today, there are an estimated 160 acres involved in kalo farming, including lo‘i kalo, dikes, and ditches.

Kalo farming is determined to be an appropriate and compatible use on Hanalei NWR (Appendices A and B) because, when farmed according to the stipulations designed to ensure compatibility with Refuge purposes, lo‘i kalo provides habitat that satisfies some of the life history requirements of threatened and endangered waterbirds and, consequently, contributes to the goals of recovery. Kalo farms provide shallow-water habitat with a variable canopy and subcanopy cover depending on growth stage and farming intensity. Like many agricultural lands, though, limitations come with benefits to native wildlife (Heard et al. 2000). Water levels and species composition in lo‘i kalo on Hanalei NWR have often historically been managed to meet kalo production goals. In contrast, water levels and species composition in rotational managed wetland (moist-soil) units are managed by Refuge staff to meet the life history requirements of threatened and endangered waterbirds.

For example, lo‘i kalo appears to provide suitable ae‘o foraging habitat, but less suitable breeding habitat. Invertebrate blooms occurring incidental to farming practices provide abundant temporary foraging resources, especially during harvest and wet fallow periods. However, if suitable breeding habitat (early successional wetlands consisting of shallow open water and mudflat) is not nearby, birds nest on dike edges where their eggs are at risk of being crushed by vehicles. In addition, adult birds, eggs, and chicks are easy prey for introduced predators. Gee (2007) observed that most ae‘o dike nests were abandoned due to human disturbance. Ae‘o appear to be semi-colonial, nesting in groups. How this influences predator avoidance is uncertain. However, a predator stalking an isolated bird nesting on a dike is less likely to be detected than one approaching a bird colony on a mudflat. Ae‘o may also nest on mudflats within lo‘i, which puts nests at risk for flooding, since water levels are manipulated to optimize kalo growth.

From 2010 to 2011, approximately 95 percent of native birds killed by predators were recovered on lo‘i kalo dikes and 5 percent were recovered elsewhere including wetlands management units. There are undoubtedly multiple interacting factors involved, such as cat abandonment along roads, tendency of certain bird species to use dikes, and availability of adequate roosting habitat away from dikes. However, open dikes serve as corridors for mammalian predators in search of food and thus more travel lanes for introduced predators may influence the rate of depredation.

Gee (2007) found that although 64 percent of ‘alae ‘ula nests (n=56 nests) in harvested lo‘i kalo hatched at least one egg, less than half of all eggs hatched (n=352 eggs), and only about three percent of chicks fledged (n=162 chicks) despite the required 3-foot radius vegetated buffer zone around the nest sites in lo‘i kalo. This indicates the need to re-evaluate buffer size and other factors during these stages (Gutscher-Chutz 2011).

Causes of nest failure include flooding, depredation of eggs by introduced avian and mammalian predators, and depredation of incubating adults during drawdowns for fertilization (Gee 2007). Successful reproduction is most likely when ‘alae ‘ula are able to incubate, hatch, and rear young (80–90 days) within the corm growth stage and prior to harvest (8–11 month period), when there are fewer water level fluctuations due to soil amendments, and, when there are abundant invertebrate and natural plant foods available.

Farming practices can have a negative or positive effect on wildlife depending on the timing and duration. Two beneficial foraging stages of kalo, the wet fallow and harvest stages, have the highest use by endangered waterbirds (Gee 2007; Gutscher-Chutz 2011). Additionally, vegetated wet fallows (greater than or equal to 25 percent cover emergent vegetation) were preferred by ‘alae ke‘oke‘o, koloa maoli, and ‘alae ‘ula. Unvegetated wet fallows (less than 25 percent cover emergent vegetation) were preferred by ae‘o and ‘alae ke‘oke‘o over other kalo stages (Gee 2007).

Soil disturbance from harvest stimulates invertebrate production (dipteran larvae and other benthic invertebrates) maximizing foraging opportunities for endangered waterbirds (Broshears 1980). In lo‘i kalo, it is the period of highest invertebrate egg laying and larval growth. Two weeks post-harvest had the highest densities of endangered waterbirds in lo‘i kalo.

Flooding of dry fallow lo‘i during rainfall events mimics irrigation of moist-soil vegetation and attracts high densities of endangered waterbirds (Gee 2007). Dry fallows for one to three months are recommended for proper vegetative breakdown and disease suppression, especially in the context of avian botulism. Six-month dry fallows can lead to increased yield, corm quality, and reduction/elimination of some diseases and pests (University of Hawai‘i College of Tropical Agriculture and Human Resources 2008). Vegetated dry fallow lo‘i greater than an acre provide foraging and roosting habitat for threatened and endangered waterbirds, while unvegetated dry fallow lo‘i or mudflats provide roosting sites for migratory shorebirds such as kōlea.

Wetland kalo farming does not replace the functions and values of natural wetland habitat, but the overall wildlife conservation benefits are positive in terms of providing additional habitat supporting some of the life history requirements for federally listed waterbirds. Thus, kalo farming would continue to be permitted on Hanalei NWR, if it continues to meet the requirements for compatibility and complies with permit requirements and policy, considering that it continues to enhance the threatened and endangered species purposes of the Refuge (USDOI 1974).

2.3.4 Riverine

Approximately 3.1 miles of the 16-mile perennial Hanalei River flows through Hanalei NWR. The Refuge does not have jurisdiction over the river itself. However, the river provides habitat for all five threatened and endangered waterbirds, primarily koloa maoli. It also provides habitat for species of

ʻoʻopu (Hawaiian amphidromous gobies) and native invertebrates such as pinao ʻula (endemic damselflies) and ʻōpae ʻoehaʻa (endemic shrimp).

Data collected over many years and used in the TMDL process have shown frequent exceedances of water quality standards for bacteria and turbidity and occasional exceedances for nutrients (nitrogen and phosphorus) in the Hanalei River. For more information, refer to Section 2.2.7 Water Quality.

2.3.5 Riparian

Hanalei NWR has approximately 189 acres of degraded riparian habitat which extends from the active river channel to the upland edge of the 100-year floodplain. The term "riparian" describes the habitat within this flood zone that is not developed or managed under another habitat category (i.e., rotational managed wetland or loʻi kalo). The term "floodplain" describes lands regulated under EO 11988 (42 FR 4393) and other laws protecting floodplains. The Hanalei riparian habitat is dominated by invasive hau (*Hibiscus tiliaceus*) primarily along river and ditch margins, and California grass and Guinea grass throughout.

2.4 Biological Integrity, Diversity, and Environmental Health (BIDEH)

The BIDEH policy (601 FW 3) defines *biological integrity* as "the biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities." *Biological diversity* is defined as "the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and communities and ecosystems in which they occur." *Environmental health* is defined as the "composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment." *Historic conditions* are defined as the "composition, structure, and functioning of ecosystems resulting from natural processes that we believe, based on sound professional judgment, were present prior to substantial human related changes to the landscape." In simplistic terms, elements of BIDEH are represented by native fish, wildlife, plants, and their habitats, as well as those ecological processes that support them. The BIDEH policy provides guidance on consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges, and associated ecosystems that represent BIDEH on each refuge.

Biological integrity theoretically lies along a continuum from a completely natural system to a biological system extensively altered by considerable human impacts to the landscape. However, no modern landscape is completely natural and unaltered by human activities. We strive to prevent the further loss of natural biological features and processes. Maintaining or restoring biological integrity is not the same as maximizing biological diversity. Maintaining habitat for a specific threatened or endangered species, even though it may reduce biological diversity at the refuge scale, helps maintain biological integrity and diversity at the ecosystem or landscape scale.

Historically, migratory and nonmigratory native birds dependent upon wetlands may have used areas now within the Refuge in some years while using other flooded areas in other years. However, because many historical wetlands have been degraded, filled, and converted to agriculture or other land uses, the remaining wetlands must provide more quality habitat, more consistently, to support the life history requirements of wetland-dependent birds. Now, to conserve bird populations at larger landscape scales, we may manage habitat characteristics such as water levels at the Refuge to cover areas for longer or more frequent periods of time than occurred historically to maintain higher densities of birds than may have occurred historically because of the loss and degradation of surrounding habitat.

On refuges, we often focus our evaluations of biological diversity at the refuge scale. These refuge evaluations, however, can contribute to assessments at larger landscape scales. We strive to maintain populations of breeding individuals that are genetically viable and functional. Evaluations of biological diversity begin with inventory and monitoring. The Refuge System's focus is on conserving native species and natural communities, such as those found under historical conditions, as well as reducing threats or stressors that may affect the viability and function of priority management habitats and species.

We evaluate environmental health by examining the extent to which environmental composition, structure, and function have been altered from historic conditions. Environmental composition refers to abiotic components such as air, water, and soils; all of which are generally interwoven with biotic components (e.g., decomposers live in soils). Environmental structure refers to the organization of abiotic components, such as atmospheric layering, aquifer structure, and topography. Environmental function refers to the processes undergone by abiotic components, such as wind, tidal regimes, evaporation, and erosion. A diversity of abiotic composition, structure, and function tends to support a diversity of biological composition, structure, and function.

We strive to manage in a holistic manner to achieve BIDEH, by managing in combination with our other mandates such as refuge purposes, Refuge System mission, and laws and policies as described in Section 1.3. Where practical, we support the return of extirpated native species in the context of surrounding landscapes. The elements of BIDEH relevant for wetlands management at Hanalei NWR are summarized in Table 2-6 below.

TABLE 2-6. BIOLOGICAL INTEGRITY, DIVERSITY, AND ENVIRONMENTAL HEALTH

Habitats	*Habitat Attributes*	*Natural Processes Responsible for these Conditions*	*Current Limiting Factors*
Emergent wetlands	Seasonal, semi-permanent, fresh and brackish, tidal and non-tidal, good water quality (e.g., ‘aka‘akai / kaluhā sedgeland) Potential conservation species: threatened and endangered waterbirds, migratory waterbirds, native wetland plants, invertebrates	Periodic riparian-driven scouring in most years, precipitation-driven inundation during wet season (Oct.–Apr.) and evapotranspiration during dry season (May–Sep.), sediment and nutrient flushing and deposition, nutrient cycling, large fall influx of migratory waterbirds, seasonally high densities of foraging, loafing, and breeding native waterbirds	Historic dams and diversions, diked impoundments, wetland fill, disrupted flow patterns, agriculture, housing, roads, climate change, pest species (e.g., California grass, Guinea grass, marsh fleabane, mangroves, hau, rats, cats, dogs, pigs)

Habitats	*Habitat Attributes*	*Natural Processes Responsible for these Conditions*	*Current Limiting Factors*
Riverine	Perennial, free-flowing, fresh and brackish, good water quality Potential conservation species: koloa maoli, ʻalae ʻula, ʻoʻopu, native invertebrates	High seasonal precipitation and natural flooding events, channel scouring, sediment and nutrient deposition, nutrient cycling, ʻoʻopu migrations	Historic dams and diversions, channelization, siltation, altered/reduced river flow during high precipitation events, contaminants, impaired water quality (excessive nutrients, sediments), climate change, pest fish and other aquatic species, human activity (boating, fishing)
Riparian	Functional floodplain and buffer zone Potential conservation species: threatened and endangered and migratory waterbirds, pueo, ʻōpeʻapeʻa, native riparian plants, and invertebrates	Periodic scouring in most years, inundation during wet season (Oct.–Apr.) and evapotranspiration during dry season (May–Sep.), sediment and nutrient flushing and deposition, nutrient cycling	Historic dams and diversions, diked impoundments, river channelization, disrupted flow patterns, agriculture, housing, roads, climate change, pest species such as California grass, Guinea grass, marsh fleabane, mangroves, hau, rats, cats, dogs, pigs

2.5 Wildlife

2.5.1 Special Status Animal and Plant Species

Several species listed under the ESA are known to occur within or in the vicinity of the wetlands at Hanalei NWR: koloa maoli, ʻalae keʻokeʻo, ʻalae ʻula, aeʻo, nēnē, ʻōpeʻapeʻa, ʻakēʻakē (band-rumped storm petrel, *Oceanodroma castro*) and ʻuaʻu (Hawaiian petrel, *Pterodroma sandwichensis*). All of these species are listed as endangered. ʻAʻo (Newell's shearwater, *Puffinus auricularis newelli*), a threatened species, was identified nearby during the nesting season. There is no designated or proposed critical habitat for any of these species. No special status plant species are known to occur on lands potentially impacted by wetlands management. .

Descriptions of the listed species that may be affected by this plan are provided below.

Koloa maoli (*Anas wyvilliana*) or Hawaiian Duck

The koloa maoli is an endemic, nonmigratory, endangered species of dabbling duck allied with the North American Mallard Complex. The Hawaiian Islands were once home to more than 13 endemic waterfowl species, including extinct giant flightless ducks (Olson and James 1991; Burney et al. 2001), descendants of migratory ducks that evolved here in the islands for hundreds of thousands to millions of years and became a unique Hawaiian species (Rhymer 2001). From this diverse assemblage, koloa maoli is one of only two endemic duck species to persist into modern times and the only native duck to remain in the main Hawaiian Islands.

The population size of koloa maoli is about 2,200 birds, including 2,000 on Kauaʻi and Niʻihau and 200 on Hawaiʻi Island. In addition, there are predominantly mallard/koloa hybrids on Oʻahu and Maui estimated at 300 birds and 50 birds, respectively (Engilis and Pratt 1993; Fowler, Eadie, and Engilis Jr. 2009). However, current population estimates are unreliable because detection rates and montane habitats were not included in calculations (Engilis, Uyehara, and Giffin 2002). The Kauaʻi population was believed to be secure from the threat of hybridization; however, hybrid birds have been confirmed within "true" koloa populations on Kauaʻi and Hawaiʻi Islands (Andrew Engilis and John Eadie, unpublished data). The threat of hybridization on Kauaʻi places the koloa maoli at a higher risk of extinction.

Hanalei and Hulēʻia NWRs are the only NWRs currently supporting true koloa maoli populations, elevating the importance of these Refuges in the species' recovery. In addition to hybridization with feral mallards, threats to koloa maoli persistence include depredation by introduced predators, habitat loss, and disease. The Hawaiian Waterbird Recovery Plan (USFWS 2011e) lists koloa maoli as having the highest recovery priority of the endangered waterbirds in the main Hawaiian Islands, with a high degree of threat due to hybridization with feral mallards and a high potential for recovery.

The koloa maoli uses diverse wetland habitats from sea level to mountain top, including palustrine emergent and riverine (Swedberg 1967; Giffin 1983; Engilis and Pratt 1993; Uyehara, Engilis, and Dugger 2008), and infrequently estuarine habitats (Engilis, Uyehara, and Giffin 2002). Koloa maoli frequent montane wetlands and skillfully maneuver winding river corridors, stream plunge pools, and forest canopy where there is little to no human activity. The species has been reported by several authors as being sensitive to regular human disturbance, at least during certain parts of its annual cycle (Swedberg 1967; Giffin 1983; Engilis, Uyehara, and Giffin 2002; Uyehara, Engilis, and Dugger 2008). Lowland habitat types include natural and human-made wetlands, riparian zones, flooded grasslands, and agricultural wetlands.

Hanalei NWR is managed with the intent of providing optimal foraging, loafing, and breeding habitat. On Kauaʻi, koloa maoli breed year-round, peaking in December–May (Swedberg 1967). Nests are usually constructed within herbaceous and/or woody vegetation in wetland-associated uplands. Plants associated with nest sites include tall and bunch-type grasses, rhizominous ferns and forbs, vines, and shrubs. On average, koloa maoli lay eight eggs (range 6–10 eggs), incubate for 28 days (range 26–30 days), and ducklings attain flight after 65–70 days (Swedberg 1967; Giffin 1983). The diet consists of aquatic invertebrates, aquatic plants, seeds, grains, green algae, snails, crustaceans, and tadpoles (Engilis, Uyehara, and Giffin 2002; USFWS 2011e).

Kauaʻi and Niʻihau islands are estimated to support 91 percent of the koloa maoli population statewide (Engilis, Uyehara, and Giffin 2002), with Hanalei and Hulēʻia NWRs currently supporting at least 25 percent of the recovery population goal of 2,000 birds, making these core protected areas and surrounding natural and agricultural wetlands of highest importance for recovery of koloa maoli. From 2010 to 2015, the average number of koloa maoli counted during monthly population monitoring at Hanalei NWR was 388 (range 131–817, SE 16.1). These numbers represent a population index because of an unknown number of koloa maoli using the Refuge nocturnally or that are undetected in dense plant cover or waterways. The species occurs on the Refuge year-round, with the lowest numbers in June and July, suggesting birds undergo a molting period off-site. During this flight feather replacement period, birds are flightless and vulnerable to predators and other environmental stresses for approximately six weeks (Figure 2-3). Hanalei NWR has worked with research partners to estimate the koloa maoli population size on the Refuge using mark-recapture methods and to identify factors limiting population size (Dugger, Malachowski, and Uyehara 2018).

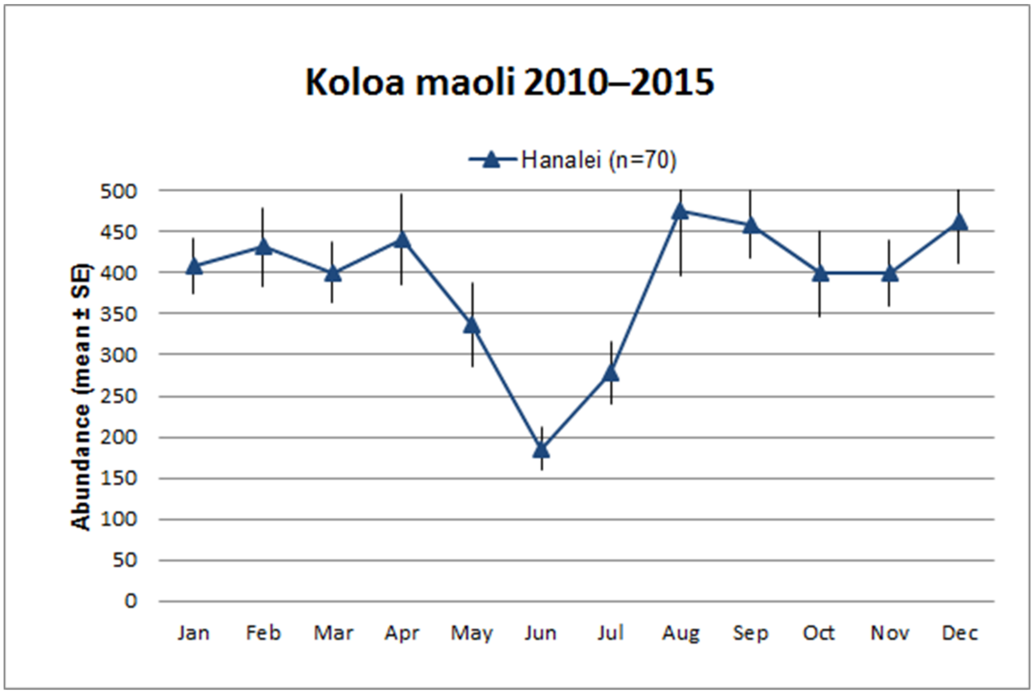


Figure 2-3. Abundance of endangered koloa maoli by month at Hanalei NWR

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

The ‘alae ke‘oke‘o is an endemic, nonmigratory, endangered species commonly recognized by its white bulbous frontal shield or, in a small percentage of the population, a red shield and dark spots near the bill tip. It has long legs with large, distinctly lobed toes. Males and females are similar in plumage with dark slate-gray body and wing feathers and white undertail feathers (Pratt and Brisbin 2002; Brisbin, Pratt, and Mowbray 2002).

‘Alae ke‘oke‘o were historically documented on all the main islands except Lana‘i and Kaho‘olawe. Currently, they are found on all the main islands except Kaho‘olawe, with 80 percent of the birds on Kaua‘i, O‘ahu, and Maui. The statewide population is estimated to range between 2,000 and 4,000 birds (Engilis and Pratt 1993). The Hawaiian Waterbird Recovery Plan (USFWS 2011e) lists ‘alae ke‘oke‘o as having a low degree of threat with a high potential for recovery.

‘Alae ke‘oke‘o are usually found on the coastal plains below 1,320 feet where wetlands are more common. They prefer habitat with a suitable mix of open water and emergent plant growth and are usually found in fresh or brackish water. ‘Alae ke‘oke‘o have been observed in montane plunge pools above an elevation of 4,950 feet on Kaua‘i (USFWS 2011e). The optimum nesting habitat is in wetlands with a ratio of dense emergent vegetation to open water ranging from 50:50 to 75:25 (USFWS 2011e). ‘Alae ke‘oke‘o usually construct floating nests of aquatic vegetation or semi-floating nests anchored to emergent vegetation such as bulrushes (Byrd et al. 1985). Nesting occurs year-round in suitable habitat with peaks in breeding varying by location (Pratt and Brisbin 2002; Brisbin, Pratt, and Mowbray 2002). On average, ‘alae ke‘oke‘o lay 5 eggs (range 1–10 eggs) (Byrd et al. 1985) and incubate for 25 days (range 23–27 days) (Shallenberger 1977). The age at fledging is probably comparable to the American coot at 75 days old (Gullion 1954). The ‘alae ke‘oke‘o prefers more open habitat than ‘alae ‘ula.‘Alae ke‘oke‘o usually forage in water that is less than 12 inches deep, although they can dive down to four feet. They forage at the water surface, in mud or sand, and in upland grassy areas near wetlands (USFWS 2011e). Diet items include seeds and leaves of aquatic plants, invertebrates including snails, insects, and crustaceans, tadpoles, and small fish (Schwartz and Schwartz 1949).

Analysis of 1986–2007 state waterbird count data indicates that the ‘alae ke‘oke‘o population is stable with a population growth rate of 0.18 percent per year, including a -0.56 percent decline on O‘ahu, Maui Nui, and Kaua‘i NWRs (Underwood et al. 2013). On Kaua‘i, ‘alae ke‘oke‘o are often found in large river valleys such as Hanalei, Lumaha‘i, and Opaeka‘a, and in reservoirs (USFWS 2011e). There is evidence that Kaua‘i birds fly to Ni‘ihau when rains fill ephemeral lakes on that island (Engilis and Pratt 1993) (Figure 2-4). If so, Hanalei NWR supports about 13 percent of the Kaua‘i/Ni‘ihau population in the winter and 20 percent in the summer. From 2010 to 2015, the average number of ‘alae ke‘oke‘o counted during monthly population monitoring at Hanalei NWR was 255 (range 35–641, SE 16.2) (Figure 2-5). These counts likely represent a minimum daytime population estimate because ‘alae ke‘oke‘o are conspicuous, use open-water wetlands and dikes, and detection rates are high.

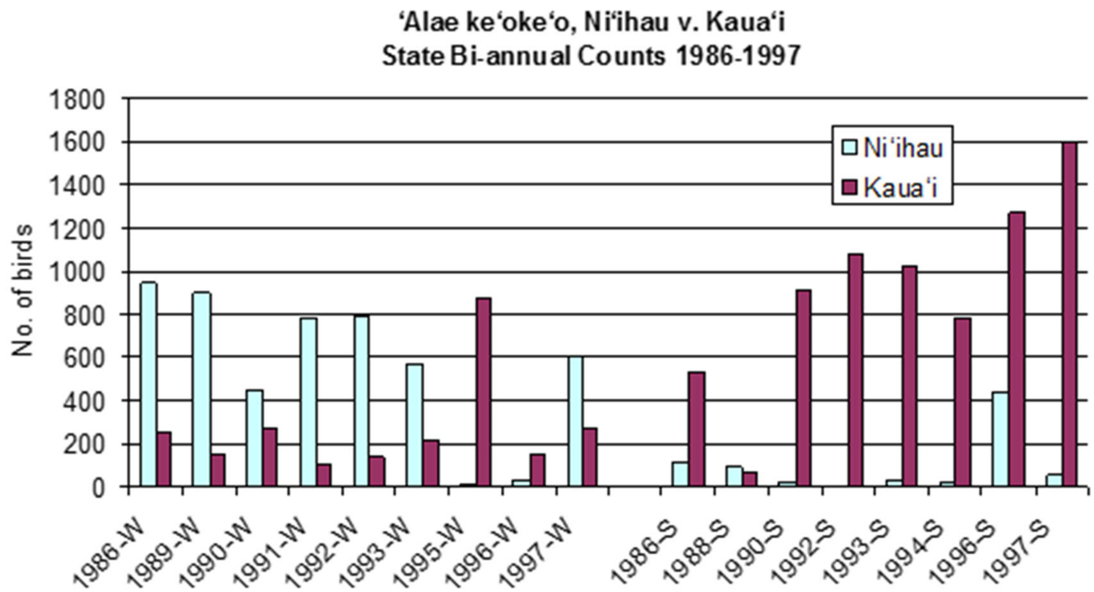


Figure 2-4. ‘Alae ke‘oke‘o State bi-annual counts 1986–1997 (years in database only) conducted during winter (W) and summer (S) indicating bird movements between Ni‘ihau and Kaua‘i in response to the flooding and drying of Ni‘ihau’s ephemeral lakes

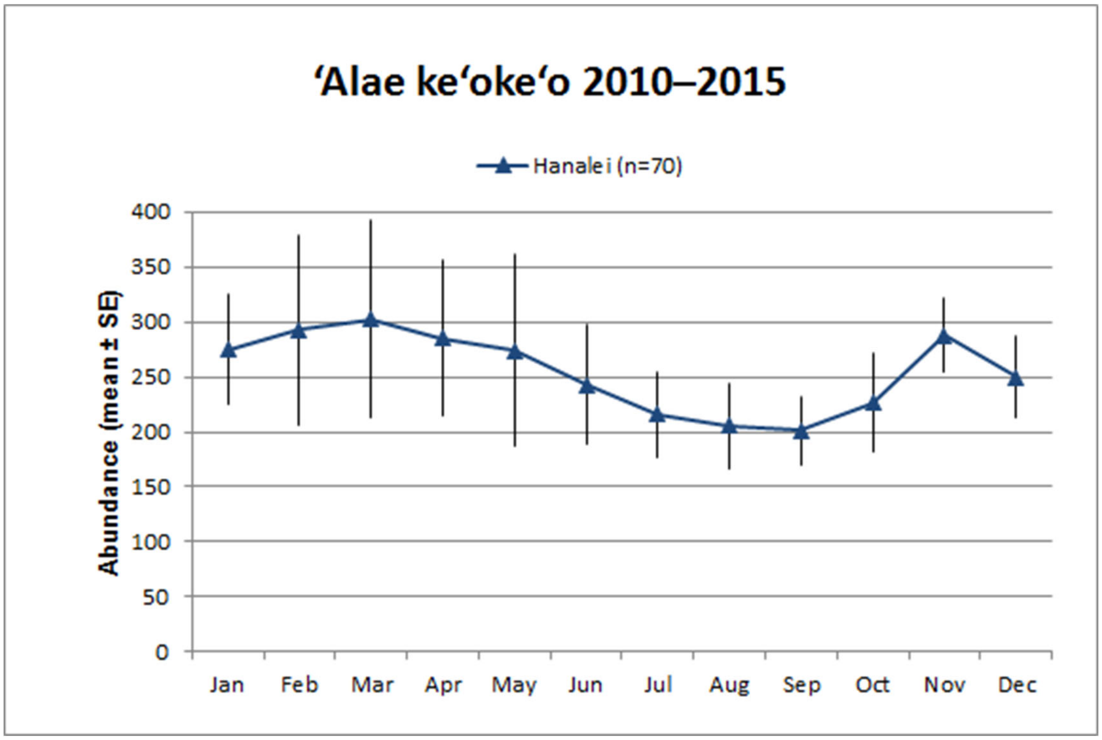


Figure 2-5. Abundance of endangered 'alae ke'oke'o by month at Hanalei NWR

'Alae 'ula (*Gallinula galeata sandvicensis*) or Hawaiian Common Gallinule

The 'alae 'ula is an endemic, nonmigratory, endangered subspecies of the common gallinule. The 'alae 'ula is black on top and slate blue below with white side stripes and a patch under the tail. It is similar to the 'alae ke'oke'o in its chicken-like appearance, but is slightly smaller and sleeker. The 'alae 'ula frontal shield and bill are crimson red with a yellow tip on the bill. Its legs and feet are yellow to greenish with a bright red "garter" at the top. The red blush on the lower legs is unique to the Hawaiian race. Both sexes are similar (Munro 1944). Juvenile birds are olive brown to grayish brown with a pale yellow or brown bill (Taylor 1998). It is also known as the moorhen, mudhen, or 'alae 'ula—the bird that showed Hawaiians how to make fire (Pukui and Curtis 1960).

Historically, the 'alae 'ula was common in lowland marshes and lo'i kalo on all islands except possibly Lana'i, Kaho'olawe, and Ni'ihau (Munro 1944). Today, 'alae 'ula are known to be distributed only on Kaua'i and O'ahu. Population declines were first noted in the early 1900s in Hilo, Hawai'i, due in part to overhunting (Henshaw 1902). By the mid-1900s, 'alae 'ula were considered rare, particularly on O'ahu, Maui, and Moloka'i (Schwartz and Schwartz 1949). Between 1959 and 1983, the State of Hawai'i released small numbers of pairs on Moloka'i, Maui, and the island of Hawai'i, apparently without successful reestablishment (W. E. Banko 1987). There have been no confirmed sightings of 'alae 'ula on Moloka'i since 1985, but a handful of sightings on Maui and the island of Hawai'i suggest sporadic interisland movements (Shallenberger 1977). The total population size is currently unknown; however, it is believed to be less than 2,000 individuals, but stable (DesRochers, Gee, and Reed 2008). The Hawaiian Waterbird Recovery Plan (USFWS 2011e) lists 'alae 'ula as having a moderate degree of threat with a high potential for recovery.

The primary threats to ʻalae ʻula are introduced predators and loss of wetland habitat due to altered hydrology, environmental contaminants, and invasive species, such as California grass and marsh fleabane (USFWS 2011e). ʻAlae ʻula are susceptible to predation by mongooses, rats, cats, and dogs. Predators of ʻalae ʻula chicks and eggs include bullfrogs, common mynahs, largemouth bass, ʻaukuʻu, and cattle egrets (Bannor and Kiviat 2002). Other potential factors limiting ʻalae ʻula include competition for food with nonnative tilapia, avian botulism, and nest loss due to flooding (Byrd and Zeillemaker 1981; Nagata 1983; USFWS 2011e).

ʻAlae ʻula inhabit freshwater marshes, cultivated wetlands, reservoirs, wet pastures, and the vegetated margins of streams and irrigation ditches typically below an elevation of 410 feet. They use brackish or saline wetlands infrequently. A high degree of interspersion of emergent vegetation patches (e.g., bulrushes, grasses) with open water is favorable because ʻalae ʻula typically forage at the edges of vegetation and nest within 7 feet of open water (Chang 1990). Habitat features include floating mats of vegetation, and water depth less than 3.3 feet, optimally with a ratio of 50:50 to 25:75 of open water to emergent cover (USFWS 2011e).

ʻAlae ʻula breed year-round, with peak activity March–August. Nests are usually placed inconspicuously in emergent vegetation over shallow water that is less than two feet deep, with emergent stalks folded over to make a platform nest. If emergent plants are insufficient, nests are placed on the ground (USFWS 2011e). ʻAlae ʻula also nest in or on emergent or floating mats of vegetation along narrow interconnected waterways (Nagata 1983; Chang 1990). In loʻi kalo, ʻalae ʻula usually nest where the kalo is older than four months old (when the canopy starts to close) near patches of other emergent plants (Byrd and Zeillemaker 1981). In lotus fields, nests were placed on the ground under lotus leaves (Nagata 1983). Plants with good structure for nesting include taller sedges and bulrushes. On average, the ʻalae ʻula have a clutch size of 5–6 eggs, which incubate for 19–22 days, and chicks attain flight at 40–50 days old (Byrd and Zeillemaker 1981; Chang 1990; Bannor and Kiviat 2002).

Information is limited on ʻalae ʻula diets, but foods appear to be similar to the common gallinule's diet and influenced by availability. Plant foods predominate but invertebrate foods increase during the spring and summer breeding months. The main foods include seeds of grasses and sedges, forbs, and legumes (Telfer and Woodside 1977); algae; aquatic insects; and snails (Schwartz and Schwartz 1949; Bannor and Kiviat 2002). The ʻalae ʻula may sporadically feed on the young shoots of kalo (Byrd and Zeillemaker 1981) and lotus (Nagata 1983). High value native and naturalized food plants include ʻahuʻawa, *Cyperus polystachyos*, and millet (DesRochers et al. 2009).

Analysis of 1986–2007 state waterbird count data indicates that the ʻalae ʻula population has moderately increased statewide at 6.86 percent per year, including 5.46 percent on Oʻahu, Maui Nui, and Kauaʻi NWRs (Underwood et al. 2013). Kauaʻi is estimated to support about 50 percent of the ʻalae ʻula population (USFWS 2011e). Hanalei and Hulēʻia NWRs currently support at least 20–25 percent of the recovery population goal of 2,000 birds, making these core protected areas and surrounding natural and agricultural wetlands of high importance for recovery of ʻalae ʻula. From 2010 to 2015, the average number of ʻalae ʻula counted during surveys at Hanalei NWR was 391 (range 203–675, SE 11.3) (Figure 2-6). These numbers represent a population index because an unknown number of ʻalae ʻula go undetected in dense plant cover or waterways. In spring 2004, call-broadcast surveys using ʻalae ʻula recordings increased detection rates by 56.3 percent. Incorporation of call-broadcast surveys would improve population estimates (DesRochers, Gee, and Reed 2008).

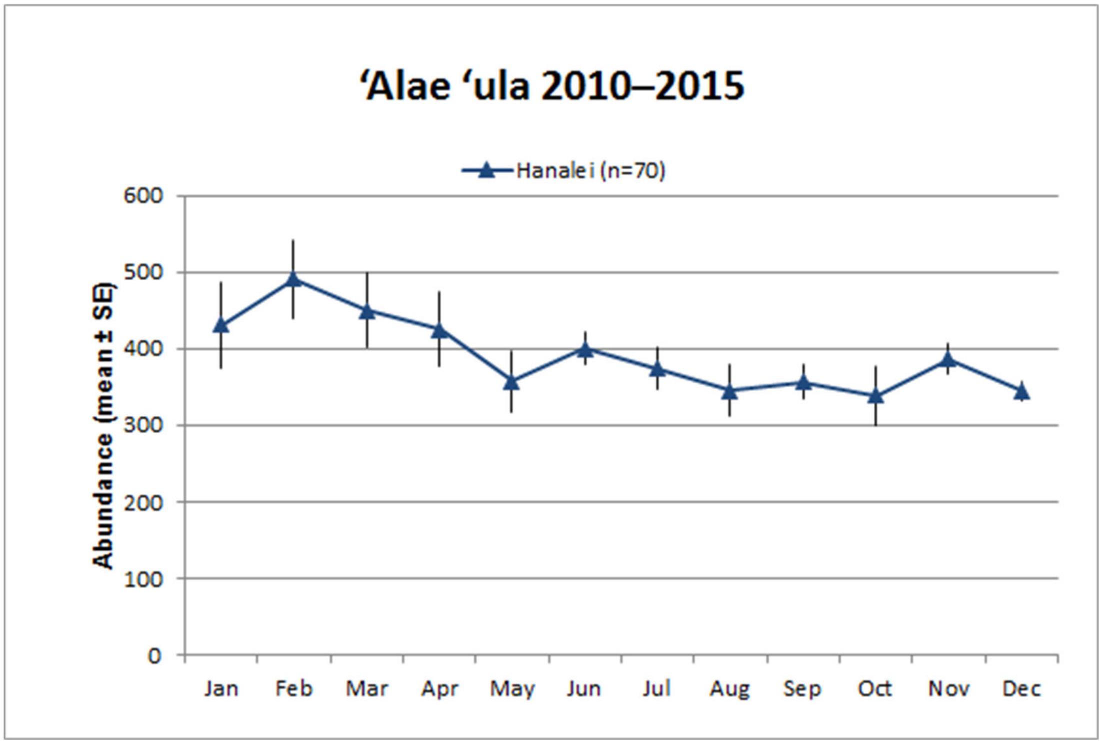


Figure 2-6. Abundance of endangered ʻalae ʻula by month at Hanalei NWR

Aeʻo (*Himantopus mexicanus knudseni*) or Hawaiian Stilt

The aeʻo is an endemic, nonmigratory, endangered subspecies of the North American black-necked stilt. It is a slender wading bird, that is black on top (except for the forehead) and white below, with distinctive long, pink legs. It differs from the black-necked stilt by having black extending lower on the forehead as well as around to the sides of the neck. It also has a longer bill, tarsus (leg), and tail (Coleman 1981; Robinson et al. 1999). Sexes are distinguished by the color of the back feathers (brownish female, black male) as well as by voice (females having a lower voice). Downy chicks are well camouflaged, tan with black speckling. Immature stilts have a brownish back and white feathers extend to cheeks as in the black-necked stilt (Coleman 1981).

Aeʻo were historically documented on all of the major islands except Lanaʻi and Kahoʻolawe (Paton and Scott 1985). Loss of coastal wetlands and pressure from overhunting caused a drop in aeʻo numbers, possibly down to as low as 200 birds in the early 1940s (Munro 1944). Aeʻo received some reprieve when hunting was prohibited in 1939 (Schwartz and Schwartz 1949). Today, aeʻo are found on all of the main Hawaiian Islands except Kahoʻolawe.

Long-term census data indicate that populations have been relatively stable or slightly increasing for the last 30 years (Reed and Oring 1993). Recent estimates place the population at approximately 1,400–2,200 birds (USFWS unpublished). As with ʻalae keʻokeʻo, census data show high year-to-year variability in the number of aeʻo observed, which can be partially explained by rainfall patterns and reproductive success (Engilis and Pratt 1993). Aeʻo readily disperse between islands and constitute a homogenous metapopulation (Reed, Oring, and Silbernagle 1994; Reed et al. 1998). The Hawaiian Waterbird Recovery Plan (USFWS 2011e) lists aeʻo as having a moderate degree of threat with a high potential for recovery.

Threats to the species include the loss of wetland habitat, predation by introduced animals, invasion of wetlands by pest plants and fish, disease, and environmental contaminants. Predation by introduced mammals may be the most important factor limiting recovery of ae‘o. Predators include pueo, ‘auku‘u, laughing gull, ‘akekeke, cattle egret, common mynah, mongoose, rat, cat, dog, and bullfrog (Robinson et al. 1999).

Ae‘o use a variety of coastal fresh, brackish, and saltwater habitats but prefer early successional wetlands. Ae‘o use exposed tidal mudflats, silted fishponds, anchialine pools, and agricultural wetlands. Native wetland plants associated with ae‘o nesting areas include ‘ae‘ae (water hyssop, *Bacopa monnieri*), ‘ākulikuli (*Portulaca oleracea*), and kaluhā (rock bulrush, *Schoenoplectus juncoides*) (Robinson et al. 1999). Lo‘i kalo in wet fallow and early growth stage (mostly open water) can provide good foraging habitats. Ae‘o are rarely found in wetlands above an elevation of 660 feet. Ephemeral lakes on Moloka‘i, Maui, and Ni‘ihau are important for ae‘o. Management techniques that mimic seasonal inundation and evaporation of wetlands are beneficial to breeding ae‘o and provide invertebrate forage for their young. Ae‘o generally forage and nest in different wetland sites, moving between areas daily.

Ae‘o are semi-colonial. Higher nesting densities are found on large mudflat expanses interspersed with sparse, low-growing vegetation (USFWS 1983a) and an abundance of invertebrates. Nests are usually placed on mudflats near shallow water and adjacent to or on low-relief islands within water bodies. Nests are found in both natural and human-made wetlands including seasonal playas, silted fishponds, irrigation reservoirs, settling basins, and kalo patches. Though mudflat islands may deter some terrestrial predators, nests and young are still susceptible to bullfrog and avian predation. The nest is a simple depression on the ground. Often, grass stems and pebbles are used for nesting material (Coleman 1981).

Ae‘o defend an area of 70–100 feet around the nest. The nesting season occurs approximately February–August but varies among years. Ae‘o lay 3–4 eggs that are incubated for approximately 24 days (Coleman 1981; Chang 1990). Chicks are precocial and are able to leave the nest within 24 hours of hatching. Chicks fledge from four to six weeks after hatching. Young may remain with both parents for several months after fledging (Coleman 1981).

Ae‘o are opportunistic feeders. They eat a wide variety of invertebrates and other aquatic organisms as they are available in shallow water and mudflats, specifically water boatmen, beetles, brine fly larvae, polycheaete worms, small crabs, fish, and tadpoles, with the aquatic insects being the most important part of the diet (Robinson et al. 1999; Shallenberger 1977).

Analysis of 1986–2007 state waterbird count data indicates the ae‘o population has moderately increased statewide at 1.98 percent per year, including 3.11 percent on O‘ahu, Maui Nui, and Kaua‘i NWRs (Underwood et al. 2013). On Kaua‘i, ae‘o are often found in large river valleys such as Hanalei, Lumaha‘i, and Opaeka‘a, and in reservoirs (USFWS 2011e). There is evidence that a portion of the Kaua‘i ae‘o population flies to Ni‘ihau when rains fill ephemeral lakes on that island (Engilis and Pratt 1993) (Figure 2-7). If so, Hanalei NWR supports about 14 percent of the Kaua‘i/Ni‘ihau population in the winter and 31 percent in the summer. From 2010 to 2015, the average number of ae‘o counted during monthly population monitoring at Hanalei NWR was 233 (range 40–362, SE 9.0) (Figure 2-8). These counts likely represent minimum daytime population estimates because ae‘o are conspicuous, use open-water wetlands, and detection rates are high.

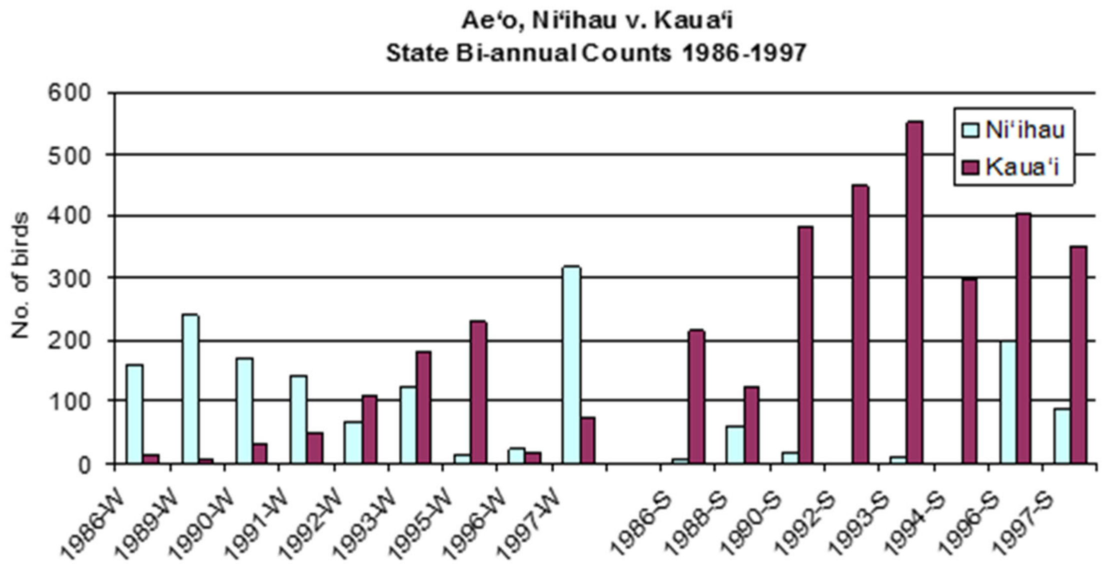


Figure 2-7. Ae'o State bi-annual counts 1986–1997 (years in database only) conducted during winter (W) and summer (S) indicating bird movements between Ni'ihau and Kaua'i in response to the flooding and drying of Ni'ihau's ephemeral lakes

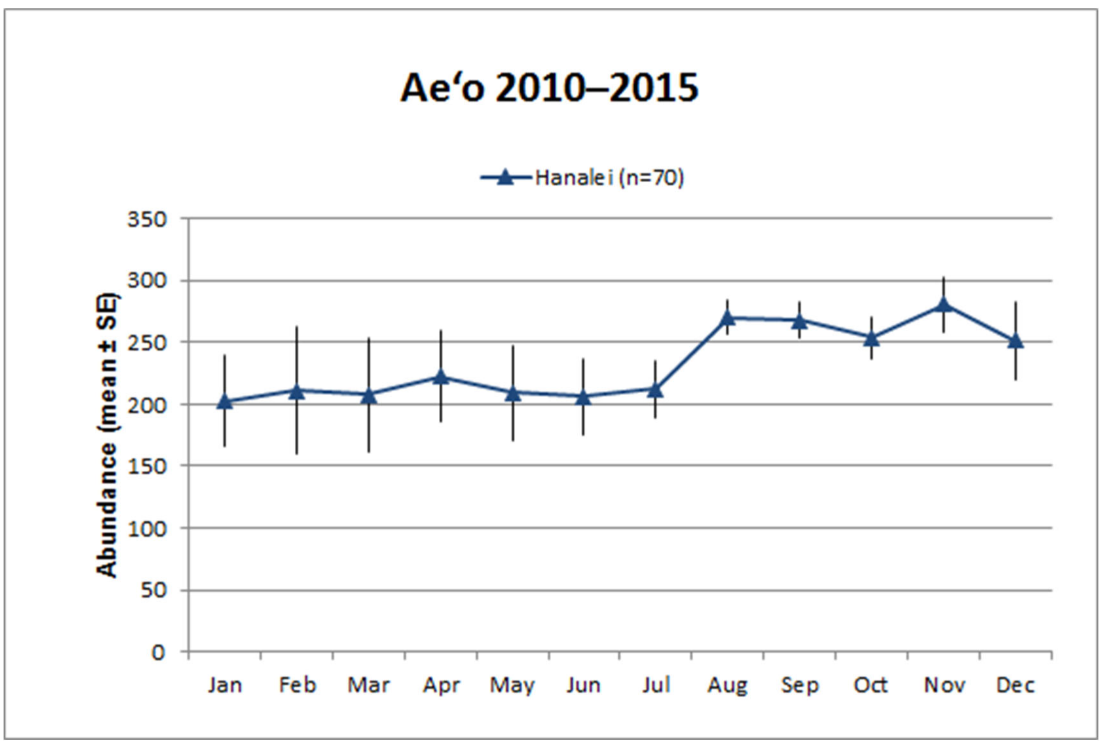


Figure 2-8. Abundance of endangered ae'o by month at Hanalei NWR

Nēnē (*Branta sandvicensis*) or Hawaiian Goose

The threatened nēnē is a member of the waterfowl family (Anatidae), an ancient descendent of the Canada goose. Though similar in appearance, the gander is slightly larger than the goose. It is light gray-brown with a mostly black head, and cream-colored neck with distinctive dark furrows, and black tail and feet. In the 1950s, the nēnē population declined to about 30 birds on Hawaiʻi because of introduced predators, historic overhunting, and habitat loss. The release of captive-bred nēnē, which began in 1960, helped save the species from extinction (USFWS 2004a). As a result of such programs, wild populations of nēnē now occur on four of the main Hawaiian Islands. In 2011, there were an estimated 2,457–2,547 nēnē on Kauaʻi, Molokaʻi, Maui, and Hawaiʻi, with Kauaʻi supporting 1,421–1,511 nēnē or 59 percent of the state population (Nēnē Recovery Action Group, unpublished data 2011; Figure 2-9). The 2017 statewide population of wild nēnē was estimated to be 3,252 individuals comprised of 1,104 on the island of Hawaiʻi, 1,482 on Kauaʻi, 627 on Maui, and 37 on Molokaʻi. These estimates include the 659 birds translocated from Kauaʻi to Hawaiʻi (598) and Maui (48) between 2011 and 2016 (DOFAW 2012). Nearly all birds are the result of an aggressive captive propagation and release program which was initiated by the territorial government (prior to becoming a state) in 1949. This program is credited with bringing nēnē back from the brink of extinction; however, despite a comeback, nēnē still face major obstacles on the road to recovery. Current threats include depredation by introduced predators, inadequate nutrition, lack of suitable lowland habitat, human-related disturbance and mortality, behavioral problems, lack of genetic diversity, and disease. The Draft Revised Recovery Plan lists nēnē as having a high degree of threat and high recovery potential (USFWS 2004a).

The implementation of recovery actions for nēnē has reduced the risk of extinction for the species. Current populations are sustained by ongoing management (e.g., predator control, habitat management for feral ungulates and nonnative plants). Certain key populations are expected to maintain current levels or increase into the future if the current level of management is continued. Consequently, nēnē were downlisted from endangered to threatened, effective January 21, 2020 (84 FR 69918).

Nēnē habitat at Hanalei NWR include grasslands dominated by introduced species, including Hilo grass (*Paspalum conjugatum*) and Bermuda grass (*Cynodon dactylon*), and open-understory riparian shrublands including hau, palustrine (managed wetland units), riverine, and loʻi kalo. Although nēnē are not obligate wetland species, they readily use open-water wetlands, reservoirs, and rivers to drink, bathe, swim, and escape from predators during breeding and molting periods. Nēnē build nests on the ground usually under woody and herbaceous plants with an open canopy. Nesting habitats range widely from beach strand and grassland to shrubland. Species composition varies by availability. For instance, in highlands, native shrubs (e.g., ʻaʻaliʻi [*Dodonaea viscosa*], ʻōhelo [*Vaccinium reticulatum*], pūkiawe [Hawaiian heather, *Leptecophylla tameiameiae*], small ʻōhiʻa [*Metrosideros polymorpha*]) predominate, but in lowlands on Kauaʻi both native (e.g., naupaka [*Scaevola* spp.], pōhinahina [chastetree, *Vitex rotundifolia*]) and nonnative (e.g., lantana [*Lantana camara*], Christmas berry [*Schinus terebinthifolius*], koa haole [white leadtree, *Leucaena leucocephala*], Guinea grass) plants are used.

The nēnē mates for life. The average nēnē clutch size is three eggs (range 1–6 eggs), incubation is usually 30 days (range 29–32 days), and goslings fledge at 10–14 weeks (P. C. Banko, Black, and Banko 1999). Breeding occurs mainly October–March and molting March–June, which is when adults become flightless for 46 weeks while they grow new flight feathers. During this period, nēnē become secretive and are extremely vulnerable to attacks by introduced predators. During the rest of the year, from June–September, nēnē disperse or flock with other family groups in nonbreeding areas where young nēnē have opportunities to find mates. Historically, nēnē were believed to have bred and molted in the lowlands during the winter then moved to higher elevations in the summer. Today, birds move daily between feeding and roosting areas and seasonally between breeding and nonbreeding areas, but altitudinal patterns are less apparent (USFWS 2004a).

The nēnē is a browsing grazer, eating the leaves, seeds, fruits, and flowers of grasses, sedges, forbs, and shrubs (P. C. Banko, Black, and Banko 1999), and will occasionally climb into or perch in bushes to reach berries, such as naupaka and māmaki (*Pipturus albidus*). In many areas, nēnē feed on cultivated grasses. In mid-elevation Hawai‘i, nēnē select forage with high water and protein content, such as the young shoots of a Kikuyu grass (*Pennisetum clandestinum*)–Spanish clover (*Desmodium sandwicense*) grassland. The nēnē prefers sward-forming grasses (turf-like growth) over bunch grasses and short grasses (2–4 inches) over tall grasses and use grasslands less during drought (Woog and Black 2001).

In partnership with DLNR and the Service’s Ecological Services Program, in April 2000, 24 nēnē were repatriated to Hanalei NWR (USFWS 2004a), and in October 2009, 36 nēnē from six family groups were translocated to Hulē‘ia NWR (Michael Mitchell 2011, pers. comm.). From 2010 to 2015, the average number of nēnē counted during monthly population monitoring at Hanalei NWR was 115 (range 40–211, SE 4.7) (Figure 2-10).

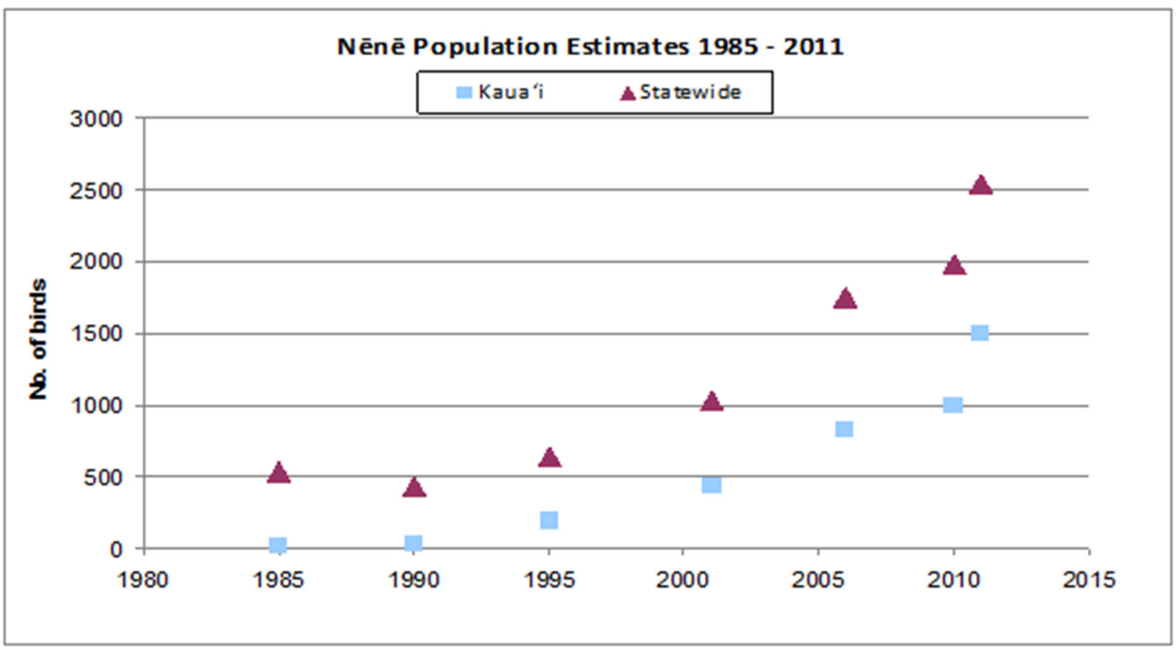


Figure 2-9. Nēnē population estimates on Kaua‘i and statewide (Nēnē Recovery Action Group, unpublished data, 2011)

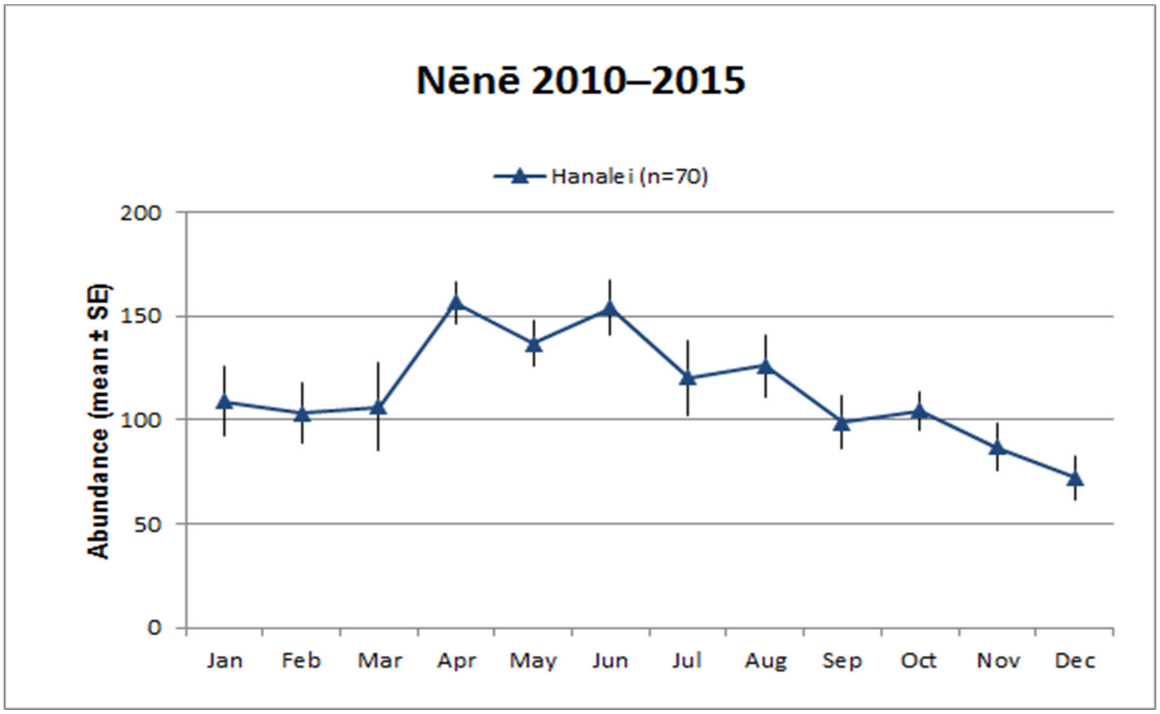
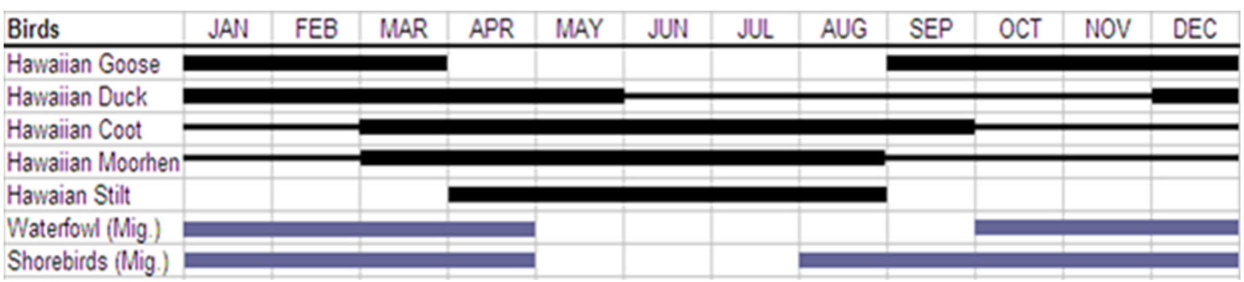


Figure 2-10. Abundance of threatened nēnē by month at Hanalei NWR

Threatened or Endangered Waterbird Peak Breeding Periods

Three of the threatened and endangered waterbirds breed year-round with peaks in breeding related to rainfall or food abundance (Figure 2-11). One species, ae'o, maintains a spring–summer breeding season probably in response to a seasonal abundance in dipteran larvae.



Peak in breeding period is indicated by bold bar.

Figure 2-11. Breeding periods of Hawaiian waterbirds

'Ōpe'ape'a (*Lasiurus cinereus semotus*) or Hawaiian hoary bat

The 'ōpe'ape'a is a medium-sized member of the vesper bat family (Vespertillionidae) which consists of nocturnal, mostly insect-eating bats. It is an endemic and endangered subspecies of the North American hoary bat, a solitary tree-rooster. The 'ōpe'ape'a is Hawai'i's only native terrestrial mammal. Males and females have a wingspan of about one foot, and females are typically larger than males. The ōpe'ape'a has frosted brown and gray fur which gives it a hoary appearance. Fur color, frosted or reddish, may be related to location or age. It is a major predator of night-flying insects such as moths, beetles, and termites. Bats forage in open and wooded landscapes and linear habitats such as windbreaks and riparian zones, and roost in trees with dense foliage and with open access for launching into flight. Females are believed to give birth to twins May–August and rear pups May–September. Pups fledge from about July–September, which is a critical time in the reproductive cycle (Menard 2001; Bonaccorso et al. 2008).

The population size is unknown. Resident populations occur on Kaua‘i, Maui, and Hawai‘i and possibly other main islands, with the highest abundance on Kaua‘i and Hawai‘i. Threats are largely unknown but may include roost disturbance, introduced predators, obstacles to flight such as barbed wire fences and vehicles, and pesticides (USFWS 1998). In winter 2010, three sightings included two bats in transit, and one foraging along the edges of palm trees surrounded by lo‘i kalo (Kim Uyehara 2010, pers. comm.). In September 2010, there were 3–5 bats detected near dwellings along ‘Ōhiki Road and downriver along Kūhiō Highway at Hanalei NWR. Occurrence on the Refuge was further confirmed through an ongoing acoustic call detection study initiated in 2016. The forested ridges and corridors appear to be suitable ‘ōpe‘ape‘a habitat, and detections just after sunset indicate bats are roosting during the day on the Refuge (Corinna Pinzari 2010, pers. comm.).

‘Akē‘akē (*Oceanodroma castro*) or Band-rumped Storm-petrel

The ‘akē‘akē is a small seabird about eight inches long. Although the Hawaiian population was previously recognized as a distinct subspecies, taxonomists today generally combine the various Pacific populations into a single taxon. The ‘akē‘akē probably was common on all of the main Hawaiian Islands when Polynesians arrived about 1,500 years ago (Berger 1972; Harrison, Telfer, and Sincock 1990). In the Hawaiian Islands, ‘akē‘akē are known to nest in remote cliff locations on Kaua‘i and Lehua Island, in steep open to vegetated cliffs, and in little vegetated, high-elevation lava fields on Hawai‘i Island (Wood et al. 2002; VanderWerf et al. 2007; T. Joyce and Holmes 2010; Paul Banko 2015, in litt. cited in 81 FR 67786; Andre Raine 2015, in litt. cited in 81 FR 67786). Vocalizations were heard in Haleakala Crater on Maui in 1992 (Johnston 1992; cited in Wood et al. 2002), on Lanai (Jay Penniman 2015, in litt. cited in 81 FR 67786), and in Hawaii Volcanoes National Park (Cindy Orlando 2015, in litt. cited 81 FR 67786).

‘Akē‘akē are regularly observed in coastal waters around Kaua‘i, Ni‘ihau, and Hawai‘i Island (Harrison, Telfer, and Sincock 1990; J. Holmes, Troy, and Joyce 2009), and in ‘‘rafts’’ (regular concentrations) of a few birds up to 100, possibly awaiting nightfall before coming ashore to breeding colonies. Kaua‘i likely has the largest population, with an estimated 221 nesting pairs in cliffs along the north shore of the island in 2002, and additional observations on the north and south side of the island in 2010 (Harrison, Telfer, and Sincock 1990; Wood et al. 2002; J. Holmes, Troy, and Joyce 2009; T. Joyce and Holmes 2010). Audio detections for Kaua‘i indicate this species may be predominantly breeding on the Na Pali coast and Waimea Canyon, with a very small number in Wainiha Valley (Andre Raine 2015, in litt. cited in 81 FR 67786).

The ‘akē‘akē (Hawai‘i Distinct Population Segment) was listed as endangered under the ESA in 2016 (81 FR 67786). The Hawaiian Islands population of the ‘akē‘akē is the only population within U.S. borders or under U.S. jurisdiction. Threats and conservation efforts for ‘akē‘akē are the same as described for ‘a‘o, below.

Cooper and Day (1995) found that seabirds were using the Hanalei Valley flyway. It is unknown what percentage of these seabirds may be ‘akē‘akē. Recent data maintains that the Hanalei flyway has the highest passage rate of seabirds on the island (DLNR Division of Forestry and Wildlife [DOFAW] n.d., unpublished data cited in DOFAW 2010).

ʻUaʻu (*Pterodroma sandwichensis*) or Hawaiian Petrel

ʻUaʻu are federally listed as endangered. The ʻuaʻu was formerly treated as a subspecies of *P. phaeopygia*, and was commonly known as the dark-rumped petrel (USFWS 1983b). The ʻuaʻu was reclassified as a full species in 1993 because of differences in morphology and vocalization. In 1997, the evolutionary split was confirmed by genetic analyses. The ʻuaʻu was once abundant on all of the main Hawaiian Islands, except Niʻihau. Today, ʻuaʻu breed in high-elevation colonies, primarily on east Maui and Mauna Loa on Hawaiʻi Island, on Lanaʻi, and to a lesser extent, on Kauaʻi, and probably Molokaʻi, Lehua, and sea stacks off Kahoʻolawe, and is estimated to be 6,500–8,300 pairs with an overall population of ~19,000 (Ainley, Telfer, and Reynolds 1997). The breeding season for ʻuaʻu is approximately April–November.

The ʻuaʻu was listed in 1967 (USFWS 1983b), pursuant to the Endangered Species Preservation Act of 1966. The Hawaiian Dark-rumped Petrel and Newell's Manx Shearwater Recovery Plan was published in 1983 (USFWS 1983b), with a species 5-year review completed in 2011 (USFWS 2011b). Critical habitat has not been designated for the ʻuaʻu (USFWS 1983b). Threats and conservation efforts for ʻuaʻu are the same as described for ʻaʻo, below.

The status of ʻuaʻu on the Refuge is unknown. However, on November 22, 2012, an adult ʻuaʻu was recovered on ʻŌhiki Road in front of the Hanalei bunkhouse, which is consistent with radar surveys from Kalihiwai showing ʻuaʻu transiting to and from breeding colonies in the morning and evening hours directly over the Refuge (Andre Raine 2012, pers. comm.). Cooper and Day (1995) found a significant proportion of ʻuaʻu were using the Hanalei Valley flyway. Recent data maintains that the Hanalei flyway has the highest passage rate on the island (DOFAW n.d., unpublished data cited in DOFAW 2010).

ʻAʻo (*Puffinus auricularis newelli*) or Newell's Shearwater

ʻAʻo are federally listed as threatened. It is a member of the genus *Puffinus* and utilizes open tropical seas and offshore waters near its island breeding grounds on forested mountain slopes.

ʻAʻo was once abundant on all of the main Hawaiian Islands. Today, the breeding population is primarily restricted to Kauaʻi; nests have also been documented on Molokaʻi and Hawaiʻi and are suspected on Maui, Lānaʻi, and possibly on Oʻahu (Ainley, Telfer, and Reynolds 1997; M. H. Reynolds and Ritchotte 1997; VanderWerf et al. 2007; Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011).

The most recent population estimate based on at-sea observations is of 84,000 birds in 1993 (Spear et al. 1995). Approximately 90 percent of the population was believed to nest on Kauaʻi (Cooper and Day 1994; Spear et al. 1995; Ainley, Telfer, and Reynolds 1997; Griesemer and Holmes 2011). Using this population estimate and allowing for an estimated 7,600 one-year-old birds that do not visit Kauaʻi, Ainley et al. (1995) estimated that the Kauaʻi island population in the mid-1990s was approximately 65,000 birds, with a breeding population of about 14,600 pairs (Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011).

Since 1993, all indications are that the ‘a‘o population has suffered a sharp decline. The number of fledglings retrieved by the Save-Our-Shearwaters (SOS) program on Kaua‘i has steadily declined since 1979, from an average of about 1,500 per year between 1979 and 1990 to an average of less than 500 collected between 1999 and 2006 (Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011). In 2009, the SOS program handled 265 retrieved birds (Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011). Day et al. (2003) reported analysis of data trends from radar surveys showing an overall decline of roughly 50–70 percent in detection rates between 1993 and 2001; radar surveys show an apparent decline of 75 percent between 1993 and 2008 (N. Holmes et al. 2011); and preliminary indications are a decline up to 80 percent from 1993 to 2015 (Andre Raine, pers. comm.). Using population models incorporating best estimates of breeding effort and success, Ainley et al. (2001) projected an annual population decrease of 3.2 percent. When anthropogenic variables influencing ‘a‘o mortality (e.g., predation, light attraction, and power line collision) were included, their models predict an annual population decline of 6.1 percent, or approximately 60 percent every 10 years (Ainley et al. 2001; Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011). Subsequent modeling by Griesemer and Holmes (2011) using radar and fallout data estimated a more severe decline of about 9–10 percent per year during the last two decades. There is little empirical data to confirm which population estimate is more accurate, but an updated estimate of at-sea ‘a‘o populations analogous (though not identical) to the Spear survey was 27,011 birds (Joyce 2016).

The ‘a‘o was listed in 1975 (USFWS 1983b), pursuant to the Endangered Species Preservation Act of 1966. The Hawaiian Dark-rumped Petrel and Newell’s Manx Shearwater Recovery Plan was published in 1983 (USFWS 1983b), with a species 5-year review completed in 2011. The review recommend uplisting to endangered due to precipitous decline in populations on Kaua‘i over the last couple of decades (USFWS 2011c). Critical habitat has not been designated for the ‘a‘o (USFWS 1983b).

Threats to ‘a‘o are many and varied and cannot be entirely eliminated. Like other birds in the order Procellariiformes, ‘a‘o exhibit strong natal philopatry (tendency to return to birth site to breed) and high nest-site fidelity. These behavioral traits, along with a protracted nesting period and ground nesting habitat, result in great vulnerability of eggs, chicks, and adults to predation by introduced mammals at the breeding colonies (Croxall et al. 2012). Predation by feral cats, feral pigs, rats (particularly black rats), dogs, and barn owls have all been documented (Planning Solutions Inc., Rana Biological Consulting Inc., and Ebbin Moser + Skaggs LLP 2011; Raine and McFarland 2014a; Raine and McFarland 2014b; Ainley, Telfer, and Reynolds 1997). Predation by small Indian mongoose is likely on islands with established mongoose populations. Light attraction (fallout) and collision with artificial structures are also contributors to ‘a‘o mortality (Ainley et al. 1995). Fledglings are the main victim of light attraction-related fallout since it is thought they use the moon and stars to guide them to the ocean and become confused by other sources of light. Collision with artificial structures, predominantly utility lines, kills adults—particularly breeding adults moving to and from montane breeding colonies in the dark (Travers et al. 2014). Habitat loss and degradation from invasive plant species or natural catastrophe (e.g., hurricane or wildfire) is often compounded with predation as reduction in dense native canopy cover can provide access for predators into breeding colonies. ‘A‘o are likely susceptible to marine-based threats as well, such as Pacific-wide changes to food supply, but limited information exists on the scope and intensity of marine-based threats.

The status of ‘a‘o on the Refuge is unknown as surveys have never been conducted there. However, radar surveys from Kalihiwai show ‘a‘o transiting to and from breeding colonies in the morning and evening hours directly over the Hanalei NWR (Andre Raine 2012, pers. comm.). The upper ridges of the Refuge have been identified as potential ‘a‘o breeding habitat (USFWS 2011a) including possibly the northeast and central ridges (Andre Raine 2012, pers. comm.). Cooper and Day (1995) found a significant proportion of ‘a‘o were using the Hanalei Valley flyway. Recent data maintains that the Hanalei flyway has the highest passage rate on the island (DOFAW n.d., unpublished data cited in DOFAW 2010). The breeding season for ‘a‘o is approximately April–November (Ainley, Telfer, and Reynolds 1997).

2.5.2 Other Key Wildlife Species Supported

Birds

In addition to the above-described species, the wetland habitats of Hanalei NWR provide feeding, resting, or breeding habitat for a variety of both resident and migratory species. Hawaiian wetlands provide critical stopover and wintering habitat for at least 36 species of migratory waterfowl (ducks, geese, swans) from both North America and Asia annually from approximately October–April. The koloa mohā (northern shoveler, *Anas clypeata*), koloa māpu (northern pintail, *Anas acuta*), lesser scaup (*Aythya affinis*), American and Eurasian wigeons (*Anas americana, Anas penelope*), and green-winged teal (*Anas crecca*) represent 95 percent of the migratory waterbird records. Of the 36 migratory waterfowl species documented for the Hawaiian Islands, at least 29 have been observed at Hanalei NWR. Of these, the most common are koloa māpu, koloa mohā, and American wigeon.

The Pacific Island region functions as an essential migratory habitat for maintaining global shorebird populations. At least 49 species of shorebirds (plovers, sandpipers, and waders) have been recorded in the Hawaiian Islands (Pyle and Pyle 2009). The most common migratory shorebirds by order of abundance are kōlea (Pacific golden-plovers, *Pluvialis fulva*), ‘akekeke (ruddy turnstones, *Arenaria interpres*), ‘ūlili (wandering tattlers, *Tringa incana*), and hunakai (sanderlings, *Calidris alba*). The only resident shorebird is the ae‘o. A majority of the migratory shorebirds occur in the Hawaiian Islands August through April (Engilis and Naughton 2004).

The kōlea is the most common shorebird in the Pacific region, with Hawai‘i supporting a substantial portion of the Alaskan breeding population during winter. The kōlea is known to make direct, nonstop trans-Pacific flights to and from Alaskan breeding grounds covering approximately 2,980 miles in three days (Johnson et al. 2011). The kioea (bristle-thighed curlew, *Numenius tahitiensis*) is the only migratory species that winters exclusively on Pacific islands, with an estimated 800 birds wintering in the northwestern Hawaiian Islands (Marks et al. 2002). The Pacific region is considered to be a critical area for supporting regional populations of these two species as well as ‘ūlili. Shorebird habitats include primarily wetlands, tidal flats, and estuaries; however, grasslands and beaches are important for the kōlea and the kioea (Engilis and Naughton 2004).

At least 24 of the 49 species of migratory shorebirds documented for the Hawaiian Islands have been observed at Hanalei NWR. Of these, the most common are kōlea, ‘ūlili, and ‘akekeke. Kōlea are by far the most numerous species on the Refuge, accounting for 90 percent of the migratory shorebirds. The primary habitat is mowed dikes, but shallow wetlands and lo‘i kalo are also used. Fallow units with open mudflats are used for night roosting, stopover, and rest/post-migration. Kōlea use the Refuge mainly August through April.

Fish

All five species of Hawaiian ‘o‘opu inhabit the Hanalei River, which includes one indigenous and three endemic true gobies and one endemic sleeper goby. The ‘o‘opu are amphidromous, migrating between freshwater and seawater, but not for the specific purpose of breeding. Instead, ‘o‘opu spawn in fresh or brackish water, and the newly hatched larvae flow out to sea for a period of feeding and growing, then return to freshwater as well-grown juveniles for period of feeding and maturing prior to reproduction. True gobies can be distinguished from sleeper gobies by their fused pelvic fins which form a sucking disc for clinging to rocks or scaling waterfalls. The most impressive climber is ‘o‘opu alamo‘o, found above the 400-foot high ‘Akaka Falls on Hawai‘i Island. Each species occupies an overlapping but unique niche in Hawaiian streams. For example, ‘o‘opu nōpili prefers faster flows of runs and riffles within middle reaches and can be used as indicators of good water quality (Yamamoto and Tagawa 2000). The greatest threat to ‘o‘opu is habitat loss and degradation including dewatering streams through diversions, dams, and channel modifications. ‘O‘opu that swim into waterways and become trapped in lo‘i kalo or other impoundments are unlikely to survive. Excessive sedimentation and nutrient loads degrade habitat and food resources. Other threats include introduced fishes including tilapia, mosquitofish, and several catfish species, and parasites associated with introduced and pest fishes.

TABLE 2-7. ‘O‘OPU OCCURRING AT HANALEI NWR

Name	*Status*	*Reach*	*Adults*	*Juveniles*	*Spawning*
Eleotridae – Sleeper Gobies					
‘O‘opu akupa *Eleotris sandwicensis*	Endemic	Lower	Predaceous	Predaceous	Rainy season
Gobiidae – True Gobies					
‘O‘opu nākea *Awaous guamensis*	Indigenous	Middle	Omnivorous	Omnivorous	Rainy season
‘O‘opu alamo‘o *Lentipes concolor*	Endemic	Upper	Omnivorous	Primarily herbivorous	Nov–Mar
‘O‘opu nōpili *Sicyopterus stimpsoni*	Endemic	Middle	Primarily herbivorous	Omnivorous	Aug–Mar
‘O‘opu naniha *Stenogobius hawaiiensis*	Endemic	Lower	Omnivorous	Omnivorous	Year-round

Yamamoto and Tagawa (2000)

Invertebrates

Lo‘i kalo supports at least three orders of annelids, 5 orders of mollusks, and 16 orders of arthropods where agricultural practices appear to drive invertebrate communities. In a lo‘i kalo macroinvertebrate study, Ampullariidae (apple snails), Chironomidae (midges), Glossiphoniidae (leeches), Lymnaeidae (pond snails), Oligochaeta (aquatic worms), Sphaeriidae (fingernail clams), and Thiaridae (thiarid snails) were the most abundant invertebrate taxa found in various crop stages, with generally higher taxa richness and insect densities in lo‘i that contained more than 25 percent naturally occurring wetland plants and low taxa richness and higher total invertebrate densities in lo‘i that contained little or no naturally- occurring wetland plants (Gutscher-Chutz 2011).

2.6 INVASIVE SPECIES

For the purpose of this WMWCP, "invasive" is a subset of nonnative species and is also used interchangeably with "pest" according to our integrated pest management (IPM) program (see Appendix D). An invasive species is defined as a species whose migration and growth within a new range is causing detrimental effects on the native biota in that range. These species become invasive because their population and growth are no longer balanced by natural predators or biological processes that kept them in balance in their native ecosystems. In the absence of these restraints, invasive species have the potential to compete with native species for limited resources, alter or destroy habitats, shift ecological relationships, prey on native species, and transmit diseases.

Invasive species are one of the most serious problems in conserving and managing natural resources. In particular, the ecological integrity of Pacific Island environments is greatly threatened by invasive species. Hawai‘i, which existed in isolation for millions of years, is an exceptionally ideal environment for invasive species. Most native species lost their natural defense mechanisms and are more vulnerable to introduced species (Meffe and Carroll 1997).

2.6.1 MAMMALS

Rat (*Rattus* spp.)

Three nonnative rat species are found throughout the Hawaiian Islands. Polynesian rats (*Rattus exulans*) arrived from the central Pacific approximately 1,500 years ago with the Polynesians who settled 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 rat species have populated nearly 82 percent of the major islands and island chains throughout the globe. Black and Polynesian rats have a large distribution and can be found from sea level to 10,000 feet. Norway rats are restricted to areas below 6,000 feet. Polynesian 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 (Tomich 1986; Tobin and Sugihara 1992; Hays and Conant 2007).

Globally, introduced *Rattus* species have caused the decline, extirpation, or extinction of insular bird species. In the main Hawaiian Islands, Atkinson (1977) suggested that black rats caused the accelerated decline or extinction of many native forest birds between 1870 and 1930. Polynesian rats are speculated to have been a contributing factor in the large-scale extinctions of Hawaiian bird species during Polynesian settlement prior to European contact. Rats continue to be a major threat to waterbirds, seabirds, and forest birds in the Hawaiian Islands. All three rat species in Hawai‘i are known predators of eggs, nestlings, young, and occasionally adults of threatened or endangered waterbirds, seabirds, migratory shorebirds, and forest birds. Rats also consume plants, insects, mollusks, herpetofauna, and other invertebrates. Because these species are also eaten by birds, a reduction in these populations may indirectly affect avian populations (Olson and James 1982; USFWS 2004a; USFWS 2005a; Mitchell et al. 2005).

The use of snap traps and ground-based application of Diphacinone rodenticide to control rats in the main Hawaiian Islands has shown a positive effect in native bird survival. Using these two treatments, rodent abundance dropped 58–90 percent within 1 month of treatments for three years in a row at Hakalau Forest NWR on the island of Hawai‘i. The estimated cost for treating a 247-acre grid in the first year was $7,000, and $2,000 per year in years two and three (Nelson et al. 2002).

At Hanalei NWR, rats and mice may be controlled year-round through the use of trapping (e.g., snap traps or self-resetting Goodnature A24 traps) set at specific targeted locations.

Cat (*Felis catus*)

Cats in the United States kill more than one million birds per day on average (Dauphine and Cooper 2011) and are recognized by the International Union for Conservation of Nature as one of the “world’s worst” invasive species (Lowe et al. 2000). Cats have a universally damaging effect on island forest birds, breeding seabirds, resident waterbirds, and migratory shorebirds and waterfowl (Smucker, Lindsey, and Mosher 2000; USFWS 2004a; USFWS 2005a; USFWS 2011e; Mitchell et al. 2005). The diet of feral cats in Hawai‘i includes insects, crustaceans, amphibians, lizards, mice, rats, birds (eggs, young, and adults), endangered ‘ōpe‘ape‘a, grasses, and seeds.

Cats are found on all the main Hawaiian Islands from sea level to 10,000 feet, in urban to very remote areas. On remote lands of Mauna Kea on the island of Hawai‘i, feral cats prey on about 11 percent of endangered palila nests (finch-billed Hawaiian honeycreeper) annually, and radio-collared male cats can range up to eight square miles. Cats are most active at night when birds are roosting or incubating eggs and are more vulnerable to predation (S. Hess 2011).

In addition, cats are reservoirs of diseases that can be transmitted to birds and other mammals including humans. Feral and domestic cats are the definitive hosts for an infectious parasite called *Toxoplasmosis gondii*, which reproduces in cat intestines and shed in cat feces. The *T. gondii* parasite has been linked to deaths of ‘ā (red-footed booby), threatened nēnē, critically endangered ‘alalā (Hawaiian crow, *Corvus hawaiiensis*) (Work et al. 2000; Work et al. 2002), and critically endangered ‘īlio-holo-i-kauaua (Hawaiian monk seal, *Monachus schauinslandi*) on the coast of Kaua‘i (Honnold et al. 2005).

At Hanalei NWR there is ongoing evidence of cats killing endangered koloa maoli, ae‘o, ‘alae ‘ula, and ‘alae ke‘oke‘o from analysis of cat stomach contents, photos taken with the use of trail cameras, and waterbird carcass recoveries on dikes. From January 2012 to December 2014, there were 305 waterbird carcasses collected on the Refuge during avian botulism surveys with cat or owl kill sign, averaging over 100 carcasses annually. Of these carcasses, 82.6 percent, 12.8 percent, and 4.6 percent were classified as cat kills (n=252), owl kills (n=39), or cat or owl kills (n=14), respectively. Of the 252 cat kills, 81 percent were ‘alae ‘ula and ‘alae ke‘oke‘o and 94 percent were threatened or endangered species.

Sources of cats on the Refuge include abandoned domestic animals and feral cats immigrating from adjacent areas. Due to ongoing threats and the presence of free-roaming cats across Kaua‘i, feral cat control is conducted on NWRs year-round. Trap cycles last from two to seven days with at least 10–25 traps per Refuge active on a bi-monthly basis. In addition, cats are trapped opportunistically when fresh carcasses of threatened or endangered birds show evidence of cat depredation or when cats have been detected in the area. Cats captured with collars and showing domesticated behavior are transported to the Kaua‘i Humane Society. Feral cats that are caught on the Refuge are humanely euthanized following the American Veterinary Medical Association (AMVA) guidelines for euthanasia (AVMA 2013). Control is conducted by trained Service staff, volunteers, or contractors. Trapping success varies widely depending on many factors, including the cat’s condition, food availability, methods, and techniques. From January 2014 to September 2019, there were 257 feral/stray cats (10,710 effective trap nights) removed from Hanalei NWR. An average of 43 (8.6 standard deviation) cats were caught each year.

Indian Mongoose (*Herpestes javanicus*)

The Indian mongoose was intentionally introduced to numerous island ecosystems during the 1800s and 1900s and has since expanded to large portions of Asia, Africa, Europe, Oceania, and the Americas. In 1883, the species was introduced to the main Hawaiian Islands as a biocontrol agent to eradicate rats from sugarcane fields. The mongoose inhabits all habitat types from sea level to nearly 10,000 feet on the islands of Hawaiʻi, Maui, Oʻahu, and Molokaʻi. In other areas of the world, mongooses appear to avoid wet areas; however, in Hawaiʻi, dense populations of mongooses are concentrated in wet habitats. The mean home range of a female in Hawaiʻi is approximately 3.5 acres, and the main reproductive period occurs February–August. The high density of mongooses in the Hawaiian Islands is due to abundant food and the lack of natural predators (Tomich 1986; Hays and Conant 2007).

Mongooses are voracious omnivores, consuming insects, reptiles, mammals, amphibians, crabs, plants, and birds. In Hawaiʻi, mongooses are diurnal predators that primarily eat invertebrates and small mammals as well as plants, birds, reptiles, and amphibians. They are a major threat to any ground-dwelling and -nesting species in Hawaiʻi. These mammals are known to eat eggs, young, and adults of the threatened and endangered waterbirds, various seabirds, migratory waterfowl and shorebirds, and young sea turtles (Mitchell et al. 2005; Hays and Conant 2007)

Since 1968, mongoose sightings have been reported in many of the inhabited and regularly travelled parts of Kauaʻi at increasing rates with varying degrees of credibility (Keanini, Speith, and Gundersen 2010). Until recently, Kauaʻi was thought to be mongoose-free. On May 23 and June 29, 2012, two live mongooses were captured in Līhue and Nāwiwili Port, reconfirming presence of mongooses on Kauaʻi. On October 11, 2016, a juvenile mongoose was captured at Līhue Airport exiting a cargo shipment. Previously, the only hard evidence of mongooses on the island was a Kalāheo roadkill of a lactating female in November 1976. In September 2010, an unconfirmed mongoose sighting was reported on Kūhiō Highway along Hanalei NWR. Less than one year earlier, a mongoose was reported at the Hanalei NWR overlook. On May 13, 2012 a mongoose was sighted on the northern boundary of Hulēʻia NWR near Halehaka Road. Other evidence includes 160 credible sightings, including more than 70 within the last 10 years, with sightings concentrated near Nāwiwili Port and Port Allen. Credible mongoose sightings occurred in 2012–2013 all over Kauaʻi, from Polihale to Lihuʻe to Kīlauea, indicating that mongooses could eventually be detected within the Refuges.

Mongooses have been detrimental to native ground-nesting birds on other Hawaiian islands, and the effects are expected to be even more detrimental on Kauaʻi, as the island is the last stronghold for several threatened and endangered species.

Feral pig (*Sus scrofa*)

Feral pigs that occur in Hawaiʻi 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 approximately 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, Chapuis, and Michel 2003; Cruz et al. 2005) and occupy every main island in the Hawaiian archipelago (Tomich 1986).

The pigs are long and narrow in shape, predominately black in color, and generally hairy. The pigs measure 3.5–4.5 feet in length and average two feet in height. Pigs are highly intelligent and elusive animals. They have been reported to be highly active in the early morning and late afternoon in tropical climates. 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. Pregnancy can occur year-round with peaks between January–March. The average sow in Hawaiʻi has 1.1 liters per year. Reproductive rates peak between 2–4 years, but breeding has occurred by 10-month-old sows (S. C. Hess et al. 2006).

Pigs are an omnivorous species that consume fruits, seeds, plant material, invertebrates, and opportunistically, the eggs and young of ground-nesting birds. In Hawaiʻi, 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 and dig up soil for earthworms and underground plant parts. Pigs act as vectors for invasive plants, such as strawberry guava (*Psidium cattleianum*) and banana poka (*Passiflora tarminiana*) (LaRosa 1992; Stone, Cuddihy, and Tunison 1992). Pigs are also vectors for human disease such as leptospirosis; they are known to harbor at least 30 viral and bacteriological diseases, many of which are transmissible to humans. They have also been known, through their digging and rooting activities, to damage cultural resources.

Other ecosystem effects can also 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 leading to degraded water quality. Pigs are controlled seasonally at Hanalei NWR, or as needed. Techniques for controlling wild pigs include exclusion fencing, shooting, and live-trapping using baited walk-in pen traps. Pig control efforts and methods vary year-to- year. There were 80 pigs removed from KNWRC in 2008 (6.7 pigs/month) and and additional 22 pigs removed during the first three months of 2011 (7.3 pigs/month) (USFWS 2011d).

2.6.2 Birds

Cattle egret (*Bubulcus ibis*)

Cattle egrets were introduced to Hawaiʻi from Florida in 1959. The release was sponsored by local ranchers and the Hawaiʻi State Board of Agriculture to control pasture insects. Nearly 150 birds were released on all the main islands except Kahoʻolawe. After one year, successful breeding was recorded on Oʻahu where egrets were quick to establish. On Kauaʻi, egret numbers remained low until 1975, when the population exploded. By 1982, Kauaʻi had three active roost sites totaling approximately 8,000 birds, including a rookery of 4,000 birds at Crater Hill in Kīlauea. By the mid-1980s, cattle egrets were well established on five of the main islands.

Cattle egrets are highly adaptable and generally found foraging in grasslands and shallow wetlands, but will also feed in roadside ditches and landfills. Roosts in the Hawaiian Islands are usually on level lowland areas near water bodies, often in trees less than 30 feet high. It is the only species in the family Ardeidae (herons) that can breed at one year of age. Reproduction in the Hawaiian Islands occurs year-round and clutch sizes average three eggs (range 2–6 eggs) (Paton, Fellows, and Tomich

1986). Chicks, known as “branchers”, begin wandering on branches at 14–21 days and fledge at 25–30 days. Some birds in Hawaiʻi may breed twice per year (Telfair 2006).

Cattle egrets are opportunistic feeders. In addition to pest insects, they consume a variety of native and nonnative invertebrates and small vertebrates such as fishes, skinks, and frogs, and seabird and threatened or endangered Hawaiian waterbird chicks (USFWS 2011d). Cattle egrets are controlled at airports to avert bird strikes and at wildlife sanctuaries to protect endangered species (Paton, Fellows, and Tomich 1986).

At Hanalei NWR, the mean number of cattle egrets counted during 1986–2006 state bi-annual waterbird surveys was 79 (range 11–233, SE 7.7), and during January 2010–May 2011 Refuge monthly counts were 90 (range 8–179, SE 10.3). From 2010 to 2015, the average number of cattle egrets counted during monthly population monitoring at Hanalei NWR was 109 (range 23–300, SE 5.3). These counts represent minimum daytime numbers in wetland areas and do not include evening roosts. From 2007 to 2010, 291 cattle egrets were removed from KNWRC, at an average of approximately 100 individuals per year (USFWS 2011d). Cattle egret hazing and removal at the Refuge is a low priority compared to control of other more damaging invasive species; however, the Refuge may need to reinstitute control techniques at some point in the future should substantial loss to threatened or endangered species due to cattle egrets become an issue again. Techniques for cattle egret removal include shooting and other methods, as regulated by the “Control Order for Introduced Migratory Bird Species in Hawaii” approved in 2017 (82 FR 34419; 50 CFR 21.55).

Feral mallard (*Anas platyrhynchos*)

Worldwide, native ducks are vulnerable to invasion and hybridization with feral mallards, particularly when populations are already suffering from habitat loss and introduced mammalian predators. The greatest threat to the persistence of endangered koloa maoli is hybridization with the introduced mallard. In the 1950s and 1960s, hundreds of mallards were imported from North American game farms to stock hunting areas in the Hawaiian Islands. Resident feral mallards are believed to be the descendants of domestic stock. Migratory mallards that occasionally stop over or winter in the Hawaiian Islands are rare, not in breeding condition, and are not known to pose a threat to koloa maoli.

In addition to the “true” mallard, there are domestic mallard breeds or “barnyard ducks.” They come in various shapes, sizes, and colors. They can breed with and are the same species as the mallard, including Pekin, Khaki Campbell, Blue Cayuga, Rouen, and Indian Runner. Although the chances of a koloa maoli and barnyard duck directly hybridizing in the wild are very small, there are concerns about the large numbers of abandoned domestic ducks found on public water bodies and the possibilities that these ducks harbor bird and human diseases (Uyehara, Engilis Jr., and Reynolds 2007).

In the late 1980s, the mallard was placed on the State of Hawaiʻi’s List of Restricted Animals for importation, which allows exceptions for research and exhibition. In 2002, the Hawaiʻi Department of Agriculture placed an embargo on all birds shipped to the islands (with some exceptions, for example, fertile eggs) to protect the public from West Nile Virus. However, the mallard continues to reproduce and be sold in the state. The state’s population index shows alarming trends with an overall slight decrease in koloa maoli observations and a substantial increase in mallard and mallard/koloa hybrid observations within the past 20 years (Hawaiʻi Conservation Alliance 2008);

genetic studies support interpretation of these trends (Fowler, Eadie, and Engilis Jr. 2009). See additional information on hybridization of koloa maoli under Section 2.5.1 (Koloa maoli).

Feral mallards and hybrids also potentially threaten other listed Hawaiian waterbirds by competing for limited wetland resources. Techniques for removing feral mallards and hybrids include live-trapping and euthanasia or shooting, which are regulated by the ESA and MBTA permits. From 2007 to 2012, the Refuge removed about one feral mallard or hybrid duck annually. In 2011 with increased monitoring, removed eight hybrid ducks to protect endangered koloa maoli (USFWS 2011d). Kaua‘i and Ni’ihau are the last stronghold for pure koloa maoli, as they hold more than 80 percent of the total population of pure koloa maoli. Removing the threat of koloa maoli hybridization by feral mallards is a primary recovery action in the Hawaiian Waterbird Recovery Plan (USFWS 2011e) and is important to achieving the Refuge’s purpose.

Barn owl (*Tyto alba*)

The barn owl, which is native to North America, is found throughout the main Hawaiian Islands, including offshore islets such as Lehua near Kaua‘i, where they were introduced in 1958 for rodent control (Pyle and Pyle 2009). Barn owls can be distinguished from pueo (Hawaiian owl) by their primarily nocturnal habits, rounder faces, and lighter coloring.

In their native environment, barn owls specialize in hunting small ground mammals and the vast majority of their food consists of small rodents. However, in the Hawaiian Islands they are known to be serious predators of seabirds and waterbirds, including the endangered koloa maoli and ‘alae ke‘oke‘o. Because barn owls will breed at any time during the year and, depending on food supply, can reproduce up to two times per year, they are able to increase rapidly in a relatively short period of time. Barn owls likely compete with the native pueo for introduced rats and mice and could potentially be limiting their population. Techniques for barn owl removal, including trapping and shooting, are regulated by the “Control Order for Introduced Migratory Bird Species in Hawaii” approved in 2017 (82 FR 34419; 50 CFR 21.55). From 2013–2019, there were 12 barn owls removed from Hanalei NWR.

2.6.3 Fishes

Fishes of the topminnow family (Poeciliidae), including guppies (*Poecilia reticulata*), mollies (*Poecilia* spp.), and mosquitofishes (*Gambusia* spp.), bear live young. Thus, only a single gravid female is necessary to establish or re-establish a population. For instance, female *Gambusia* can bear up to 50–100 live young every 4–5 weeks, 5 or more times per season. In the tropics, where *Gambusia* have fewer seasonal constraints, there is evidence of year-round reproduction. Thus, in one year a single mature female *Gambusia* could produce 500–1200 offspring, and her female offspring are able to reproduce as early as 18 days (Pyke 2008), resulting in tens of thousands of *Gambusia* within several months. Although small fishes provide a food source for the native ‘auku‘u and are opportunistically fed on by adult ae‘o (Broshears 1980), introduced mosquitofish and mollies can negatively impact endangered waterbirds through competition for invertebrate foods and are potentially a major source of nitrogen in wetlands.

Introduced tilapia can indirectly impact native birds by heavily modifying aquatic plant communities and degrading water quality (MacKenzie, Bruland, and Kryss 2008). At Keālia Pond NWR in Maui, Wirwa (2007) found that tilapia reduced macroinvertebrate densities by 48–96 percent. In addition, high densities of these exotic fishes increase the risk of avian botulism by impairing water quality and providing a protein substrate for the pathogen. The primary techniques to control invasive fishes in the managed wetland units are water level drawdowns to concentrate and expose fish to fish-eating birds and fish screens to keep fishes out.

2.6.4 Amphibians

Bullfrog (*Rana catesbeiana*)

Bullfrogs are native to eastern North America. They were intentionally introduced to Hawai‘i from California in the late 1800s to provide a food source for people. They now occur on Kaua‘i, O‘ahu, Moloka‘i, Maui, and Hawai‘i. Bullfrogs are highly predaceous, feeding on insects and animals that can fit in their large mouths (Kishinami 2001). Bullfrogs have a negative effect on native Hawaiian species. Endangered koloa maoli ducklings have been found in the stomach contents of bullfrogs on O‘ahu (Engilis, Uyehara, and Giffin 2002). Studies using radio transmitters to track the fate of endangered ae‘o chicks at James Campbell NWR on O‘ahu found that bullfrogs were responsible for 45 percent of ae‘o chick deaths over two years (Eizenga n.d., unpublished data).

In temperate zones, bullfrog maturity is attained at a body length of 3–4 inches, females annually lay 1,000–25,000 eggs, eggs hatch in 3–4 days, and larvae mature in two years. In the tropics, frogs mature at a faster rate and reproduce more frequently (Bury and Whelan 1984). Techniques to control bullfrogs include water level drawdowns to expose bullfrogs to bird predators such as ‘auku‘u, lured swim-in traps, and spot-lighting and spearing. Bullfrog control efforts and methods at Hanalei NWR vary from year to year and are not comparable among years. In 2007, 2008, and 2010, a total of 1,981 bullfrogs were removed from the Refuge with a high of 1,721 bullfrogs in 2008 (USFWS 2011d).

Cane toad (*Bufo marinus*)

Cane toads, which are native to Latin America, have a broad geographic range that includes a majority of the Pacific region. The toads were brought to the Hawaiian Islands in 1932 to control insect pests. The adults only require water for breeding, an event which results in thousands of eggs per mating occurrence. Tadpoles are a food source for waterbirds. Cane toads are active at night and primarily feed on cockroaches, crickets, grasshoppers, grubs, earthworms, slugs, spiders, centipedes, and snails. In addition, these highly invasive amphibians could be a potential predator of endangered waterbird eggs and young (Yamamoto and Tagawa 2000; Kishinami 2001).

Coqui (*Eleutherodactylus coqui*)

Coqui frogs, which are native to Puerto Rico, were accidentally introduced to the Hawaiian Islands in the late 1980s through eggs or frogs in nursery plants. They are small, nocturnally active, brown frogs approximately 1 inch in length. Their habitat includes moist leaf bases of foliage and leaf litter from the coastal zone to 4,000 feet elevation or higher. Coqui are a human health and quality of life nuisance because of the male’s loud, high-pitched, two-note call “co-kee,” heard primarily at night. They eat large number of small insects, in native and nonnative habitats, posing a threat to native insects and insectivores (Kishinami 2001). Coqui have occurred on five of the main Hawaiian Islands including the Island of Kaua‘i. In 2001, a breeding population was discovered in Lawai, but after extensive eradication efforts by the Kaua‘i Invasive Species Committee (KISC) and partners, Kaua‘i was declared “coqui-free” in June 2012. Coqui are not known to occur on the Refuge. However, in May 2014 KISC responded to a report of coqui on the north shore of Kaua‘i (State of Hawai‘i

Department of Agriculture 2014). In April 2017, a single male coqui was contained and eliminated in Līhuʻe (Else 2017).

2.6.5 GOLDEN APPLE SNAIL *(POMACEA CANALICULATA)*

Between 20 and 30 species of introduced snails are established on the Hawaiian Islands (Staples and Cowie 2001). Of the four apple snail species in the Hawaiian Islands, the most invasive is the channeled or golden apple snail (*Pomacea canaliculata*). Apple snails became pests when they were introduced to loʻi kalo in the 1980s for aquaculture (Yamamoto and Tagawa 2000). They are prolific feeders and breeders. Female snails lay 200–500 eggs per cluster and can lay clusters every two weeks. An adult snail lives 2–5 years, depositing more than 12,000 eggs in a year. Snails forage on algae, kalo, and a wide range of aquatic plants. Small snails are a food source for waterbirds, and large snail shells are regularly found with the meat eaten out in ʻalae ʻula and koloa maoli nests. However, apple snails have been implicated in the decline of native species in Southeast Asia (Cowie 2002). Apple snails are controlled by water level drawdowns, tilling or disking, and dry fallows. In loʻi kalo, apple snails are also collected by hand and crushed.

2.6.6 PLANTS

Invasive species are recognized as a major threat to native ecosystems and to the survival of threatened and endangered species. At the ecosystem level, invasive plants have been shown to be capable of changing fire regimes, altering nutrient cycling patterns, and modifying the surface runoff of water. Invasive plants can physically displace native species and displace 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. Furthermore, compared to native plants, nonnative plants lack their natural enemies in the introduced range, which again gives them a competitive edge over native species. Invasive plants are also often faster growing, and have life history traits that easily and quickly colonize, establish, and displace native species (Vitousek 1990; D'Antonio and Vitousek 1992; Blossey and Notzold 1995).

Approximately 1,100 species of naturalized nonnative plants occur in Hawaiʻi—almost half the flora of the Hawaiian Islands. Invasive plants are successful in island ecosystems due to a multitude of traits. According to Staples, Herbst, and Imada (2000), invasive plants in Hawaiʻi are:

- 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;
- Producing small seeds/spores early in life;
- Experiencing long reproductive periods; and
- Dispersed by animals with no special germination requirements.

The control and eradication of pest plants has been the top priority of natural resource managers in Hawaiʻi. In the wetland habitats of the Refuge, invasive plant species can drastically reduce the value of wetland habitat to native species. Nonnative species out-compete more desirable plant species and smother open-water and mudflat habitats. In addition, the high biomass characteristic of invasive grasses produces a high amount of fuel for fire, which threatens nearby residential and commercial land uses. In Hawai‘i, plants grow year-round; therefore, maintaining habitat by controlling nonnative plants is a full-time task which requires adequate staff and lots of resources. At Hanalei NWR, a combination of control techniques are employed for invasive plant removal including chemical, mechanical (hand and tractor), and water level manipulations.

California grass (*Urochloa mutica*)

California grass (Family–Poaceae) is a sprawling perennial with culms (stems) up to 20 feet long and rooting at the nodes. Stolons and leaf sheaths are densely hairy. California grass occurs pantropically as a pasture grass and its native range is unknown, although it is suspected to have originated in sub-Saharan Africa. California grass occurs in aquatic environments such as the openings of wet forests, marshes, and other open water areas. It is reported to be well adapted to a wide range of soil conditions (sandy to clay) and tolerates moderate shade but prefers full sun (Wagner, Herbst, and Sohmer 1999).

In Hawai‘i, California grass occurs between sea level and 3,445 feet on the five main Hawaiian Islands. The grass can form monotypic stands reaching 5 feet in height, with rooting runners up to 18 feet in length. Throughout the state, it has been reported to grow in a wide range of moisture conditions. It grows prolifically in wet, swampy habitats, but it can also withstand severe drought. In addition to displacing native plants, California grass alters and destroys aquatic environments, causing a loss in bird habitat.

The grass also interferes with stream flow and poses a nuisance to marine navigation when grass rafts float out to sea. The Hawai‘i-Pacific Weed Risk Assessment is a research project conducted by the University of Hawai‘i and the U.S. Forest Service to identify plants that pose a high risk in Hawai‘i and other Pacific Islands. The assessment score of 18 (high risk) for California grass reflects its invasion potential. It also designates the species as H (Hawai‘i), meaning the species is “documented to cause significant ecological or economic harm in Hawai‘i” (Motooka et al. 2003). Techniques used to control California grass include an integrated system of mowing, disking, tilling, hand-pulling, and application of herbicides.

Guinea grass (*Megathyrsus maximus*)

Guinea grass is a large, clumping, perennial grass that is native to Africa but has been widely introduced to other regions as a pasture forage crop and now is distributed throughout in the tropics. Guinea grass became naturalized in the Hawaiian Islands by 1871 (Motooka et al. 2003). It quickly became a problematic invader in Hawaiian landscapes because it is propagated readily by seed and by division of the roots, is adapted to a wide range of ecosystems (e.g., dry to mesic), and alters flammability by increasing fuel loads and continuity. At Hanalei NWR, techniques for controlling Guinea grass is the same as for California grass.

Pluchea spp.

In Hawai‘i, *Pluchea* spp. (Family–Asteraceae) comprises two shrub species— Indian fleabane (*P. indica*) and sourbush (*P. carolinensis*)—and a hybrid species. Indian fleabane readily hybridizes with sourbush to form the intermediate plant *Pluchea* x *fosbergii*. The leaves of this hybrid species are usually more similar to *P. indica*, while the inflorescence more closely resembles sourbush. The hybrid *P.* x *fosbergii* can be found where the two species occur together (Wagner, Herbst, and Sohmer 1999)

Sourbush is an erect aromatic shrub native to parts of North and South America. The species has naturalized in Hawaiʻi, Guam, Taiwan, Africa, and other tropical and Pacific areas. It can grow in poor soil conditions; however, it cannot withstand shade and severe competition from brush and grass. In dry habitats, the fast-growing shrub can form thickets. In Hawaiʻi, sourbush has spread to all the main islands since its arrival in the 1930s. This shrub is able to grow in a wide array of habitats, ranging in distribution from dry coastal areas to open forests at an elevation of 2,953 feet. The plant seeds prolifically and the seeds are easily dispersed by wind (Mueller-Dombois and Fosberg 1998; Wagner, Herbst, and Sohmer 1999). Techniques used to control *Pluchea* spp. include an integrated system of manual removal and application of herbicides.

Cattail (*Typha latifolia*)

The common cattail (Family–Typhaceae) is native to northern Africa, Eurasia, and North America. It was first noted on Oʻahu in 1979 and has since spread to Molokaʻi, Hawaiʻi, and Kauaʻi (Wagner, Herbst, and Sohmer 1999). This plant spreads rapidly both by rhizome and seed, forms dense patches, and excludes native plants and animals. Each flowering head can produce 250,000 seeds, which are wind- and water-dispersed and remain viable for 100 years. On Kauaʻi, cattail occurs in natural and agricultural wetlands of Māhāʻulepū, Niumalu, Keālia, Nukoliʻi, Puhi, Waimea Valley, Hanapēpē, and Kōloa, with the largest population in Makaweli Valley in loʻi kalo. Cattail is listed as one of the state's high-profile invasive species targeted for control (Keanini, Speith, and Gundersen 2010). At Hanalei NWR, cattail occurs in small patches totaling <0.25 acre.

Hau (*Hibiscus tiliaceus*)

Hau is a fast growing, evergreen, sprawling tree that typically grows 10–33 feet tall (Elevitch and Thomson 2006). It is indigenous to many parts of the tropics and was possibly brought to Hawaiʻi by early Polynesian voyagers. Early Hawaiians used hau as a valuable resource for the many products that could be made from its bark and stems, such as canoe parts, crafts, medicines, and cordage (Elevitch and Thomson 2006; White 2019). The plant was managed to limit its encroachment, promote floodplain drainage, and protected water-delivery systems. However, management of hau has not kept up with its prolific growth and has resulted in its rapid spread throughout many waterways, including the Hanalei River.

The tall hau stems often fall over from their own weight. Once fallen, the branches continue to grow as new stems, producing an interwoven growth of vegetation. The roots of hau form dense mats across the channel, trapping sediment and slowing stream velocity. These roots and branches obstruct stream flow, forcing water out of the banks, promoting erosion and altering the hydrology, and eliminating habitat. The obstructed streamflow inhibits both the seaward migration of larvae from endemic stream fauna but also the return of migrating post larvae and juveniles. Further, hau has large leaves that aide in its fast growth but occlude the understory and the river channel. The lack of sunlight and the deposition of large quantities of leave material produces anoxic stream conditions that prevent freshwater species from inhabiting the river channel (USFWS 2017a).

2.7 Avian Botulism

Although the first case was reported in the late 1970s, outbreaks of avian botulism type C, a paralytic disease caused by ingestion of a toxin produced by the bacterium *Clostridium botulinum*, have occurred with regularity at Hanalei NWR since November/December 2011. Between 2011–2018, there were 1,342 cases of avian botulism recorded on the Refuge (Reynolds et al. 2019). In 2019, the total number of sick and dead native birds affected by avian botulism was 157, with 90 percent of these birds affected during a July–December outbreak (Kim Uyehara 2020, pers. comm.). These botulism outbreaks have killed individuals of all five threatened or endangered waterbird species occurring on the Refuge and have been particularly detrimental to koloa maoli, which represents 62% of birds affected (Reynolds et al. 2019). Unlike mainland avian botulism events, outbreaks on the Refuge can occur year-round due to lack of seasonal variability in temperatures; however, they have been most prevalent during the winter months.

C. botulinum is a strict anaerobe that occurs naturally in soil, often lying dormant until the appearance of favorable conditions for growth and toxin production. During the growth phase of *C. botulinum*, the bacterium produces potent neurotoxins. Botulinum spores can be found in wetland sediments and the tissues of aquatic invertebrates and many vertebrates, creating many pathways for outbreaks to occur once conditions for growth are favorable. One of the more common mechanisms of large avian botulism outbreaks is the carcass-maggot cycle, where fly larvae feed on an infected carcass and are in turn consumed by birds that become affected and die, leading to more sites for maggots to feed. Ingestion of the botulinum toxin by birds inhibits the neurotransmitter acetylcholine and results in eventual paralysis of the voluntary muscles. This can lead to death by drowning, starvation, or predation (Rocke and Friend 1999).

Environmental conditions associated with avian botulism outbreaks include temperatures between 20– 40°C, low dissolved oxygen, pH between 7.5 and 9.0, negative redox (oxidation/reduction) potential, and sources of decaying organic matter (especially protein such as decaying fish) (Rocke and Bollinger 2007; Rocke and Samuel 1999). The hydrological infrastructure and management of the Refuge, particularly within certain areas of lo‘i kalo, might influence the abiotic growth factors for *C. botulinum*, alter the availability of growth media, or lead to buildups of the toxin in areas with less water flow to flush the toxin. Factors leading to *C. botulinum* growth might also vary naturally or with other management practices, such as lo‘i kalo drawdowns, fertilization, or pesticide application. Hotspot (density) mapping of avian botulism cases based on data from 2011–2018 showed that although the location of hotspots varied somewhat from year to year, the most severe outbreaks (i.e., highest density botulism hotspot) occurred in lo‘i kalo in the northern part of the Refuge. The kalo regions Refuge-wide had similar densities of koloa maoli; however, the northern kalo regions (northeast and west) contained more dead/sick koloa maoli relative to the numbers of live/healthy koloa maoli using these areas (McDonald 2016).

Because the Refuge provides core habitat for threatened and endangered waterbirds, especially koloa maoli, botulism outbreaks further threaten the recovery of these species. An avian botulism task force has been formed to study the problem and make recommendations. Research and monitoring (of both birds and water quality) have been undertaken to better understand the drivers of the outbreaks in the system. The Refuge is also currently engaged in improving water system infrastructure to promote higher water quality and facilitate better flushing and drainage so that waterbird exposure to warm, anaerobic soil conditions with decaying protein sources is minimized. Following improvements to infrastructure on the Refuge, some reductions in bird deaths were seen over the past several years. Additional strategies identified to address avian botulism are described in Chapter 4.

CHAPTER 3. RESOURCES OF CONCERN

3.1 ANALYSIS OF RESOURCES OF CONCERN

In identifying resources of concern (ROCs), the planning team followed the process outlined in the Service's *Identifying Refuge Resources of Concern and Management Priorities: A Handbook* (Taylor and Paveglio 2017). As defined in the Service's Policy on HMPs (620 FW 1), ROCs are:

> "all plant and/or animal species, species groups, or communities specifically identified in refuge purpose(s), System mission, or international, national, regional, state, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a refuge whose purpose is to protect 'migrating waterfowl and shorebirds.' Federal or State threatened and endangered species on that same refuge are also a resource of concern under terms of the respective endangered species acts (620 FW 1.4G)"

Habitats or plant communities are ROCs when they are specifically identified in refuge purposes, when they support species or species groups identified in refuge purposes, when they support Refuge System ROCs, and/or when they are important in the maintenance or restoration of BIDEH.

3.2 SELECTION OF PRIORITY RESOURCES OF CONCERN APPLICABLE TO WETLANDS MANAGEMENT AND WATERBIRD CONSERVATION

Early in the planning process, the planning team collectively identified ROCs for 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 ROCs. The team then selected priority ROCs from the ROC list. The main criteria for selecting priority ROCs included the following requirements:

- The resource must be reflective of the Refuge's establishing purpose(s) and the Refuge System mission;
- The resource must include the main natural habitat types found at the Refuge;
- The resource must be recommended as a conservation priority in the Wildlife and Habitat Management Review; or
- The resource must be federally or state-listed, a candidate for listing, or a species of concern.

Other criteria that were considered in the selection of priority ROCs included the following:

- Species groups and/or Refuge features of special management concern;
- Species contributing to the BIDEH of the ecosystem; and
- Species where it is feasible to estimate abundance and distribution (needed for future monitoring and adaptive management).

In developing its listing of priority ROCs, the planning team selected not only species mentioned in establishing documents for the Refuge, but also species that captured the ecological attributes of habitats required by larger suites of species. The ecological attributes of habitats should meet the life history requirements of ROCs and are therefore important to sustain the long-term viability of the priority ROC and other benefitting species. Ecological attributes of habitats include vegetation structure, species composition, and age class; hydrologic regime; and disturbance events. These provide measurable indicators that strongly correlate with the ability of a habitat to support a given species. Tables listing the desired conditions for habitat types found on the Refuge were developed based on scientific literature review and team members' professional judgment. These desired conditions for specific ecological attributes were then used to help design habitat goals and objectives, as presented in Chapter 4. However, not all ecological attributes or indicators were deemed ultimately feasible or necessary to design an objective around. Other factors, such as the ability to reasonably influence or measure certain indicators, played a role in determining the parameters chosen for each habitat objective. Thus, ecological attributes should be viewed as a step in the planning process.

Limiting factors were also considered in developing objectives. A limiting factor is a threat to, or an impairment or degradation of, the natural processes responsible for creating and maintaining plant and animal communities. In developing objectives and strategies, the team gave priority to mitigating or abating limiting factors that presented high risk to ROCs. In many cases, limiting factors occur on a regional or landscape scale and are beyond the control of individual refuges. Therefore, objectives and strategies may seek to mimic, rather than restore, natural processes. For example, mowing may be used to maintain a desirable vegetation structure, when restoring native grassland communities may be impractical. Through the consideration of BIDEH, the Refuge will provide for or maintain all appropriate native habitats and species. Refuge management priorities may change over time, and because the WMWCP is designed to be a living, flexible document, changes will be made at appropriate times.

Table 3-1 identifies the priority ROCs for Hanalei NWR wetlands management and waterbird conservation. Definitions for the column headings are as follows:

- **Focal Resources:** Species or species groups that are highly associated with conditions that represent the needs of larger groups of species or communities that have similar requirements (e.g., habitats, ecological and/or ecosystem processes) and respond to management similarly. Management will be focused on attaining conditions required by the focal resource. Other species using the associated habitat type will generally be expected to benefit as a result of management for the focal resource.
- **Habitat Type:** The general habitat description used by the focal resources.
- **Habitat Structure:** The specific and measurable habitat attributes considered necessary to support the focal resource.
- **Life History Requirement:** The general season of use for the focal resource.
- **Other Benefiting Species:** Other species that are expected to benefit from management for the selected focal resource. The list is not comprehensive.

TABLE 3-1. PRIORITY RESOURCES OF CONCERN

Habitat Type	*Habitat Structure*[2]	*Life History Requirements*	*Other Benefitting Species*
Focal Resource: Koloa maoli			
Emergent wetlands	Early to mid-successional, mosaic of shallow (<8 in. deep) open water and 50–75% cover, seed-bearing wetland plants, abundant macroinvertebrates, no feral mallards or hybrids	Foraging, loafing, courtship, brood-rearing, molting	Migratory waterfowl, shorebirds, ‘alae ‘ula, ae‘o, ‘alae ke‘oke‘o
Lo‘i kalo	Mosaic of wet fallow (6–8 in. deep), dry fallow, early- to late-stage cultivated fields with shallow open water (3–6 in. deep) and 10–75% kalo cover with ≥10% beneficial non-kalo emergent (moist-soil) plants; abundant macroinvertebrates; no feral mallards or hybrids; and <1 avian botulism outbreak annually	Foraging, loafing, courtship, brood-rearing, molting	Migratory waterfowl, shorebirds, ‘alae ‘ula, ae‘o, ‘alae ke‘oke‘o
Riverine	Step-pool structure (calm pools that form at the base of falls or runs) with exposed mudflat, boulders, or rocky ledges, and aquatic vegetation and invertebrates, point bars and islands	Foraging, loafing, courtship, brood-rearing, molting	‘Alae ‘ula, ‘o‘opu, native invertebrates
Herbaceous uplands adjacent to wetlands or waterways	Dense canopy >10 in. tall with dead or dying plant material to build nests	Nesting	‘Alae ‘ula, ‘alae ke‘oke‘o
Focal Resource: ‘Alae ‘ula and ‘Alae ke‘oke‘o			
Emergent wetlands	Mid- to late- successional, mosaic of shallow open water (<8 in. deep) and 50–75% cover, seed-bearing, robust emergent, and submerged plants, abundant macroinvertebrates	Foraging, loafing, breeding, molting	Migratory waterfowl, shorebirds, koloa maoli, nēnē
Lo‘i kalo	Mosaic of wet fallow (6–8 in. deep), dry fallow, early- to late-stage cultivated fields with shallow open water (3–6 in. deep) and 10–75% kalo cover with ≥10% beneficial non-kalo emergent (moist-soil) plants; abundant macroinvertebrates; and <1 avian botulism annually	Foraging, loafing, breeding, molting	Migratory waterfowl, shorebirds, koloa maoli, nēnē

[2] For all habitat structures, no introduced predators or competitors and no or low human disturbance.

Habitat Type	*Habitat Structure*[2]	*Life History Requirements*	*Other Benefitting Species*
Seasonal playa wetlands	Early-successional mosaic of shallow (<3 in. deep) open water and exposed mudflat with <25% cover, abundant macroinvertebrates	Foraging, loafing, breeding	Migratory waterfowl, shorebirds, ‘alae ‘ula, ‘alae ke‘oke‘o, koloa maoli
Lo‘i kalo	Mosaic of wet fallow (6–8 in. deep), dry fallow, early- to late-stage cultivated fields with shallow open water (3–6 in. deep) and 10–75% kalo cover with ≥10% beneficial non-kalo emergent (moist-soil) plants; abundant macroinvertebrates; and <1 avian botulism outbreak annually	Foraging, loafing, breeding	Migratory waterfowl, shorebirds, ‘alae ‘ula, ‘alae ke‘oke‘o, koloa maoli
Focal Resource: Nēnē			
Short grasslands	Mix of grasses, sedges, and legumes managed at 4–6 in. height	Foraging, loafing, courtship, brood-rearing	Migratory waterfowl, shorebirds, ‘alae ke‘oke‘oko, ‘alae ‘ula, koloa maoli
Riparian/upland shrublands	Woody or mixed woody-herbaceous cover with open understory near short grasslands, patches of native legumes and shrubs with berries (e.g., naupaka, māmaki)	Foraging, nesting, loafing	Koloa maoli, ‘ōpe‘ape‘a
Riparian/ riverine	Short herbaceous cover adjacent to deep open water channels	Molting	Koloa maoli, ‘alae ke‘oke‘oko, ‘alae ‘ula, ‘o‘opu, native invertebrates

3.3 Reconciling Conflicting Habitat Needs for Resources of Concern

Given the Service’s mandates to manage for biological integrity on a landscape or ecosystem scale, we do not foresee significant conflicting habitat needs for the resources of concern. For example, we manage wetlands in a rotational manner to provide for all key life history events of wetland-dependent species. Although the habitat uses of the threatened and endangered waterbirds indicate niche partitioning, all niches overlap in space and time. Furthermore, all five species are sympatric (populations occupy the same geographic areas) to varying degrees in the fossil/subfossil record with at least 36 other native birds (Burney et al. 2001). Likewise, we do not foresee habitat conflicts with the endangered ‘ōpe‘ape‘a, which is the solitary, tree-roosting, more recent colonist. That said, the Refuge underwent two wildlife and habitat reviews (Paveglio et al. 2000; USFWS 2007) to evaluate its highest and best use (Schroeder et al. 2004). The reviews identified wetlands habitat management to meet Hawaiian waterbird life history needs, with endangered koloa maoli as a focal species, as the highest priority. Subsequent research supports this recommendation, considering Kaua‘i/Ni‘ihau is the last stronghold for koloa maoli, with other Hawaiian islands consisting primarily of a hybrid swarm through introgression of predominantly feral mallard genes (Wells et al. 2016). Both lo‘i kalo and rotational managed wetlands are used regularly by this species, with managed wetlands used for a wider range of life history events (Malachowski and Dugger 2018). The Refuge, additionally, is estimated to support approximately half the state’s endangered ‘alae ‘ula population, highlighting the importance of the Refuge to this species as well, including the vulnerability of both species and others to chance events associated with disease and climate change.

CHAPTER 4. MANAGEMENT GOALS, OBJECTIVES, AND STRATEGIES

Goals and objectives are the unifying elements of successful refuge management. They focus and describe management priorities and actions that resolve issues and help a refuge fulfill the refuge purpose(s), the Refuge System mission and goals, other statutory requirements, and larger-scale plans as appropriate. Management goals lead to objectives that direct effort into incremental and measurable steps toward achieving those goals. Finally, strategies identify specific tools and actions to accomplish objectives (USFWS and USGS 2004). Some strategies apply to multiple goals or objectives; these are presented in Section 4.1.

The goals for Hanalei NWR wetlands management and waterbird conservation are presented in Sections 4.2 and 4.3, respectively. The goal order does not imply any priority. Each goal is followed by the objectives that pertain to it. The "Rationale" section provides additional information and the reasoning behind the objectives and strategies.

4.1 STRATEGIES THAT APPLY TO MULTIPLE GOALS OR OBJECTIVES

Some goals or objectives are supported by common strategies. These are presented below to reduce the length and redundancy of the individual goal and objective descriptions.

Adaptive Management. Based upon the Adaptive Management Implementation policy (522 DM 1), the Refuge will employ adaptive management for conserving, protecting, and where appropriate, restoring lands and resources. Within Title 43 of 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 DOI Adaptive Management Technical Guide further 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. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process" (Williams, Szaro, and Shapiro 2009). Adaptive management accounts for the fact that knowledge about fish, wildlife, plants, habitats, and the ecological processes supporting them is incomplete and changing over time. The role of natural variability contributing to ecological resilience also is recognized as an important principle for adaptive management. It is not a "trial and error" process, but rather adaptive management emphasizes learning while doing based upon available scientific information and best professional judgment considering site-specific biotic and abiotic factors on Refuge lands.

The Service recognizes that there is a critical need for transparency as the WMWCP is implemented. This transparency as it pertains to adaptive management includes both the learning and decision-making processes. The following discussion describes how the Service will move forward using adaptive management (adapted from Williams, Szaro, and Shapiro 2009 and Knutson et al. 2017).

- Stakeholder involvement: Ensure stakeholder commitment to adaptively manage the enterprise for its duration.
- Objectives: Identify clear, measurable, and agreed-upon management objectives to guide decision-making and evaluate management effectiveness over time.

- Management actions: Identify a set of potential management actions for decision-making.
- Models: Identify models that characterize different ideas (hypotheses) about how the system works.
- Monitoring plans: Design and implement a monitoring plan to track resource status and other key resource attributes.
- Decision-making:
  - Select management actions based on management objectives, resource conditions, and understanding. As the Service and our partners learn through the adaptive management process, new information may show the need for adjustments, confirm existing strategies, or identify additional information. Based on the best information available at the time, the Service will make decisions for future management actions.
  - The Service is committed to bringing together interested parties to assist with the evaluation of available information, as well as consultation about management options and their implications prior to making course-changing decisions. This process does not diminish the Service's legal authority to make decisions but rather serves to enhance the decision-making process by enabling the Service to approach issues from multiple perspectives, thereby finding creative solutions to complex challenges.
- Follow-up monitoring: Use monitoring to track system responses to management actions.
- Assessment: Improve understanding of resource dynamics by comparing predicted and observed changes in resource status.
- Information sharing/learning: The Service is committed to an adaptive management process that will bring diverse interests together through various forums to share information and site-specific results so that all those engaged can learn together. These forums would evolve over time but would include collaborative mechanisms with others such as (and potentially evolving from) the collaborative groups that have been active during the CCP and WMWCP processes (e.g., the avian botulism task force). The timing and frequency of information sharing and learning will be determined by how rapidly new information is being acquired, level of partners' interest and engagement, ecological cycles, and the forum being used. The Service will also share the results of its inventory and monitoring work on an ongoing basis and strive to be responsive to partners' requests for open discussion and collaboration in assessing the need for adaptive changes in management to achieve the goals and objectives of the WMWCP.

As described in the Service's Habitat Management Planning policy (620 FW 1), annual habitat work plans (AHWPs) provide the mechanism for effectively implementing adaptive management on a refuge over time. Specifically, adaptive management entails assessing and modifying management actions, as necessary, in order to achieve habitat objectives. Management strategies and prescriptions are evaluated by comparing results to desired outcomes to assess their effectiveness (Figure 4-1). The Refuge staff has articulated specific and measurable habitat management objectives associated with wetlands and waterbird conservation (see Sections 4.2 and 4.3), where Refuge surveys within its forthcoming inventory and monitoring plan would be assessing progress toward achieving them. Using adaptive management (Figure 4-1) and the decision flowchart (Figure 4-2), management of the wetland units, lo'i kalo, and other priority areas (Figure 4-3) will be undertaken as described in Sections 4.2 and 4.3 goals and objectives.

As previously mentioned, documenting survey results also provides a feedback loop to inform any needed and timely adjustments to management actions. Because planned and implemented management actions to achieve habitat objectives would be documented by Refuge staff and permittees (kalo farming and livestock grazing) using a format consistent with specifications for AHWPs (620 FW 1, Exhibit 2), the Refuge staff would support fundamental components of managing Refuge resources adaptively (objectives, documenting management actions, and implementing surveys to evaluate progress) in accordance with Service and Departmental policies described herein.

Avian Botulism Surveillance and Control. Refuge staff, interns, and volunteers will continue to conduct regular surveillance of lo‘i kalo and rotational managed wetland units in order to control and minimize the outbreak of avian botulism. Research and monitoring on the potential environmental drivers of avian botulism outbreaks (e.g., water quality and water use) will continue. Methods for improving efficiency and detection of avian botulism such as the use of highly trained dogs to locate carcasses and the development of a new diagnostic assay, which uses samples from avian blood, native and invasive invertebrates, fish, and/or amphibians, will continue to be explored. Other methods for responding to avian botulism outbreaks include immediate response for dead bird removal and sick bird treatment.

The Refuge will continue to monitor and manage water levels to provide suitable waterbird habitat and prevent disease outbreaks such as avian botulism. Continued efforts over the life of this plan to improve various aspects of the Refuge water delivery infrastructure (e.g., supply pipelines, ditches and valves, water control structures, drains) will increase water quantity, improve water flushing ability, and reduce water temperatures where they are most needed. These efforts will help to minimize the presence of conditions conducive to botulism spore germination and with proper water management, will reduce the severity of outbreaks as they occur, especially in the northern kalo farming units on Hanalei NWR, which have been identified as avian botulism hotspots over time.

Cultural and Historic Resource Protection and Section 106 Compliance. Cultural and historic resources on refuges receive protection and consideration in accordance with federal cultural resources laws, Executive Orders, regulations, and policies and procedures established by the DOI and the Service. Actions with the potential to affect cultural and historic resources will undergo a thorough review before being implemented, as is consistent with the requirements of cultural resource laws. All ground-disturbing projects will undergo a review (including, but not limited to, archaeological and cultural surveys) under Section 106 of the NHPA. The Service will provide our Regional Historic Preservation Officer (RHPO) a description and location of projects and activities that affect ground and structures, including project requests from third parties. Information will include any alternatives being considered. We will also coordinate and consult with the State Historic Preservation Division (SHPD) and seek assistance from the Native Hawaiian community and organizations on issues related to cultural resources, education, and interpretation; special programs; and NHPA.

Implementation Subject to Funding Availability. After the WMWCP is completed, actions will be implemented as funding becomes available. Draft project priorities and projected staffing/funding needs are in Appendix E, although special funding initiatives, unforeseeable management issues, and other budget issues will likely require adjustments to the implementation schedule in the future. The WMWCP assumes adequate staffing and funding for implementation. However, without these resources some strategies may be deferred or modified.

Integrated Pest Management. 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 WMWCP, 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 accordance with DOI and Service policies 517 DM 1 and 569 FW 1 respectively, an IPM approach would be utilized, where practicable, to eradicate, control, or contain pest and invasive species (herein collectively referred to as pests) on the Refuge. 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 mechanical/physical (e.g., mowing, brush-cutting, excavation, prescribed fire), cultural (e.g., water levels), 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 or waters, the most specific (selective) chemical available for the target species would be used unless considerations of persistence or other environmental or biotic hazards would preclude it. In accordance with 517 DM 1, pesticide usage would be further restricted because only pesticides registered with the EPA in full compliance with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and as provided in regulations, orders, or permits issued by EPA may be applied on lands and waters under Refuge jurisdiction.

Environmental harm by nonnative 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 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; out-competing 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 waterbird use may result from pest plant infestations reducing the availability and abundance of native wetland plants that provide forage during the winter; increased predation on native species may occur because pest plants also provide cover for predators.

Environmental harm may involve detrimental changes in ecological processes. For example, Guinea grass infestations can alter fire return intervals by displacing native species and communities of bunch grasses, forbs, and shrubs. Environmental harm may also cause or be associated with economic losses and damage to human, plant, and animal health. For example, invasions by fire-prone grasses that alter entire plant and animal communities by eliminating or sharply reducing populations of many native plant and animal species can also greatly increase fire-fighting costs.

The program to control introduced predators is aimed at minimizing entry of species that threaten threatened and endangered species populations and native ecosystems year-round using exclusion (e.g., fences), habitat modification (e.g., removal of trees used by introduced cattle egrets for roosting, water drawdowns), hazing (e.g., for cattle egrets), and control/eradication (e.g., reducing or eliminating populations of ants, mice, rats, barn owls, feral cats, feral dogs, feral pigs, and mongooses, if they are detected.

Pesticides, including periodic use of 5 percent borax (sodium tetraborate decahydrate), will continue to be used to control invasive ants that threaten threatened and endangered nesting birds. Humane kill traps will continue to be used to control rats and mice. Live traps will be used to capture nonnative animals such as bullfrogs, barn owls, feral chickens, feral cats, dogs, and pigs. In addition to other methods, pellet guns may be used to humanely dispatch nonnative trapped rats, feral chickens, amphibians, and small reptiles. When other methods are impractical or unsafe, firearms will be employed to humanely dispatch introduced predators and other nonnative animals such as feral cats, feral pigs, feral chickens, barn owls, and cattle egrets. Given the need to minimize stress on animals, shooting at times is the most practical, humane, and effective method, particularly for wild or free-ranging animals. All methods of animal dispatch will follow the AVMA guidelines for euthanasia (AVMA 2013). Firearms, which include pellet guns, will only be used by highly skilled shooters trained and federally certified in their use (USFWS 2017b). Control of introduced predators and pests will be conducted by trained Service staff, volunteers, or contractors.

Specific predator control attributes were developed for Objective 1.1 based on bird mortality data collected from 2010–2011, when the KNWRC had one dedicated predator control technician. For instance, since 95 percent of the depredated threatened or endangered birds were recovered on lo'i kalo dikes and 5 percent were recovered elsewhere including wetlands management units, species-specific attributes were divided among habitat types to reflect these proportions. As there is insufficient information to determine exactly how many birds are actually lost due to introduced predators; how these numbers interact with disease, contaminants, human disturbance of nests or young; or how they relate to natural mortality or population-level effects, the species-specific attributes within the habitat objectives provide a baseline by which to monitor the predator management program and develop more effective techniques. Understanding relative impacts of predators to bird life stages and species will also help in designing a more effective predator control program.

See Appendix D for the Refuge's IPM program documentation to manage pests for this WMWCP. Along with a more detailed discussion of IPM techniques, this documentation describes the selective use of pesticides for pest management on refuges, where necessary. Throughout the life of the WMWCP, proposed pesticide uses on the Refuge would be evaluated for potential effects to biological resources and environmental quality. These potential effects would be documented in "Chemical Profiles" (see Appendix D). Pesticide uses with appropriate and practical BMPs for habitat management as well as cropland/facilities maintenance would be approved for use on refuges where there likely would be only minor, temporary, and localized effects to species and environmental quality based upon nonexceedance of threshold values in Chemical Profiles. However, pesticides may be used on a refuge where substantial effects to species and the environment are possible (exceed threshold values) in order to protect human health and safety (e.g., mosquito-borne disease).

Inventory, Monitoring, and Research. Inventory and monitoring (I&M) is required on Refuge System units based on legal mandates including the Refuge Improvement Act; NEPA final rule (43 CFR 46); and NEPA and agency decision-making (40 CFR 1505); as well as DOI and Service policies such as Habitat Management (620 FW 1); BIDEH (601 FW 3); Compatibility (603 FW 2); Fire Management (621 FW 1); IPM (517 DM 1, 569 FW 1); and Adaptive Management (522 DM 1). Inventory and monitoring on refuges is intended to: (1) Gather baseline data and record benchmark conditions used to support refuge planning; (2) Estimate the status of, and trends in fish, wildlife, plant populations, and their habitats; (3) Assess trends in BIDEH (601 FW 3); (4) Evaluate the effectiveness of management actions in contributing to established goals for fish and wildlife conservation by using adaptive management (522 DM 1); (5) Provide surveillance to detect changes in the structure and function of ecological systems; (6) Establish baseline measures and monitor wilderness character of designated wilderness on refuges to evaluate the effects of refuge management activities and uses (610 FW 2); (7) Record impacts of environmental stressors, including climate change, on natural resources and ecological processes; and (8) Support the Service's goal of landscape conservation by assessing similar management actions across refuges and with Service partners, including actions by multiple refuges, one or more Regions, Joint Ventures (JVs), and Landscape Conservation Cooperatives (LCCs) (701 FW 2).

High-priority research is facilitated on Refuge lands to provide the best science for habitat and wildlife management (see Appendices A and B). Examples of research projects 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, and modeling of wildlife populations. Projects may be species-specific, Refuge-specific, or evaluate the relative contribution of the Refuge to larger landscape (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 and waters. In combination with results of I&M, research would promote adaptive management on Refuge lands and waters and be used to refine management strategies, where necessary, over time in order to achieve resource objectives. Scientific publications resulting from research on Refuge lands and waters will help increase the visibility of the Refuge System as a leader in the development of the best science for resource conservation and management.

In accordance with the Inventory and Monitoring policy (701 FW 2), Hanalei NWR is developing an Inventory and Monitoring Plan (IMP). The IMP will present current and expected I&M activities (surveys) for Hanalei NWR. Most surveys in the IMP will be Refuge-specific; they evaluate and refine efficacy of resource management actions and measure progress toward achieving resource management objectives identified in refuge planning documents. Some surveys also gather baseline data to develop practical and measurable objectives for restoration projects or provide baseline data on biological integrity of the Refuge. The IMP will also include cooperative surveys addressing resource issues of the Service at larger landscape scales beyond the Refuge boundary or needs of other agencies and organizations. For cooperative surveys, Refuge lands are one of multiple sites including other Refuges to address broad-scale resource information needs. Key components of the IMP will include a comprehensive list of surveys, prioritization of these surveys, surveys selected for implementation, status of protocols for surveys, a rationale for each survey including its connection with management objectives, and a signature page documenting IMP review and approval. Although the IMP will identify many surveys that would need to be conducted on the Refuge, the number of surveys implemented on an annual basis is contingent upon a number of factors, including available Refuge funding and staffing as well as support from partners.

Feral Mallard and Mallard/Koloa Hybrid Removal. Feral mallards are one of the most serious threats to the continued existence of endangered koloa maoli throughout its geographic distribution (USFWS 2011e). Feral mallards threaten koloa maoli with extinction through hybridization, which could lead to loss of koloa maoli as a unique Hawaiian species after only a few generations. DNA analysis indicates nonmigratory feral mallards (domesticated mallards that have escaped or been released into the wild) are cross-breeding with endangered koloa maoli (Uyehara, Engilis Jr., and Reynolds 2007; Fowler, Eadie, and Engilis Jr. 2009). In addition, feral mallards likely threaten koloa maoli and other threatened and endangered waterbirds by competing with them for limited wetlands resources, such as food and nesting sites. Removal of the threat of hybridization is a primary recovery action in the Hawaiian Waterbird Recovery Plan (USFWS 2011e). DNA analysis indicates a very low level of hybridization is present on Hanalei and Hulē'ia Refuges (Malachowski et al. 2013). However, there is work to be done on the status of the Oʻahu population and the potential threats of new sources of feral or hybrid ducks flying or being shipped to Kauaʻi.

Fish Screening. The presence and abundance of exotic fish species such as tilapia (*Oreochromis mossambicus*, *Sarotherodon melanotheron*) and poeciliid fish (*Poecilia* hybrid sp., *Gambusia affinis*) in coastal wetlands depletes food resources (e.g., aquatic insects) for native birds (McGuire 2006), degrades water quality (MacKenzie and Bruland 2012), introduces parasites (Font 2007), and increases the risk of avian botulism. Native ʻoʻopu can also enter wetlands, where they may become trapped and are unlikely to fulfill their lifecycles. The Service will continue to install and use fish screens at Hanalei NWR as a non-lethal method excluding both exotic and native fish from areas managed for threatened and endangered waterbirds. Where possible, barriers would be installed at the intake pipe of a given unit prior to the opening of the intake valves and subsequent re-inundation of the wetland.

Partnerships. Partnerships are critical components in maintaining and continuing efforts to implement resource management improvements (such as restoring habitat for threatened and endangered species). These partnerships typically involve joining forces with federal, state, and local agencies as well as nongovernmental organizations, schools, and Friends of the Refuge groups.

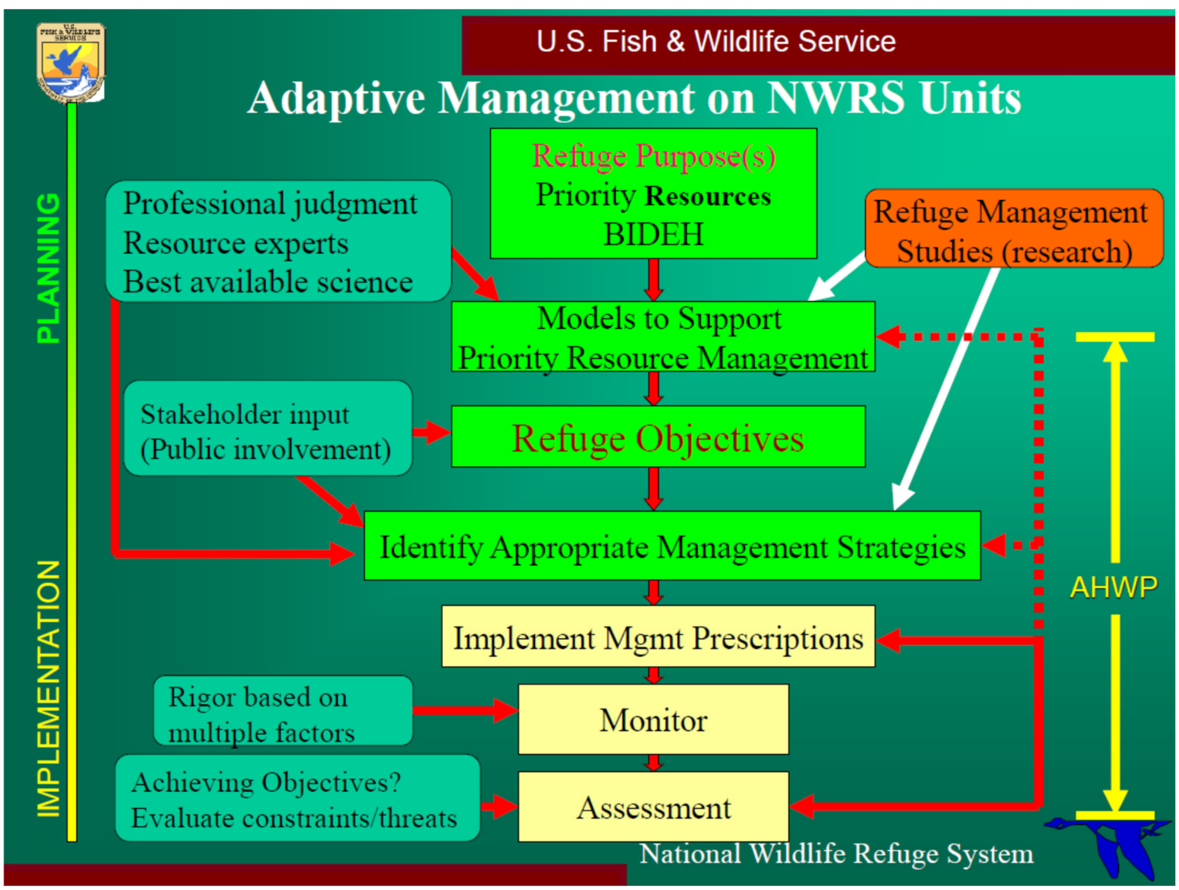


Figure 4-1. *Adaptive management on National Wildlife Refuge System units*

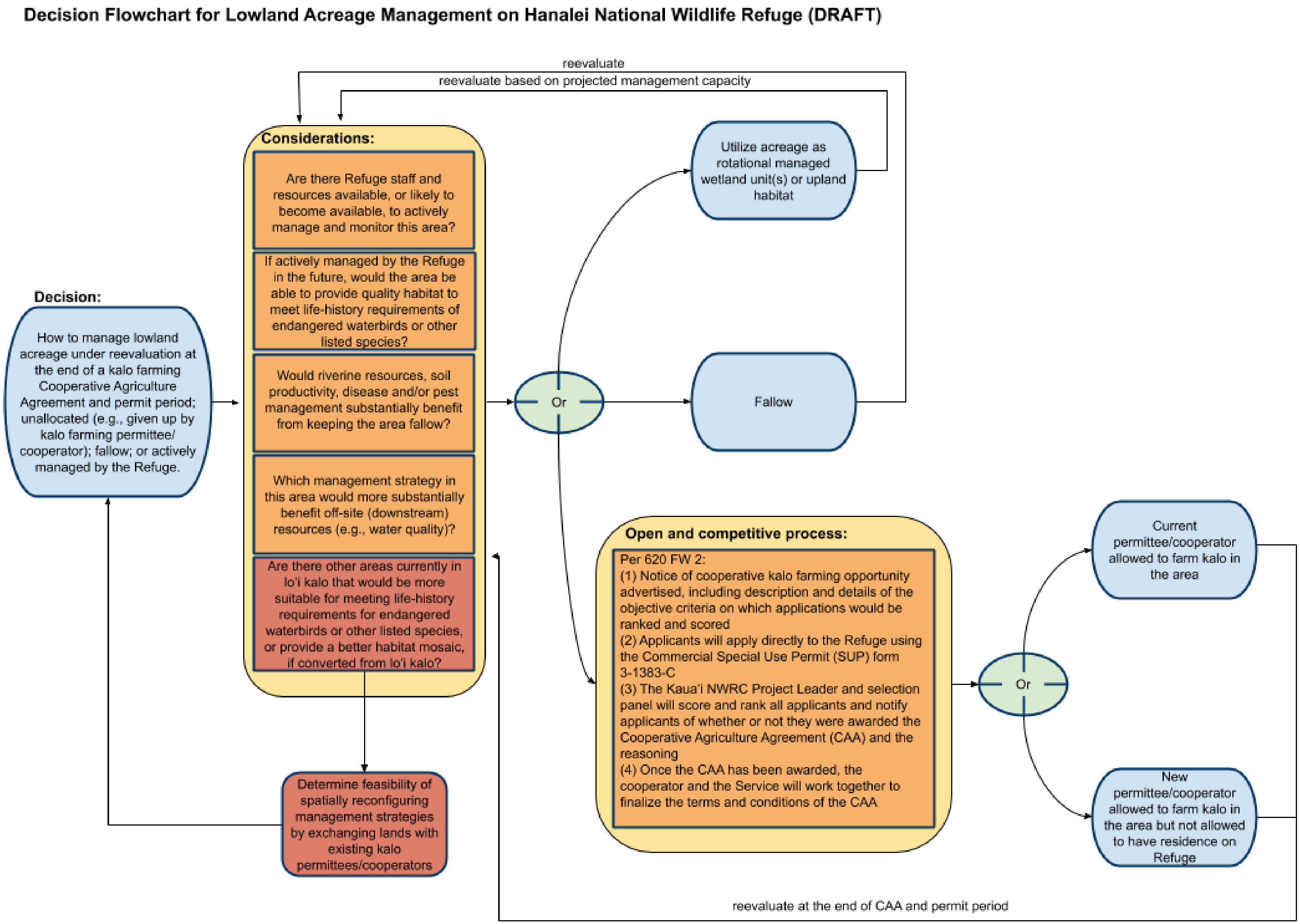
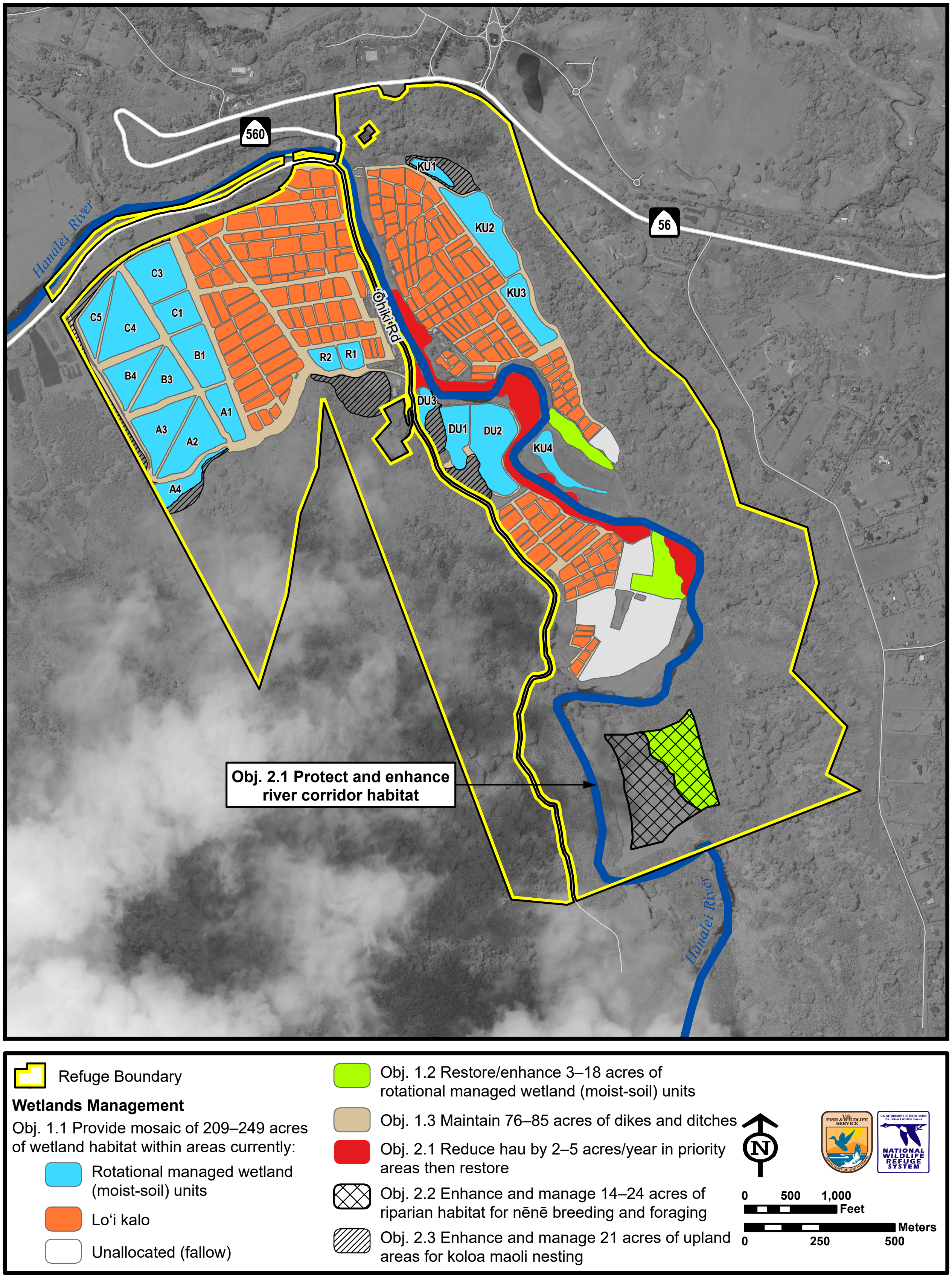


Figure 4-2. *Active management flowchart, Hanalei NWR*

Figure 4-2. Wetlands management summary, Hanalei NWR



Map Date: 7/9/2019 File: 11-102-1b.mxd
Data Source: USFWS 2019; Imagery from DigitalGlobe 6/3/2019
USFWS R1 Refuge Inventory and Monitoring Branch

4.2 GOAL 1: PROTECT, RESTORE, ENHANCE, AND MANAGE WETLAND HABITATS TO MEET THE LIFE HISTORY NEEDS OF THREATENED AND ENDANGERED HAWAIIAN WATERBIRDS TO PROMOTE THEIR RECOVERY.

OBJECTIVE 1.1 PROVIDE WETLAND HABITAT FOR FORAGING, LOAFING, AND BREEDING THREATENED AND ENDANGERED WATERBIRDS.

Provide a mosaic of approximately 209–249 acres of wetland habitat (rotational managed wetlands and lo‘i kalo) for foraging, loafing, and breeding threatened and endangered waterbirds throughout the year, with the following attributes:

- Abundant macroinvertebrates (e.g., damselflies, midges, small mollusks and crustaceans) for foraging;
- <5% cover of pest plants (e.g., California grass, *Paspalum*, Guinea grass, cattail);
- Minimal human disturbance year-round;
- No feral mallards or their hybrids;
- Early-successional managed wetlands for koloa maoli, ae‘o, and ‘alae ke‘oke‘o foraging and loafing:
    - Recently-flooded mosaic of shallow (<8 inches, mostly 3–4 inches), open water and 50–75% cover of short (<12 inches tall), non-persistent emergents (e.g., *Fimbristylis*, *Cyperus*, *Eleocharis*);
- Mid-successional managed wetlands for koloa maoli breeding and ‘alae ‘ula foraging and loafing:
    - Mosaic of shallow (<8 inches, mostly 3–4 inches), open water with a 50–75% canopy cover of tall (12–60 inches) emergents (e.g., kāmole, millet, ‘ahu‘awa) and 25% understory cover of short (<6 inches tall) non-persistent emergents (e.g., *Fimbristylis*, *Cyperus*, *Eleocharis*);
    - Presence of submerged aquatic vegetation (e.g., pondweeds) enhanced by fish exclusion devices;
- Late-successional managed wetlands for ‘alae ‘ula and ‘alae ke‘oke‘o breeding and koloa maoli molting:
    - Mosaic of open water (3–12 inches) with initially a 50–75% cover of tall (>24 inches) robust emergents (e.g., kāmole, nānaku, Manchurian wild rice) declining to 25–50% cover as marsh matures;
    - Interspersion with sufficient vegetative edge to provide visual barriers to maximize territories available for breeding;
    - Presence of submerged aquatic vegetation (e.g., pondweeds);
- Early-successional managed wetlands for ae‘o breeding:
    - Recently flooded mosaic of shallow (<3 inches), open water and exposed mudflat (saturated and unsaturated) with sparse (<25% cover) of low-growing (<6 inches tall) emergent plants (e.g., *Fimbristylis*, *Bacopa*);
    - Undulating, irregular topography creating unsaturated mudflats with gradual slopes (~15:1) during drawdown to provide nesting adjacent to foraging habitat;
    - Reproductive success of ≥2 hatchlings and ≥1 fledglings per nest;
- Managed wetlands for ‘alae ke‘oke‘o breeding:

  - Mosaic of open water (10–14 inches) with initially a 50–75% cover of tall (>24 inches) robust emergents (e.g., kāmole, nānaku, Manchurian wild rice) declining to 25–50% cover as marsh matures;
  - Interspersion with sufficient vegetative edge to provide visual barriers to maximize territories available for breeding;
  - Presence of submerged aquatic vegetation (e.g., pondweeds);
- Predation rates within rotational managed wetlands:
  - Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year.
- Lo‘i kalo:
  - During all flooded stages for foraging and breeding threatened and endangered waterbirds:
    - 10–25% of total lo‘i acreage in beneficial non-kalo emergent plants (≥3 species of low-growing annuals, <6–12 inches tall; e.g., *Fimbristylis littoralis*, *Cyperus* spp., *Eleocharis* spp., *Ludwigia* spp., *Schoenoplectus juncoides*)
    - 75% cover of herbaceous plants on the total length lo‘i banks (≥3 species; e.g., *Fimbristylis dichotoma*, *Bacopa monnieri*, *Cyperus polystachyos*, *Echinochloa crus-galli*); and
    - Water depth 3–6 inches.
  - During harvest, to protect nesting and brood-rearing habitat for threatened and endangered waterbirds:
    - Minimum 6-foot radius unharvested vegetation buffer around threatened or endangered waterbird nests.
  - During fallow, to enhance foraging resources for threatened and endangered waterbirds:
    - Minimum 30-day wet fallow period;
    - Presence of moist-soil plants;
    - Water depth 6–8 inches; and
    - Optional dry fallow period ≤180 days total.
  - <1 avian botulism outbreak annually and negligible impacts on threatened and endangered waterbird populations
- Predation rates within lo‘i kalo:
  - Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤20 individual threatened or endangered waterbirds per year.

Strategies Applied to Achieve Objective

1.1.1. Assignment of available wetland/lowland areas for rotational managed wetland (moist-soil) units, lo‘i kalo (via CAA), fallow or upland habitat (e.g., koloa nesting habitat, Objective 2.4) based on decision flowchart (Figure 4-2)

Rotational managed wetlands

1.1.2. Mowing, disking, rototilling, and water level management, as needed, to set back wetland plant succession and provide suitable habitat structure and function. See Appendix C for additional information

1.1.3. From Quarterly Management Unit Assessments (QMUA), manage water accordingly (e.g., spigots, riser boards) to stimulate plant and invertebrate production

1.1.4. Transplant native bulrush for nesting material and visual barriers

1.1.5. Maintain minimal water level fluctuations during threatened and endangered waterbird laying and incubation periods

1.1.6. Limited and responsible public use authorized in advance via guided tours, environmental education, and SUPs within closed areas of the Refuge. Refuge staff presence consistent with a level necessary to conduct biological monitoring, predator control, water management, refuge operations, and maintenance, under normal circumstances, 1–5 visits per week

1.1.7. Prior to implementing maintenance schedule, perform a waterbird nest/brood search in accordance with established protocol

1.1.8. As possible, schedule maintenance outside of peak rail (‘alae ke‘oke‘o and ‘alae ‘ula) breeding and koloa maoli molting season or conduct nest/brood searches commensurate with breeding activity

1.1.9. Use IPM strategies including mechanical/physical (e.g., mowing, brush-cutting, excavation, prescribed fire), cultural (e.g., water levels), chemical (herbicides), biological, and other suitable techniques to control California grass, *Paspalum*, Guinea grass, cattail, and other pest/undesirable plants

1.1.10. Live-trapping and humanely dispatching feral mallards and their hybrids

1.1.11. Live-trapping, humanely dispatching, and bait stations to remove vertebrate pests that prey on threatened and endangered waterbirds

1.1.12. Maintain existing three miles of fence to protect wetland management units from feral pigs and dogs

Lo‘i kalo: permitting

1.1.13. Kalo farming on the Refuge, and necessary activities related to kalo farming, including permits for existing residences and sheds, would be authorized through a CAA and documented on a Commercial Activities SUP for each permittee/cooperator. The CAAs and SUPs would authorize kalo farming and necessary related activities for 1–5 years each. The CAA and SUP would describe allowed and prohibited activities both on the Refuge and within permit areas, and responsibilities of the Service and the permittee/cooperator. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD

Lo‘i kalo: vegetation structure for foraging and breeding threatened and endangered waterbirds

1.1.14. Enhance vegetation structure of lo‘i habitat (all stages) for foraging and breeding threatened and endangered waterbirds by maintaining either:

- ≥10% cover of beneficial non-kalo emergent plants (≥3 species of low-growing annuals, <6–12 inches tall; e.g., *Fimbristylis littoralis*, *Cyperus* spp., *Eleocharis* spp., *Ludwigia* spp., *Schoenoplectus juncoides*) in understory within each lo‘i;
- ≥20% cover of beneficial non-kalo emergent plants in understory on ≥50% of lo‘i; or
- ≥10% of total lo‘i acreage in vegetated wet fallow (approximately nine month period: germinate, grow emergent vegetation >4”, flood six months) to promote growth of non-kalo emergent plants (See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility)

Lo‘i kalo: nesting and brood-rearing habitat

1.1.15. Require kalo permittees/cooperators to report and inform all farm workers and the Refuge manager or biologist about the nests of threatened and endangered Hawaiian waterbirds found within their permit area within 24 hours of discovery and mark nests. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.16. In lo‘i where threatened or endangered waterbird nests are found, kalo permittees/cooperators would be required to keep the lo‘i flooded to a depth of 3–6 inches and if the nest is found in a field being harvested, a minimum 6-foot radius area of unharvested kalo plants must be maintained around each active waterbird nest until the young birds fledge or leave the lo‘i on their own accord. Kalo permittee/cooperators must coordinate with Refuge staff to minimize impacts or take of birds by implementing additional protective measures as needed, such as delaying harvest in areas where nests are known to occur until the young birds fledge or leave the lo‘i of their own accord. Permittees/cooperators would plant and maintain lo‘i in a way that would distribute kalo at different stages of maturity among different lo‘i, so that harvesting of all lo‘i at one time would not occur. This would allow kalo farmers the continued ability to harvest in lo‘i that do not have a nest present. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.17. Initiate a study of the relative effectiveness of different size nest buffers on nest and fledging success of threatened and endangered Hawaiian waterbirds within three years; modify buffer requirements and compatibility stipulations if necessary

1.1.18. During kalo harvest, leave kalo and non-kalo plants until threatened or endangered Hawaiian waterbird nestling fledges

1.1.19. Minimize water level fluctuations (e.g., drawdowns) in lo‘i where nests occur (to prevent flooding or collapse of waterbird nests and brood platforms)

1.1.20. Trample aquatic plants into soil to facilitate vegetative breakdown for invertebrate production

Lo‘i kalo: foraging resources in fallow areas

1.1.21. Fallow lo‘i and flood to maximize foraging opportunities for threatened and endangered waterbirds during this period of high invertebrate egg laying and larval growth; longer fallow periods enhance soil productivity. Minimum required 30-day wet fallow period followed by optional dry fallow period ≤180 days total. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

Lo‘i kalo: avian botulism prevention and response

1.1.22. Require kalo permittee/cooperators to participate in implementing relevant aspects of the Avian Botulism Prevention and Response Protocol as part of their CAA and SUP. If a given kalo patch is identified as an avian botulism hotspot, then work with Refuge staff to change environmental conditions. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.23. Require kalo permittees/cooperators to report sick or dead birds to the Refuge manager or biologist within 24 hours. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.24. Thoroughly drain and aerate every kalo patch after the 30-day wet fallow period prior to replanting. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.25. In avian botulism-prone areas, implement Avian Botulism Prevention and Response Protocol BMPs, which include the following measures (see Appendix B, Cooperative

Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility):

- Reconfigure pipelines to remove all flow-through (i.e., lo‘i-to-lo‘i) drains
- Drain, harvest, and dry fallowing lo‘i for ≥30 days, pending Refuge request

1.1.26. Work with kalo permittees/cooperators and other partners (e.g., National Resources Conservation Service) to continue to develop, implement, and monitor effectiveness of BMPs for Hanalei NWR to improve water quality and flow and reduce the number and severity of avian botulism outbreaks that can cause sickness and mortality. These BMPs include, but are not limited to:

- Using fresh and cool supply water in a well-circulated manner in each lo‘i kalo
- Adequately draining and aerating the soils of lo‘i kalo, which also requires proper maintenance of assigned drainage ditches (see Objective 1.3)
- Maintaining free-flowing internal water supply lines (i.e., regularly monitor and keep supply ditches, supply pipes, and screens free of clogs)
- Maintaining conditions where irrigation "cross-flow" occurs across each path. Cross-flow can be improved by draining from the opposite corner of the patch from the supply pipe, preferably downwind
- Minimizing periods of stagnant water and percolation periods by keeping supply and drain pipes open regularly
- Reducing sediment runoff into the river

1.1.27. Meet quarterly, or as necessary, with Refuge kalo permittees/cooperators to coordinate avian botulism response

Lo‘i kalo: overall reduction in farming intensity and improvement in water quality

1.1.28. Work with kalo permittees/cooperators and other experts to find or refine strategies that benefit threatened and endangered waterbirds and kalo and support the Refuge purpose; for example:

- Reduction in farming intensity and labor expenses
- Ecologically friendly alternatives to traditional chemical fertilizers (e.g., slow-release fertilizer, use of nitrogen-fixing vegetation)
- Organic kalo farming
- "Wildlife-friendly" BMPs or certifications

1.1.29. Require kalo permittees/cooperators to participate in a comprehensive Refuge water budget analysis and implement recommended changes to ensure adequate water supply throughout the Refuge. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility.

1.1.30. Minimize the runoff of excess fertilizer from kalo farms by:

- Developing and implementing a fertilizer management (use) plan for all Refuge kalo farms within two years, with the objective of minimizing losses of nutrients through leaching to groundwater and surface runoff (while improving conditions to prevent avian botulism outbreaks). See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility.
- Periodic soil testing for all farms to determine existing nutrient amount, estimate losses from leaching and surface water runoff, determine crop needs, fertilizer application efficiency, and associated water levels fluctuations for fertilization

1.1.31. Within two years, develop and implement an herbicide management plan for all Refuge kalo farms and rotational managed wetland units (see also Objective 2.1 and Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility)

1.1.32. Work with kalo permittees/cooperators to ensure accurate and specific fertilizer and herbicide reporting annually, in accordance with federal laws and requirements

Lo‘i kalo: invasive species management

1.1.33. Use IPM strategies including mechanical/physical, cultural, chemical, biological, and other suitable techniques to control pest plants (see Appendix D)

1.1.34. Cooperatively implement fencing, live-trapping, and bait stations (non-flood areas only) on kalo production acres to exclude and remove vertebrate pests that prey on threatened and endangered waterbirds

1.1.35. Require kalo permittees/cooperators to report stray dogs or cats found on the Refuge to the Refuge manager or biologist within eight hours of discovery. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility.

Lo‘i kalo: collaboration

1.1.36. Coordinate annually with individual Refuge permittees/cooperators on SUP or, starting during implementation of this plan, CAA. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.37. Conduct bi-annual Refuge-permittee/cooperators meetings/workshops (e.g., avian botulism, water use and systems, monitoring, plant identification).

1.1.38. Work with kalo permittees/cooperators on priority research and monitoring needs, as described in the IMP

1.1.39. Cooperatively maintain fences, gates, roads, water control structures, drainage ditches, signs, and other infrastructure in partnership with the kalo permittees/cooperators. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.1.40. Within three years of WMWCP completion, develop incentive mechanisms for the use of more sustainable and wildlife-friendly farming practices (e.g., maintaining larger nest buffers and use of ≥60-day vegetated wet-fallow period followed by a 2–6-month dry fallow period after tilling organic matter into soil)

1.1.41. Continue to work cooperatively with kalo farmers to describe and quantify the costs of the goods and services the Service provides to the farmers, the benefits the Service receives as a result of allowing kalo farming on the Refuge, and the fair market value for kalo farming (including evaluation of land rents for comparable agriculture-related residential and farm-storage uses) to develop a fair and rational cost-sharing program related to kalo farming

1.1.42. Develop a compliance monitoring system that is reviewed and updated annually

Rationale

Wetland habitats at Hanalei NWR are currently managed as rotational managed wetland units (86 acres) or lo‘i kalo farmed through SUPs (approximately 123 acres, excluding dikes and ditches). Lowland acreage that is currently unallocated to kalo farmers and composed of fallow lo‘i kalo and their associated dikes and ditches totals 22 acres. An additional 3–18 acres of lowlands that are not currently in rotational managed wetland units, lo‘i kalo, or fallow would be restored to functional managed wetland units (Objective 1.2). Under this WMWCP, available lowland/wetland acreage on the Refuge would be allocated towards rotational managed wetlands, lo‘i kalo (via CAAs, see

Section 1.3.2), fallow, or upland habitat (e.g., koloa nesting habitat, Objective 2.4) based on a decision flowchart (Figure 4-2) and re-evaluated periodically using an adaptive management framework. Use of this framework would ensure that the purpose of the Refuge is fulfilled by providing habitats that meet life history requirements for threatened and endangered waterbirds, while allowing for management flexibility to adjust to changing conditions (e.g., additional information from inventory and monitoring, disease outbreaks, availability of funding and resources, compliance with conditions of CAAs). This framework would also enable the spatial reconfiguration of management strategies; for example, retired or unallocated acreage could be exchanged for existing lo‘i kalo acreage depending upon soil, hydrological, and other environmental conditions.

Moist-soil management techniques would be used within rotational managed wetland units to manipulate native and naturalized beneficial nonnative vegetation to provide important structure for threatened and endangered waterbird nesting, foraging, brooding, loafing, and thermal/escape cover. The use of seasonal water drawdowns with periodic soil disturbance (e.g., disking, rototilling) within these wetland units attempts to mimic the natural dynamics of seasonally flooded natural wetlands (e.g., flood events and precipitation/drying cycles). Moist-soil management oxidizes wetland bottoms and incorporates plant material into the soil increasing its fertility and producing an abundance and diversity of aquatic invertebrates as well as creates a seed bed for germination of native/naturalized wetland plants. Annual plants resulting from moist-soil management produce an abundance of seeds that are readily available and consumed by waterbirds. The energy available from these seeds is often as high as or higher than agricultural crops. As moist-soil annuals decompose, they provide substrate and forage for aquatic invertebrates which are also an important food resource for waterbirds, particularly young waterbirds and pre-laying hens. In addition, some of the challenges associated with agricultural crops (e.g., disturbance, loss of crops to foraging wildlife) do not occur or cause less adverse impacts when moist-soil management strategies are implemented. With consistent management, rotational managed wetlands provide for all of the life history needs of the threatened and endangered waterbirds year-round. Attributes for rotational managed wetland units vary depending upon successional stage and focal species. See Appendix C for more information and rationale.

For centuries, kalo, as well as other aquaculture crops, have provided habitat for Hawaiian waterbirds. Although agricultural or cultivated wetlands do not replace all of the functions and values of natural wetlands, many of these lands, if left unmanaged, may revert to solid stands of monotypic, invasive vegetation which is of little value to waterbirds. Because kalo farming is conducted on a year-round basis, the crops are staggered to continually produce a harvestable crop. This results in all stages of kalo growth, including open- and closed-canopy stages along with open water and mudflats, available at any given time. All of these conditions provide some benefits for the waterbirds. However, lo‘i kalo provides unstable (e.g., fluctuating water levels, artificial additives) and thus lower quality habitat for threatened and endangered waterbirds when compared to wetlands managed for a varied moist-soil plant community. Like many agricultural lands, limitations come with the benefits to native wildlife (Heard et al. 2000). Water levels and species composition have often historically been managed primarily to meet kalo production goals; whereas, water levels and species composition in rotational managed wetland units are managed by Refuge staff to meet the life history requirements of threatened and endangered waterbirds. Despite limitations (e.g., disturbance during breeding events, agro-chemicals), kalo farms offer shallow-water habitat that can satisfy some of the life history requirements of threatened and endangered waterbirds (Gee 2007; Gutscher-Chutz 2011) and provide a means to manage supplemental waterbird habitat on Hanalei NWR, when managed consistent with the Refuge purpose to recover threatened and endangered species.

Kalo farming existed prior to and at the time of the establishment of the Hanalei NWR and continues to be an important part of the area's agricultural history. The nine kalo farmers on Hanalei Refuge collectively are the largest producers of kalo in the State of Hawaiʻi, estimated at 40–60 percent (Gutscher-Chutz 2011; NASS 2012; Cho, Yamakawa, and Hollyer 2007). Kalo is a staple food for the people of Hawaiʻi and is important in Hawaiian culture. The Service values the cultural and historical significance of kalo in Hanalei Valley. When the Refuge was established in 1972 for the purpose of endangered waterbird recovery, kalo farming, implemented in a way that was determined as being compatible with that Refuge purpose, was continued via a permit system and integrated as one of the strategies for wetlands management (USDOI 1974).

The Service appreciates the role of individual farmers in maintaining the kalo farming tradition and associated wetland habitat functions and values. The Service's intent is to work with local farmers in order to preserve and perpetuate kalo farming on the Refuge, using BMPs, in a manner compatible with the conservation and recovery of threatened and endangered waterbirds.

To ensure consistency with the Service mission, Refuge purpose, and Refuge System policies (e.g., policy on BIDEH of the Refuge System) and remain compliant with laws (e.g., ESA), the Service is required to re-evaluate the compatibility of kalo farming every 10 years. The intent of the Service is to ensure kalo farming remains compatible with the Refuge's purpose to recover federally listed species. However, issues with kalo farming on a Refuge include ongoing violations of basic SUP terms by some permittees (e.g., pet cats, dogs on dikes, storage of refuse and abandoned vehicles on site, no or limited 30-day wet fallow, incomplete reporting of fertilizer, pesticide use, or discovered threatened or endangered bird nests), sedimentation and nutrient enrichment of receiving waters, and intensive removal of non-kalo emergent plants used as food, cover, and nesting material by threatened or endangered waterbirds. Strategies related to kalo farming at Hanalei NWR under this objective are intended to cooperatively provide and enhance habitat within kalo farms to meet the life history needs of threatened and endangered waterbirds and promote their recovery; and improve compliance with SUP terms and cooperative wildlife-friendly farming. In the short- to medium-term, emphasis during implementation would be on strategies related to reducing the frequency and severity of avian botulism outbreaks. The rationales for specific groups of strategies follow.

Providing and enhancing vegetation structure of loʻi kalo as habitat (all stages) for foraging and breeding threatened and endangered waterbirds (Strategy 1.1.14)

The growth stages of kalo include young (root establishment and leaf growth stages, 0–5 months), mature (corm growth stage, 5–9 months) when water is maintained at 1–6 inch depth (University of Hawaiʻi College of Tropical Agriculture and Human Resources 2008), and pre-harvest (late corm growth stage, 10–12 months) when water is drawn down 1–2 weeks before harvest. Kalo canopy cover ranges from 10–90% depending on the stage. Kalo provides thermal and escape cover (e.g., from introduced predators) for ʻalae ʻula, ʻalae keʻokeʻo (Gee 2007), and koloa maoli year-round. Mature kalo habitat contains medium to dense growth (>50% kalo cover) and provides nesting habitat for ʻalae ʻula and ʻalae keʻokeʻo (Gee 2007). During pre-harvest, reduction in canopy cover and declining water levels stimulates aquatic plant and invertebrate production and enhances foraging resources for endangered waterbirds.

Waterbirds are more sensitive to sudden changes in habitat conditions during critical periods such as breeding. For example, removal of non-kalo vegetation and water level fluctuations during breeding could result in nest desertion or access by predators. On the other hand, when birds are not breeding, removal of invasive weed species from the loʻi is a beneficial farm practice because plants are maintained at a mid-successional stage. Without weed control that is done periodically, lo'i can become overgrown within 4–6 months, which leads to reduced values to wildlife and may reduce kalo production.

Waterbirds are generally opportunistic and use plants that are available for foraging and breeding. Many kalo farmers intensively remove non-kalo emergent vegetation during the first 4–6 months of growth to prevent these plants from out-competing kalo, which can provide more of an open-water habitat for ae'o. However, this practice also decreases vegetative structure available to invertebrates, nesting 'alae 'ula and 'alae ke'oke'o, and foraging for 'alae 'ula, 'alae ke'oke'o, and koloa maoli. Less intensive removal of selected emergent plants would provide additional seeds, leaves, and invertebrate food resources for all threatened and endangered waterbirds and enhance visual obscurity for breeding 'alae 'ula. Byrd and Zeillemaker (1981) found 'alae 'ula favored grasses, sedges, and ferns over kalo to build their nests when these plants were available nearby within their established territories, and Gee (2007) found 46% of 48 nests built in patches of annuals (*S. juncoides*, *C. difformis*, *L. palustris*) beneath the kalo canopy. Allowing non-kalo emergent plants beneficial to waterbirds would diversify invertebrates available for food (Gutscher-Chutz 2011) and increase the quantity and quality of plants available for forage, nesting material, and nest anchors for multiple waterbird species. In addition, non-kalo emergent plants would assist with filtration, assimilation, and retaining nutrients and sediments on land. Under this WMWCP, permittees would allow at least three species of selected plants beneficial to threatened and endangered waterbirds to grow from seedbank interspersed within the understory, on either ≥10% of each of their lo'i permitted for farming or ≥20% of each lo'i on at least half of their lo'i permitted for farming; or maintain ≥10% of their total lo'i acreage under permit in vegetated wet fallow. Collectively, implementation of these options would result in enhanced habitat, while also maintaining open-water habitat for shorebirds. Providing "non-kalo food sources" and nesting material in and around the existing lo'i kalo would also reduce the potential for crop depredation.

Protect nesting and brood-rearing habitat in kalo (Strategies 1.1.15–1.1.19)

Kalo harvesting is done manually within a period of several days up to four weeks depending on the size of lo'i, number of workers (Gee 2007), and other environmental conditions. During this period, the leaves die back (~25% kalo cover) and the lo'i is reflooded (~2–6 inches). Of the kalo stages, the harvest stage along with wet fallows had the highest use by endangered waterbirds (Gee 2007; Gutscher-Chutz 2011). Broshears (1980) found a strong positive relationship between ae'o and chironomid densities following harvest. Farmers could naturally restore soil structure by trampling or tilling aquatic plants into the soil, to enhance organic matter and promote beneficial microorganisms.

On kalo farms, Byrd and Zeillemaker (1981) found that 95% of the 80 'alae 'ula nests in kalo were more than four months old, the age at which the kalo canopy starts to close. However, this could be an overestimate because nests were documented opportunistically, primarily during harvest. Currently, when a farmer discovers an 'alae 'ula or 'alae ke'oke'o nest while harvesting, the farmer is required to leave an unharvested 3-foot radius buffer around the nest. This nest buffer is not based on empirical data and appears to be inadequate (Gee 2007) and in need of expansion and re-evaluation (Paveglio et al. 1999) to prevent detrimental effects on breeding adults and offspring.

'Alae 'ula nest and fledging success from a study conducted in 2004 was 64% and 3%, respectively (Gee 2007). Nest and brood failures are attributed to predation, abandonment, and flooding (Gee 2007), indicating the need to re-evaluate nest buffer and other factors during this period (Gutscher-Chutz 2011). Nest platforms are also used for brood-rearing. Although inadequate buffer size has been identified as a factor, it is uncertain if buffer size alone or combined with other factors causes brood failure.

Under this WMWCP, the Refuge recognizes the need for research to determine adequate buffer size (see Strategy 1.1.17) or alternate strategies (see Strategy 1.1.18). Assessment of nesting success would be undertaken to verify the effects of buffer size during post-harvest periods. In the interim, in lo‘i where threatened or endangered waterbird nests are found, the current 3-foot radius buffer would be changed to a minimum 6-foot radius buffer around nests. Kalo farmers would be required to keep the lo‘i flooded and coordinate with Refuge staff to minimize impacts or take of birds by implementing additional protective measures as needed, such as delaying harvest in areas where nests are known to occur until the young birds fledge or leave the lo‘i of their own accord.

Drawdowns in lo‘i with active nests during any stage may result in nest collapse and failure (Paveglio et al. 1999; Gee 2007) by exposing eggs, flightless young, and breeding adults to introduced mammalian predators. Gutscher-Chutz (2011) recommended slow drawdowns at half-inch increments to extend the time in which invertebrates are available to endangered waterbirds for foraging; however, this may not apply in avian botulism hotspots where the area needs to be drained or flushed quickly.

Provide and enhance foraging resources in fallow lo‘i kalo (Strategy 1.1.21)

A wet fallow is when the lo‘i is flooded during the post-harvest, pre-planting period for 30 or more days. Of all kalo stages, the wet fallows and harvest stages had the highest use by endangered waterbirds (Gee 2007; Gutscher-Chutz 2011). Additionally, vegetated wet fallows (≥25% cover emergent vegetation) were preferred by ‘alae ke‘oke‘o, koloa maoli, and ‘alae ‘ula, and unvegetated wet fallows (<25% cover emergent vegetation) were preferred by ae‘o and ‘alae ke‘oke‘o over other kalo stages (Gee 2007). Soil disturbance from harvest stimulates invertebrate production (dipteran larvae and other benthic invertebrates), maximizing foraging opportunities for endangered waterbirds (Broshears 1980). In lo‘i kalo, it is the period of highest invertebrate egg laying and larval growth. Two weeks post-harvest had the highest densities of endangered waterbirds in lo‘i kalo.

There are two types of dry fallows, vegetated (≥ 25% cover vegetation) and unvegetated (<25% cover vegetation). Flooding of dry fallow lo‘i during rainfall events mimics irrigation of moist-soil vegetation and attracts high densities of endangered waterbirds (Gee 2007). Dry fallows for 1–3 months are recommended for proper vegetative breakdown and disease suppression. Six-month dry fallows can lead to increased yield, corm quality, and reduction or elimination of some diseases and pests (Uchida et al. 2008). Vegetated dry fallow lo‘i (>1 acre) provides foraging and roosting habitat for threatened nēnē and endangered waterbirds, including koloa maoli nesting habitat, while unvegetated dry fallow lo‘i or mudflats provide roosting sites for migratory shorebirds such as kōlea.

Avian botulism prevention and response (Strategies 1.1.22–1.1.27)

The Refuge would continue to cooperate with kalo permittees/cooperators to implement a multi-pronged approach towards minimizing the number and severity of avian botulism outbreaks. Preventative measures include BMPs for improving drainage and circulation within lo‘i kalo. The quantity of cool, clean, well-oxygenated and well-circulated water through lo‘i kalo is important for lowering the likelihood of an avian botulism outbreak. If a given lo‘i kalo is avian botulism prone, then reconfiguring pipelines to remove flow-through (i.e., lo‘i-to-lo‘i) drains is mandatory because these lines can contribute to environmental conditions more conducive to botulism outbreaks, spread the botulism toxin between patches, and prolong avian botulism outbreaks.

In addition to using plenty of water, one of the most important actions that Refuge kalo farmers can do to help prevent avian botulism is to thoroughly drain, dry, and fully aerate their soils. After the wet fallow period, Refuge kalo farmers will be required to drain and disk and/or till the soils of each patch. Soil (and water) aeration reduces the anaerobic environmental conditions required for the bacteria (*Clostridium botulinum*) to germinate and improves soil health through oxygenation. Lo‘i kalo identified as “continuous problem” patches in hotspot areas, including those areas that are slow or unable to completely drain (and disk and/or till), will be required to have their wet fallow period replaced with an extended dry fallow period followed by extensive soil aeration.

A key strategy for avian botulism response is to require kalo farmers report sick or dead birds to the Refuge manager or biologist within 24 hours of detection. The botulism toxin is a fast-acting neurotoxin that can kill koloa (which are approximately 65% of the birds afflicted) within as short as eight hours if not given an antidote, which the Refuge biologist has available on-Refuge. Avian botulism affected birds often drown because the toxin affects the nervous system and the birds’ ability to hold their head up out of the water. If an afflicted bird is given this antidote soon enough and the bird is properly hydrated and kept warm, then their chances of survival go up exponentially. The recovery rate is good if the afflicted bird can be caught, given the anti-toxin, and taken to the “Save Our Shearwaters” facility at the Kaua‘i Humane Society, in a timely manner. If the bird is already dead when found, then removal of the carcass may stop the botulism outbreak or prevent continuation of an ongoing outbreak. Bird carcasses can develop maggots that have the toxin; other birds may eat the toxic maggots and the outbreak cycle continues and may expand. Thus, it is important to remove dead birds before maggots develop.

Additional strategies related to avian botulism prevention and response are mentioned above in Section 4.1, Avian Botulism Surveillance and Control.

Overall reduction in farming intensity (e.g., human disturbance, chemical load, water level fluctuations) and improvement in water quality (Strategies 1.1.28–1.1.32)

The Refuge would continue to work cooperatively with the kalo permittees/cooperators to resolve issues and come up with workable solutions and measurable, achievable goals for both kalo farming and threatened and endangered waterbird recovery. Issues would include, but are not limited to, methods to reduce farming intensity and enhance waterbird habitat as was recommended in a Refuge review (Paveglio et al. 1999) and habitat use studies (Gee 2007; Gutscher-Chutz 2011); and strategies and practices to improve water quality of receiving waters (Tetra Tech and HDOH 2008; Sustainable Resources Group International Inc. 2012; see also Objective 2.1).

Specific strategies to reduce chemical inputs to lo‘i kalo include the development and implementation of fertilizer and herbicide management plans. A fertilizer management plan is a conservation practice recommended to be prepared for any activities where fertilizer is used to promote plant growth. The objective of the plan is to ensure application of fertilizer amounts that minimize losses of nutrients through leaching to groundwater and surface water runoff. A fertilizer management plan may be comprised of a soil test to determine existing nutrient amounts, generated estimates of losses from leaching and surface water runoff, crop needs, fertilizer application efficiency, and irrigation scheduling (Sustainable Resources Group International Inc. 2014). An herbicide management plan would detail the type, timing, number of applications per year, maximum rate per application, and locations and buffer zones for herbicide use.

Invasive species management (Strategies 1.1.33–1.1.35)

The Refuge would explore cooperative programs to control introduced predators and other pests in kalo habitat. It is critical to control predators during the breeding season to reduce mortality and increase reproductive success and survival of threatened and endangered waterbirds. In 2004, predation by cattle egrets, ʻaukuʻu, cats, rats, or owls, accounted for 17.6% and 22.9% of ʻalae ʻula and aeʻo nest losses, respectively (Gee 2007). Bullfrogs are also a considerable predator of waterbird chicks. Nonnative predator control benefits multiple native species, including endangered koloa maoli, ʻalae ʻula, ʻalae keʻokeʻo, nēnē, and migratory birds (USFWS 2011e) and is important to achieve the Refuge purpose. Pest and nonnative predator control also reduces losses to kalo farmers (e.g., pigs cause severe damage to loʻi kalo by digging up and eating kalo, rats and feral chickens depredate kalo corms).

Collaboration with kalo permittees (Strategies 1.1.36–1.1.42)

The use of kalo farming as a wetland management tool for providing supplemental threatened and endangered waterbird habitat on Hanalei NWR requires effective communication and collaboration between the Service and kalo permittees/cooperators. Occasionally, threatened and endangered waterbird management goals and objectives may conflict with optimal kalo water management and production. The Service aims to strengthen relationships with the permittees through regular communication, information sharing and learning, and incorporation of multiple perspectives so that collaborative solutions could be developed and implemented.

Currently, in exchange for kalo permittees' contribution to waterbird recovery, the Service provides multiple benefits to the permittees, including:

- Permit fees currently set at a reduced rate to compensate permittees for practices that may be required to favor threatened and endangered waterbirds in kalo-bird conflicts. The permit fee for kalo farming on Hanalei NWR is $25/acre/year, which is comparable to 1898 annexation rates for rice farming ($30–35/acre; Coulter and Chun 1937). This fee has not increased since the Refuge was established in 1972. This fee applies only to cultivated acres (loʻi) and is not applied to other farm use areas used for houses, storage, etc. This fee does not go directly to Hanalei NWR, but instead goes to the U.S. Department of Treasury general funds.
- Not requiring resident farmers to pay property tax for their homes or associated land;
- Not requiring farmers to purchase liability insurance;
- Coordination and technical assistance (e.g., workshops and meeting with permittees);
- Installation, operation, and maintenance of the main irrigation system;
- Drainage ditch cleaning;
- Maintenance of primary access roads on the Refuge;
- Invasive species management (including feral pigs, feral cats, rats, chickens, Guinea grass, California grass, *Paspalum* grasses, and *Albizia* trees) including the construction and maintenance of over two miles of perimeter fence;
- Avian botulism control and surveillance;
- Coordination and implementation of BMPs for sustainable farming and prevention and limitation of avian disease outbreaks;
- Ensuring compliance and coverage for pesticide and fertilizer application;

- Disposal of waste related to farming and houses;
- Equipment sharing; and
- Monitoring and controlling trespassing, theft, poaching, and other illegal activities.

In addition to the core requirements (stipulations) maintained to ensure compatibility of kalo farming, the Service proposes developing incentive mechanisms within three years of WMWCP completion to reward more sustainable farming practices and support a phased approach to implementation of management strategies related to kalo farming. Each permittee/cooperator and their farming practices would be reviewed per the terms of the CAA.

The Service is working cooperatively with kalo farmers to describe and quantify the costs of the goods and services the Service provides to the farmers, the benefits the Service receives as a result of allowing kalo farming on the Refuge, and the fair market value for kalo farming to develop a fair and rational cost-sharing program related to kalo farming. This study will facilitate collaboration between the Service and the kalo farmers by providing cost-benefit analysis and illustrating both parties' responsibilities and contributions towards kalo farming on the Refuge.

Cost-sharing would be implemented through kalo farming CAAs. Per the cooperative agricultural use policy (620 FW 2), cost-sharing is defined as the portion of the costs for cooperative agriculture on Refuge System lands that are borne by the cooperator. Cost-sharing can vary depending on the needs and objectives of the particular refuge land. For example, the Service may provide the cooperator with the right to perform agricultural practices on Refuge land and a percentage of any resulting crop yield, as well as the ability to use Service water, equipment, or Refuge staff. In exchange, the cooperator may provide the Service with labor, equipment, and materials; a percentage of any resulting crop yield; or maintenance, rehabilitation, or reestablishment of specific habitat conditions on Refuge lands.

The Service policy on the administration of specialized uses (5 Refuge Manual [RM] 17) requires that specialized uses, which include economic, recreational, right-of-way, and other privileged uses, must be accompanied by a fee or cooperative exchange to recover the costs of administering the SUP and use and/or the fair market value of the benefit received.

OBJECTIVE 1.2 RESTORE AND/OR ENHANCE SEASONAL/ROTATIONAL WETLAND HABITAT TO BENEFIT THREATENED AND ENDANGERED AND MIGRATORY WATERBIRDS.

Within 7 years, restore and/or enhance an additional 3–18 acres of seasonal/rotational wetland habitats for threatened and endangered and migratory waterbirds, with the following attributes (as in Objective 1.1*):

- Recently flooded mosaic of shallow (<8 inches, mostly 3–4 inches), open water and 50–75% cover of short (<12 inches tall), non-persistent emergents (e.g., *Fimbristylis*, *Cyperus*, *Eleocharis*);
- Abundant macroinvertebrates (e.g., damselflies, crayfish, midges) for foraging;
- Minimal human disturbance year-round;
- <5% cover of pest plants (e.g., California grass, *Paspalum*, Guinea grass); and
- No feral mallards or their hybrids.

*Once completed, the rotational managed wetland units would be managed for habitat attributes in Objective 1.1 and incorporated into the 18–24 month rotation.

Strategies Applied to Achieve Objective:

Restoration and enhancement

1.2.1. Remove hau
1.2.2. Use mowing to remove invasive species and clear area
1.2.3. Explore use of seasonal livestock grazing, on an experimental basis and including pre- and post-monitoring, to remove invasive species and clear area (see also Appendix B, Cooperative Grazing CD)
1.2.4. Evaluate any areas being considered for domestic livestock grazing and develop a Prescribed Grazing Plan that identify mitigation measures such as fencing animals out of water resources, riparian buffer zones
1.2.5. Install water control structures

Management:

1.2.6. Mowing, disking, rototilling, and water level management, as needed, to set back wetland plant succession and provide suitable habitat structure and function. See Appendix C for additional information
1.2.7. Contour pond bottoms to create variable topography
1.2.8. Create sloughs to promote drainage
1.2.9. Pulse water/flood in 2–4-inch increments during first six months to promote vegetative growth
1.2.10. Flood after water pulse to break down vegetation that promotes invertebrate production
1.2.11. Slow drawdown (over 1–3 weeks), as needed to control pest fish (e.g., tilapia and poeciliid fish), concentrate invertebrates, and promote invertebrate/plant growth
1.2.12. Public use and management activities by Refuge staff are timed and conducted to prevent or minimize disturbance
1.2.13. Use IPM strategies including mechanical/physical, cultural, chemical, biological, and other suitable techniques to control Guinea grass, red mangrove, cattail, and other pest/undesirable plants
1.2.14. Live-trapping and humanely dispatching feral mallards and mallard/koloa hybrids
1.2.15. Live-trapping, humanely dispatching, and bait stations to remove vertebrate pests that prey on threatened and endangered waterbirds
1.2.16. Maintain existing three miles of fence to protect wetlands management units from pigs and dogs

Rationale

At Hanalei NWR there are currently 3–18 acres of lowlands that are not currently in rotational managed wetland units or lo‘i kalo and could be restored to functional managed wetland units. The areas include three acres in between the KU4 wetland unit on the south and lo‘i kalo on the north, 5 acres bordered on the west and south by fallow lo‘i kalo and to the east by a hau-dominated area, and also 10 acres located near a riparian grassland and adjacent hau dominated area by the Hanalei River diversion. These areas would need to be opened up using heavy equipment, herbicides, and/or grazing to remove California grass. Water delivery systems and water control structures would need to be installed.

At least initially, grazing programs would be conducted on a short-term, experimental basis (with 1-year SUP/CAA) to determine whether the grazing program could create the habitat conditions being sought. Grazing program parameters (timing, frequency, intensity, or other elements) would be developed and documented in a grazing plan for the Refuge and associated BMPs for grazing. See Appendix B, Cooperative Grazing CD for more information.

Once the new wetlands management units are functional, they would be managed as described in Objective 1.1 to provide for the life history requirements of threatened and endangered waterbirds and continue to fulfill the purpose of the Refuge. These activities would provide safe equipment and vehicle access, structurally sound dikes, topographic features suitable for waterbird habitat management, a functional and efficient water delivery system that allows for water level management, restored hydrologic functions and vegetation structure to regain waterbird habitat values, and protected and managed habitat.

OBJECTIVE 1.3 MAINTAIN DIKES AND DITCHES FOR WATER DELIVERY AND FORAGING AND BREEDING WATERBIRDS.

Provide and maintain 76–85 acres of dikes and ditches for water delivery and nēnē, koloa maoli, ‘alae‘ula, and ‘alae ke‘oke‘o foraging and loafing throughout the year, with the following attributes:

- ≥75% of dikes at 4–6 inch vegetation height;
- >75% of ditch banks contain 100% herbaceous cover; and
- <5% of ditch banks contain pest woody vegetation (e.g., sourbush, shoebutton ardisia).

Strategies Applied to Achieve Objective

1.3.1. Develop and utilize BMPs for ditch maintenance to minimize adverse water quality impacts. For example:
- Reduce use of chemical treatments on bank vegetation
- Utilize mechanical methods of drain ditch vegetation control in order to minimize herbicide use
- Maintain vegetated banks to control erosion and filter sediment and nutrients
- Explore methods for sustainable removal of nutrients and sediment (e.g., experiment with beneficial wetland/ditch remediation areas, use of floating racks of plants to assist in removing nutrients and sediment

1.3.2. Rehabilitate dike around DU ponds
1.3.3. Rehabilitate main irrigation intake on China Ditch
1.3.4. Conduct assessment of dike size and integrity as part of maintenance to ensure wetland management is supported sufficiently; rehabilitate, as necessary
1.3.5. Use IPM strategies including mechanical/physical, cultural, chemical, biological, and other suitable techniques to control pest/invasive plants

Rotational managed wetlands

1.3.6. Mowing to set back plant succession and provide suitable habitat structure and function

Lo‘i kalo

1.3.7. Cooperatively manage drainage ditches with kalo farmers to maintain free flow (e.g., the ability to efficiently drain lo‘i kalo), while exploring methods to reduce sediment and nutrient loading within the river. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

1.3.8. Document individual and shared maintenance responsibilities in a Plan of Operations associated with CAAs. Finalize maps of shared drainage ditch cleaning and fence maintenance responsibilities annually

1.3.9. Maintain dikes using mowing or brush-cutting. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility

Rationale

Dikes and ditches support water level management within both rotational managed wetlands and kalo farms on Hanalei NWR. Enhancement of dikes may provide additional forage for grazers like nēnē, ‘alae ‘ula, and ‘alae ke‘oke‘o. Maintaining dikes with low-intermediate growing grasses and leafy forbs also helps to control pest plants and reduces concealment cover for introduced predators. Less frequent mowing reduces expenses for fossil fuels and disturbance to threatened and endangered waterbirds. Enhancement of ditches may provide additional forage and nesting material for ‘alae ‘ula. Vegetated ditch banks would also help to trap sediment and nutrients, thereby reducing Hanalei River inputs.

The Watershed Management Plan for Hanalei Bay Watershed (Sustainable Resources Group International Inc. 2014) recommends that surface water discharges from Hanalei NWR (both from lo‘i kalo and rotational managed wetland units) should pass through a constructed wetland designed to filter excess nutrients and sediment before the water reaches the Hanalei River. This constructed wetland(s) could help to bio-remediate nutrients by using native sedges and soil microbes to uptake excess nutrients in addition to collecting sediment carried in the water coming from the Refuge. The Refuge would experiment with beneficial wetland/ditch remediation areas to improve water quality of receiving waters. However, if these constructed wetlands are not effective, concentrate agricultural discharge, accumulate chemicals and toxins, and/or create conditions conducive to avian botulism outbreaks (e.g., warm, high nutrient, stagnant) which put threatened and endangered waterbirds at higher risk, then these constructed wetlands would be discontinued.

The opportunity currently exists to establish riparian buffer zones to attenuate sedimentation and nutrient enrichment of receiving waters, utilize the existing drainage ditches to perform some functions of bio-remediation and sediment filtration by allowing some ground cover vegetation to grow in the ditch. Improved ditch management, along with use of BMPs for kalo cultivation and fertilizer and pesticide management plans, would support water quality improvements (see Goal 1).

Additionally, the Service is replacing kalo pipelines containing re-used water (water draining into multiple lo‘i kalo) with fresh water sources. See Section 4.1, Avian Botulism Surveillance and Control, and Objective 1.1 for more information.

4.3 Goal 2: Protect, restore, and manage the riverine and riparian ecosystem to benefit native plant and animal communities.

Objective 2.1 Protect and enhance river corridor habitat.

Protect and enhance BIDEH of 3.1 miles of Hanalei River for native fish, wildlife, and humans throughout the year, with the following attributes:

- Multiple stream assessment indices (e.g., biotic integrity) suggest a positive trend in the health of river resources; and
- Community-based stewardship of Hanalei River watershed.

Strategies Applied to Achieve Objective:

2.1.1. Develop, implement, and monitor the effectiveness of BMPs for Hanalei NWR to improve water quality (e.g., assist with meeting State standards for reduction in nutrients)
2.1.2. Develop and implement water quality and flow monitoring program
2.1.3. Work with partners to develop a watershed-scale hau management plan
2.1.4. Reduction of hau by 2–5 acre/year in priority areas (e.g., blocking drainage, potential cause of accelerated erosion) and restore area with native or beneficial nonnative plant community
2.1.5. Work with partners (e.g., Hanalei Watershed Hui, EPA, Department of Health) to implement a community-based watershed management plan to address excessive sources of anthropogenic sediment and nutrients from Refuge lands
2.1.6. Work with Hawaiʻi Division of Aquatic Resources and other partners to develop an Aquatic Resources Management Plan
2.1.7. Work with partners (e.g., Hanalei Watershed Hui, DLNR, hiking organizations) to continually stabilize Ōkolehao Trail
2.1.8. Support additional research to set measurable and attainable milestones for nutrient load reductions in river
2.1.9. Develop and implement a fertilizer management plan for all Refuge kalo farms (see Objective 1.1 and Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility)
2.1.10. Develop and implement a herbicide management plan for all Refuge kalo farms and rotational managed wetland units (see Objective 1.1 and See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility)
2.1.11. Evaluate any areas being considered for domestic livestock grazing and develop a Prescribed Grazing Plan that identifies mitigation measures such as fencing animals out of water resources, riparian buffer zones (see Objective 1.2, Objective 2.2, and Appendix B, Cooperative Grazing)
2.1.12. Monitor and provide feedback to the DLNR regarding the effects of the Hanalei River breach repair on irrigation water levels at the Refuge
2.1.13. As soon as possible, work with the Army Corps of Engineers to re-evaluate the floodplain at Hanalei NWR to update the findings from the study completed in 1999 based on the most current conditions and using new technology for more accurate and

detailed analysis to see if any modifications to dike elevation or other infrastructure are recommended

2.1.14. Use IPM strategies including mechanical/physical, cultural, chemical, biological, and other suitable techniques to control hau, Guinea grass, and other pest/undesirable plants

2.1.15. Kalo permittees/cooperators would be prohibited from dumping or disposing of any non-composted organic materials (e.g. green waste from outside sources, peelings or residues from kalo/poi mills) on the Refuge. See Appendix B, Cooperative Kalo Farming; Residences and Farm Storage Areas CD, Stipulations to Ensure Compatibility.

Rationale

Approximately 3.1 miles of the 16-mile perennial Hanalei River (an American Heritage River) flows through Hanalei NWR. The 24 square-mile watershed originates at the Mount Wai'ale'ale summit, one of the wettest spots on earth, and terminates at Hanalei Bay, a popular recreational area. The Refuge is located within the lower basin, and represents 6% of the land area in the Hanalei watershed. The river provides habitat for 5 species of threatened and endangered waterbirds, primarily koloa maoli; 5 species of 'o'opu (Hawaiian amphidromous gobies); and native invertebrates such as pinao 'ula (endemic damselflies) and 'ōpae 'oeha'a (endemic shrimp).

Nonnative hau is an invasive species that grows thickly along the banks of the Hanalei River, slowing and backing up flow, thus exacerbating flooding during large rain events. Hau removal would be coordinated with partners and be prioritized in areas where drainage is blocked or where it causes accelerated erosion that threatens homes or other structures.

Water quality data collected over many years in the Hanalei Bay watershed have shown frequent exceedances of water quality standards for bacteria and turbidity and occasional exceedances for nutrients (nitrogen and phosphorus) (e.g., Berg 1995; Berg, McGurk, and Calhoun 1997; Berg 2007; see also Section 2.2.7). The Hanalei River is on the EPA 303(d) List of Impaired Waters for enterococci, excessive nutrients, and turbidity (see Section 2.2 for more information). The Phase 1 TMDLs report identified Hanalei NWR as one of multiple sources in the watershed contributing sediment and nutrients to the bay, and recommended cesspool closure, upgrading septic systems, ungulate fencing and management, stream restoration, trail stabilization, road management, and education to reduce fertilizer and sediment inputs to the river. Based on sampling within Hanalei Bay, two studies suggest that agricultural runoff is the primary source of nitrogen in the bay (Derse et al. 2007; Knee et al. 2008). Two biotic integrity indices suggest habitat in the upper Hanalei River is in good condition and the lower portion is moderately impaired (Tetra Tech and HDOH 2008).

As a major land owner in the Hanalei Watershed, the Service takes a leading role to reduce the sediment, bacteria, and agricultural-based contamination in the Hanalei River. Mitigation and clean-up methods are not as effective as minimizing the run-off of identified pollutants. Refuge strategies include (1) focusing on priority projects on Refuge lands and (2) working with partners to develop watershed-level initiatives. Priority projects on Refuge land may include passive restoration (cessation of anthropogenic activities causing degradation); road improvement (e.g., water bars, riparian buffers, retire old roads); feral pig control; control of large, introduced cattle egret rookeries along the river; riparian buffer zone establishment (no development); diverting storm runoff to vegetated flats (instead of waterways); restoration of native plant communities adapted to riparian conditions, and investigating efficient methods for sediment control (e.g., sediment traps on major drains). The Refuge and partners intend to evaluate the environmental and economic effects of slow-release nitrogen fertilizer in wetland kalo as an alternative to traditional fertilizers. Additional water quality concerns are the prevalence of wet tilling and other disturbance of the soil during kalo production which can cause turbid water to flow back into the river if drains are open during or within a week after the process. The Refuge would be developing, implementing, and monitoring the effectiveness of BMPs to improve water quality on-site.

OBJECTIVE 2.2 ENHANCE AND MANAGE RIPARIAN HABITAT FOR NĒNĒ BREEDING AND FORAGING.

Within 5 to 10 years, enhance and manage 14–24 acres of riparian grassland habitat for breeding and foraging nēnē throughout the year with the following attributes:

- High-value grass-sedge forage for nēnē maintained at approximately 4–6 inches vegetation height;
- ≥150-foot riparian/wildlife buffer zone; and
- ≤2 nēnē mortalities by introduced predators (e.g., cats, barn owls, dogs, rats) per year.

Strategies Applied to Achieve Objective:

2.2.1. Mowing of grassy sedgelands to set back plant succession and provide suitable habitat structure and function
2.2.2. Explore use of seasonal livestock grazing on 14–24 acres (see Appendix B, Cooperative Grazing)
2.2.3. Evaluate any areas being considered for domestic livestock grazing and develop a Prescribed Grazing Plan that identifies mitigation measures such as fencing animals out of water resources, riparian buffer zones
2.2.4. Integrate monitoring needs for establishing baseline conditions and evaluating effectiveness of livestock grazing for enhancing nēnē breeding and foraging habitat into the IMP
2.2.5. Install water delivery system (~100 feet of 6-inch pipeline and supply valves)
2.2.6. Build and maintain 1–1.5 miles of new protective fencing
2.2.7. Establish ≥150-foot riparian/wildlife buffer zones
2.2.8. Use IPM strategies including mechanical/physical, cultural, chemical, biological, and other suitable techniques to control pest/undesirable plants
2.2.9. Live-trapping, humanely dispatching, and bait stations to remove vertebrate pests that prey on threatened nēnē

Rationale

Nēnē are browsing grazers of grasses, sedges, forbs, and shrubs and typically nest in edges of open-understory woodlands. No studies have been conducted on nēnē lowland foods. However, research conducted at mid-elevations on Hawai‘i Island found that: (1) nēnē fed mainly on cultivated grasses; (2) legumes and grass leaves had more protein than berries and grass seeds; (3) pasture grasses had more protein than shrubland grasses; (4) mowed or livestock-grazed grasses had more protein than rank grasses; and (5) breeding success was higher for nēnē with more grasses in their diet (Black et al. 1994; Woog and Black 2001). Birds selected forage with high water and protein content such as the young shoots of a Kikuyu grass-Spanish clover grassland, and preferred sward-forming (turf-like growth) over bunch grasses, and short grasses (2–4 inches) over tall grasses (Woog and Black 2001).

At Hanalei NWR, 14–24 acres of riparian grassland located near southern boundary of the Refuge and encircled on three sides by the Hanalei River would be enhanced and managed for breeding and foraging nēnē. Mowing is a recommended strategy for nēnē because it can provide more consistent habitat structure and forage timed to meet the requirements of the annual cycle.

Livestock grazing would potentially be used to open up and maintain areas currently choked with pest California grass. A ≥150-foot riparian buffer would be established to protect river resources from sediment or nutrients associated with grassland and livestock management and provide for koloa maoli and ʻalae ʻula nesting habitat. The area inside the buffer zone would be fenced to protect breeding and molting birds and allow for seasonal livestock grazing during the nēnē nonbreeding season (approximately May–September). Through CAA, a local livestock grazer, following a prescribed grazing plan that would minimize effects on river resources and maximize nēnē habitat values, would provide managed grasslands for nēnē. See Appendix B, Cooperative Grazing CD for more information.

Nēnē eggs and goslings are vulnerable to introduced predators including rats, mongooses, dogs, cats, and pigs. Adult nēnē are mainly vulnerable to dogs and cats, especially during their synchronous molt of flight feathers, which renders birds flightless. It is critical to control introduced predators to reduce mortality and increase reproductive success and survival. Controlling introduced predators would also benefit multiple migratory and federally listed bird species, including endangered aeʻo, ʻalae keʻokeʻo, ʻalae ʻula, and koloa maoli (USFWS 2011e), and are important to achieve the purposes of the Refuge.

OBJECTIVE 2.3 ENHANCE AND MANAGE UPLAND AREAS FOR KOLOA MAOLI NESTING.

Within two years, enhance and manage 21 acres of upland habitat for nesting koloa maoli:

- Non-flooded;
- Dense vegetative canopy (>75% horizontal visual obscurity at 18 inches; less dense above) dominated by ferns, forbs, and grasses;
- Vertical structure (18–36 inches);
- >10% of residual plant material;
- Minimal human disturbance year-round;
- <5% cover of pest plants (e.g., California grass, Guinea grass);
- No feral mallards or their hybrids; and
- ≤2 individual koloa maoli mortalities by introduced predators (e.g., cats, barn owls, dogs, rats) per year.

Strategies Applied to Achieve Objective

2.3.1. Mowing, disking, cultipacking, and rototilling to provide suitable habitat structure and function

2.3.2. Use IPM strategies including mechanical/physical (e.g., mowing, brush-cutting, excavation, prescribed fire), cultural (e.g., water levels), chemical (herbicides), biological, and other suitable techniques to control California grass, Guinea grass, and other pest/undesirable plants

2.3.3. Prior to implementing maintenance schedule, perform a waterbird nest/brood search in accordance with established protocol

Rationale

Little is known about koloa maoli nesting habitat, but it is likely they historically occupied a wide range of mesic and wet coastal, lowland, and montane habitats as they do today. In lowlands, it is presumed that wetland-associated, managed, grassy-herblands free from inundation, disturbance, and introduced predators provide suitable nest sites. On Kaua‘i, koloa maoli nest from sea level to 3,500 feet elevation. Although koloa maoli nests have been documented in all months of the year, 77 percent were recorded December to May (Swedberg 1967) and 74 percent were initiated December to April (C. Malachowski, unpublished data). Nests are usually placed on the ground and concealed by dense shoreline or upland vegetation near freshwater resources including wetlands, water impoundments, ditches, and streams. They are often found at base of bunch grasses with overhanging tussocks (e.g., kāwelu, *Eragrostis variabilis*, broomsedge, *Andropogon* spp.), but are also found in ferns, shrubs, and rhizominous herbs (Engilis, Uyehara, and Giffin 2002).

On Hanalei NWR, a small sample of nests were characterized (n=21). Habitat types included kalo farms, forest, managed wetlands, grasslands, and scrub/shrub in association with dikes, upland flats, dry lo‘i kalo/wetland impoundments, and mountain ridges. Ferns (uluhe, *Dicranopteris linearis*), forbs (e.g., wedelia, *Spahagneticola trilobata*), and grasses (e.g., California grass) dominated ground covers within 45 feet of nests, with smaller components of sedges, shrubs, trees, vines, and bare ground. The mean ground vegetation height above nests was 40 inches, with 66 to 95 percent vertical visual obscurity. Horizontal visual obscurity ranged from approximately 28 percent concealment 66 inches above nests to 75 percent at the bases of nests. Nests were constructed of stems, leaves, and seed pod casings of nearby plants and variable amounts of down. The distance of nests to water varied from four inches to 330 feet, with a mean distance of 90 feet (C. Malachowski, unpublished data). Although a larger unbiased sample is needed to understand habitat suitability, these nests provide an initial characterization of koloa maoli nest sites.

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APPENDIX A. DRAFT APPROPRIATE USE FINDINGS

FINDING OF APPROPRIATENESS OF A REFUGE USE

Use of this form is required for documenting all appropriate use findings (603 FW 1)

Refuge Name: Hanalei National Wildlife Refuge, County of Kaua‘i, Hawai‘i

Use: Cooperative Kalo Farming; Residences and Farm Storage Areas (Residential [other] and Farming)

This is a: ______ New Use ✔ Existing Use

A. Does this use qualify for an appropriateness review exemption?
(Please Check One)

Some refuge uses are exempted from an appropriateness review [603 FW 1.2; 603 FW 1.2(A)]. Appropriate use finding exemptions are documented through the use of this form.

______ This use is "protected," "conditioned," or otherwise provided for under law or regulation.
Examples include the use of snow machines, airplanes, or motorboats on Alaska refuges under certain conditions per the ANILCA. Provide a written justification as to how this use qualifies for this particular exemption.

______ The Service does not have jurisdiction over the use
This could be as a result of treaty rights, court orders, consent decrees, pre-existing rights (such as subsurface Non-Federal oil and gas or mineral rights, grandfathered easements, etc.). Provide a written justification as to how this use qualifies for this particular exemption.

______ This is a Right-of-Way Permit request
Right-of-way requests are subject to 340 FW 3 and compatibility determinations (603 FW 2). Attach a brief explanation as to how this use qualifies for this particular exemption.

✔ This use DOES NOT qualify for an appropriateness review exemption.
Proceed to evaluate the use under Part B.

If the use meets one of the three qualifying exemptions above, then it is exempt from an appropriate use determination. Skip Parts B, C, D and E and complete Parts F and G, sign and date, and submit a copy to the Refuge Supervisor.

B. Is the use administratively determined as appropriate in law or policy?
(Please Check One)

The following refuge uses are appropriate because they have been administratively determined as appropriate uses by statute or policy [603 FW 1.11(A)(1); 603 FW 1.6(A)(3)].

______ This use is a wildlife-dependent recreational use.
Hunting, Fishing, Wildlife Observation, Wildlife Photography, Environmental Education, or Interpretation.

______ This use involves the take of fish and wildlife under state/territorial regulations.
Including other forms of state-regulated take beyond hunting and fishing.

✔ This use HAS NOT been administratively determined as appropriate by statute or policy.
Proceed to evaluate the use under Part C.

If the use meets one of the two qualifying definitions above, then it is appropriate. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

C. Is the use appropriate because it contributes to the refuge's purpose(s), goals, or objectives or Refuge System mission?

(Please check one.)

Refuge managers, in their sound professional judgement, may determine a refuge use to be appropriate if it contributes to fulfilling the refuge purpose(s), goals, or objectives described in the refuge's comprehensive conservation plan, or the Refuge System mission [603 FW 1.11 (A)(2)]. Urban wildlife refuges have the additional goal of fostering environmental awareness through outreach programs and activities that develop an informed and involved populace that supports fish and wildlife conservation [110 FW 1.5].

✔ This use contributes to the refuge purpose(s), goals, or objectives, or Refuge System mission.
Provide a written justification of how the use contributes to the qualifying purpose(s), goals, or objectives or Refuge System mission. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

____ This use DOES NOT contribute to refuge purpose(s), goals, objectives, or Refuge System mission.
Proceed to evaluate the use under Part D.

D. Is this use appropriate?

Decision Criteria:	**YES**	**NO**
(1) Does the use comply with applicable laws and regulations (Federal, State/Territorial, tribal,and local)?		
(2) Is the use consistent with applicable Executive orders and Department and Service policies?		
(3) Is the use consistent with public safety?		
(4) Is the use consistent with the goals and objectives of approved management plans or other management document?		
(5) If this is the first time the use has been proposed or if it was previously found appropriate, check Yes. If the use was previously analyzed but denied, check No.		
(6) Is the use manageable within available budget and staff?		
(7) Will the use be manageable in the future with existing resources? [603 FW 1.11 (A)(3)(h)].		
(8) Does the use contribute to the public's understanding and appreciation of the refuge's natural and cultural resources?		
(9) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality [603 FW 1.6 (D)], compatible, wildlife-dependent recreation into the future?		
(10) Is the use on an urban wildlife refuge [110 FW 1.15] and/or will it help new audiences become familiar and comfortable with fish, wildlife and their habitats?		

If the answer is "NO" to (1), (2), or (3), mark the use as "Not Appropriate" under Part G. If the answer is "NO" to any of (4) through (10), the use will generally be "Not Appropriate." Refuge managers may, however, check one or more of boxes (4) through (10) and still find the use "Appropriate" by providing a written justification of the finding and how the factor(s) are mitigated or of minimal effect.

Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

E. Consultation with State/Territorial Fish and Wildlife Agency
(Please check one.)

Refuge managers must consult with the applicable State/Territorial fish and wildlife agency when a request for a use could affect fish, wildlife, or other resources that are of concern to a State fish and wildlife agency [603 FW 1.7E(3) and 1.12].

__✔__ Consultation WAS required.

Consultation took place on: ____________
(Month/Date/Year)

Proceed to Part F.

_______ Consultation WAS NOT required.
Proceed to Part F.

F. Is the use significantly complex or potentially controversial?
(Please check one.)

__✔__ Yes

If Yes, date the Regional Chief was briefed: ____________
(Month/Date/Year)

Proceed to Part G.

_______ No
Proceed to Part G.

G. Finding

Based on my review of all relevant factors, I find the refuge use identified above:

_______ Exempted _______ Not Appropriate __✔__ Appropriate*

[* Includes findings that a use is administratively determined as appropriate (Section B and C) or is found appropriate through the use of the decision tool (Section D).]

Refuge Manager ________________________ Date ____________________

H. Concurrence

The Refuge Supervisor MUST concur and sign a finding of "Not Appropriate" for an EXISTING use if the designation is made OUTSIDE of the Comprehensive Conservation Plan process. The Refuge Supervisor MUST concur and sign a finding of "Appropriate" for any proposed NEW use. Signature from the Refuge Supervisor WILL NOT be necessary for a finding of "Not Appropriate" with a proposed NEW use.

Refuge Supervisor ________________________ Date ____________________

Any use found to be "Appropriate" will require the development of a compatibility determination before the use may be allowed on Refuge lands.

A.2 Finding of Appropriateness of a Refuge Use: Supplement to FWS Form 3-2319

Further Explanation of Answers Provided for the Decision Criteria:

Project: Cooperative Kalo Farming; Residences and Farm Storage Areas (Residential [other] and Farming)

Justification of how this use contributes to the Refuge's purpose(s), goals, or objectives or Refuge System mission:

The purpose of Hanalei National Wildlife Refuge (NWR or Refuge) is to benefit species listed under the Endangered Species Act of 1973 (ESA). At Hanalei NWR, the management focus includes supporting the recovery of five federally-listed Hawaiian waterbirds: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*); endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*); and threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

This use involves cooperative farming of kalo (taro, *Colocasia esculenta*) in lo‘i (an impounded terrace or field) and the use of residences, farm storage sheds and surrounding lands, in support of kalo farming on Hanalei NWR. Kalo farming on the Refuge meets the definition of cooperative agriculture because (1) it is conducted in support of resource management objectives for managing shallow-water habitat to satisfy life history requirements of threatened and endangered Hawaiian waterbirds (Objective 1.1 in the draft Wetlands Management and Waterbird Conservation Plan [dWMWCP]) and (2) there is substantial involvement between the Service and the cooperator, as defined by 620 U.S. Fish and Wildlife Service Manual (FW) 2 and 505 U.S. Department of the Interior Department Manual 2.9.

The dWMWCP describes cooperative kalo farming as a component of the overall management of lowland/wetland habitats on the Refuge. Under the dWMWCP, available lowland/wetland acreage on the Refuge would be allocated between rotational managed wetlands, lo‘i kalo, fallow, or upland habitat based on a decision flowchart and reevaluated periodically using an adaptive management framework. As currently practiced, kalo farming directly or indirectly supports Refuge goals. Implementation of new Special Use Permit (SUP) and Cooperative Agriculture Agreement (CAA) conditions would be expected to enhance support of kalo farming for these Refuge goals outlined within the dWMWCP:

- Cultivation of kalo supports Goal 1 by satisfying some of the life history needs of threatened and endangered Hawaiian waterbirds and supplementing the native and naturalized habitats provided by the rotational wetland (moist-soil) management units on the Refuge; and
- Current kalo farming practices directly support Goal 1 by creating a diverse, year-round mosaic of wetland habitats that satisfy some of the life history needs of threatened and endangered Hawaiian waterbirds. Conversely, some farming practices reduce food and cover, and cause disturbance to threatened or endangered breeding birds. Implementation of strengthened permit and agreement conditions would increase the value of lo‘i kalo to threatened and endangered Hawaiian waterbird, helping to ensure this practice remains compatible with the Refuge purpose.

The subject residences, storage sheds, and the immediately surrounding areas are supportive of kalo farming on the Refuge. By extension, these buildings and areas support the same Refuge goals as does kalo farming.

As practiced in the past, kalo farming on the Refuge provided wetland habitat of a quality that satisfied some of the life history requirements of threatened and endangered Hawaiian waterbirds. However, this use, like many agricultural uses, has limitations that come with the benefits to native wildlife (Heard et al. 2000). Agronomic practices, such as drawdowns for fertilizer applications, may contribute to threatened or endangered waterbird nest collapse and failure and the impaired quality of receiving waters. It is proposed that conditions of the kalo farming permits/agreements be strengthened to address these and other issues.

Appropriate and compatible cooperative kalo farming would require farmers to enhance vegetation structure and diversity of lo‘i habitat (all stages) for foraging and breeding threatened and endangered waterbirds to promote growth of non-kalo emergent plants by maintaining either:

- ≥ 10 percent cover of beneficial non-kalo emergent plants in understory within each lo‘i;
- ≥ 20 percent cover of beneficial non-kalo emergent plants in understory on ≥ 50 percent of lo‘i; or
- ≥ 10 percent of total lo‘i acreage in vegetated wet fallow (approximately nine month period: germinate, grow emergent vegetation > 4 inches, flood 6 months).

In lo‘i where threatened or endangered waterbird nests are found, farmers would be required to:

- maintain a minimum six-foot radius unharvested buffer around the nest;
- keep the lo‘i flooded to a depth of three to six inches; and
- coordinate with Refuge staff to minimize impacts or take of birds by implementing additional protective measures as needed, such as delaying harvest in areas where nests are known to occur until the young birds fledge or leave the lo‘i of their own accord.

Farmers would plant and maintain lo‘i in a way that would distribute kalo at different stages of maturity among different lo‘i, so that harvesting of all lo‘i at one time would not occur. This would allow kalo farmers the continued ability to harvest in lo‘i that do not have a nest present.

During fallow, farmers would be required to enhance foraging resources for threatened and endangered waterbirds (may vary in documented avian botulism areas) by providing:

- a minimum 30-day wet fallow period immediately post-harvest (may require a dry period for soil aeration) with water depth 6–8 inches and with the presence of moist-soil plants; and
- an optional dry fallow period ≤ 6 months total depending on needs and conditions.

Farmers would be required to participate in implementing relevant aspects of the Avian Botulism Prevention and Response Protocol. Hanalei NWR staff would work cooperatively with farmers and other partners to develop best management practices for kalo farming consistent with recovery of threatened and endangered Hawaiian waterbirds and improvements in the quality of discharge waters. Farmers would be required to report fertilizer and herbicide use annually and participate in the development of fertilizer and herbicide management plans.

The Service would work with the farmers and others to conduct studies to evaluate the benefits for waterbirds of various kalo farming practices. For example, one study would evaluate the effects on fledging success of increasing the diameters of nest buffers. Another study would evaluate the efficacy of slow-release and/or other more sustainable options for fertilizers and assess their effects on the quality of discharge waters.

Results of all of these studies would be used to appropriately modify conditions of kalo farming permits/agreements. Phased implementation of these additional sustainable and wildlife friendly farming techniques would address identified concerns about intensive kalo farming on the Refuge and cause the beneficial aspects of this use to increase and its detrimental effects to diminish. Monitoring would help ensure that benefits were realized.

Although not solely related to kalo farming and associated activities, vehicle traffic along ʻŌhiki Road threatens threatened and endangered waterbirds. From 2003 to 2008, the Service documented, on average, four threatened or endangered bird deaths each year on this road (Letter from M. Hawkes to W. Kudo, June 25, 2008). From 2013 to 2015, we documented on average 14 threatened or endangered and migratory bird deaths each year on this road, including 22 ʻalae ʻula, 11 ʻalae ke oke o, seven nēnē, and two kōlea. During the first six months of 2016, 15 additional threatened or endangered birds were recorded as struck by vehicles on the same road, nearly three birds per month. These numbers indicate an increasing trend in threatened and endangered bird deaths on ʻŌhiki Road (Letter from H. Tonneson to L. Tabata, July 29, 2016). Along with the general public, kalo farming permittee/cooperators would need to comply with the posted speed limit (15 miles per hour) and use pullouts as appropriate to halt the loss of threatened and endangered species from vehicle strikes and resolve other issues, including public safety.

Currently, five of the Refuge kalo farmers live in residences on the Refuge. The Refuge's other four kalo farmers live off-site and maintain storage sheds on the Refuge. In both cases, the farmers also use the areas immediately surrounding their residences and storage sheds for storage of equipment and supplies and, for resident farmers, for landscaping, fruit and vegetable gardening, outbuildings, livestock, and pets.

The subject residences and storage sheds were constructed prior to Service acquisition of the Refuge. The lands underlying and surrounding the buildings are part of the Refuge and owned by the Service. This arrangement is typical of traditional tenant-farming systems in Hawaiʻi.

There are some challenges with the management of these buildings and the surrounding lands. Areas surrounding some residences have grown in size over the years, consuming actual or potential wildlife habitat and increasing the human footprint and zone of wildlife disturbance. Within or adjacent to some residential, storage, and farm areas, there has been a growing accumulation of abandoned vehicles, equipment, and supplies that are not being actively used which provide habitat for feral cats and rodents. Organic wastes and other refuse have been dumped on Refuge property. This can attract pests, predators, and disease vectors; and it is contrary to Service policies (Resource Conservation and Recovery Act of 1976 (RCRA), as amended (42 United States Code (U.S.C.) 6901–6992k)—Solid Waste (Nonhazardous); 50 Code of Federal Regulations (CFR) 27.93, Abandonment of Property; 50 CFR 27.94, Disposal of Waste; and 561 FW 5, Managing, Recycling, and Disposing of Non-Hazardous Solid Waste). In addition, it encourages native birds to feed on kalo which is not part of their natural diet. In other areas, equipment and supplies (including fertilizers, pesticides, and petroleum products) are stored outdoors or inside three-sided shelters directly on the ground. Exposure to weather and periodic Hanalei Valley flooding increases the potential for damage of storage containers, and leakage of petroleum products, heavy metals, fertilizers, and/or pesticides into the underlying soil and surface and ground waters. During high-water events, these contaminants, when not properly stored, are dispersed onto the Refuge and downriver.

Enforcement and conditions of future commercial SUPs for farming residences, storage sheds, outbuildings, and the immediately surrounding areas would be strengthened to address these and other issues. For example, there would be a specific acreage limit placed on the size of permit areas (i.e., the residences, outbuildings, and the immediately surrounding areas; and the storage sheds and immediately surrounding areas). The boundaries of these areas would be clearly marked. Requirements regarding storage of equipment and supplies and dumping would be strengthened and clarified. Farmers would be required to maintain their buildings and surrounding grounds consistent with county and state requirements.

All of these strengthened conditions would address identified concerns about residences, storage sheds, outbuildings, and the immediately surrounding areas and would assist in diminishing detrimental effects. Monitoring would help ensure that benefits were realized.

To ensure the compatibility of this use, staff will be dedicated to managing, monitoring, and reporting on the kalo farming program, which would include a qualified biologist(s) to implement a monitoring and adaptive management program.

Overall, the proposed use would contribute to the achievement of the Refuge's purposes and the National Wildlife Refuge System mission. The proposed use evaluated herein is more fully described and evaluated in the compatibility determination for this use and the documents referenced there (Appendix B).

REFERENCES CITED:

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FINDING OF APPROPRIATENESS OF A REFUGE USE

Use of this form is required for documenting all appropriate use findings (603 FW 1)

Refuge Name: Hanalei National Wildlife Refuge, County of Kaua‘i, Hawai‘i

Use: Cooperative Grazing

This is a: ✔ New Use ________ Existing Use

A. Does this use qualify for an appropriateness review exemption?
(Please Check One)

Some refuge uses are exempted from an appropriateness review [603 FW 1.2; 603 FW 1.2(A)]. Appropriate use finding exemptions are documented through the use of this form.

________ This use is "protected," "conditioned," or otherwise provided for under law or regulation.
Examples include the use of snow machines, airplanes, or motorboats on Alaska refuges under certain conditions per the ANILCA. Provide a written justification as to how this use qualifies for this particular exemption.

________ The Service does not have jurisdiction over the use
This could be as a result of treaty rights, court orders, consent decrees, pre-existing rights (such as subsurface Non-Federal oil and gas or mineral rights, grandfathered easements, etc.). Provide a written justification as to how this use qualifies for this particular exemption.

________ This is a Right-of-Way Permit request
Right-of-way requests are subject to 340 FW 3 and compatibility determinations (603 FW 2). Attach a brief explanation as to how this use qualifies for this particular exemption.

✔ This use DOES NOT qualify for an appropriateness review exemption.
Proceed to evaluate the use under Part B.

If the use meets one of the three qualifying exemptions above, then it is exempt from an appropriate use determination. Skip Parts B, C, D and E and complete Parts F and G, sign and date, and submit a copy to the Refuge Supervisor.

B. Is the use administratively determined as appropriate in law or policy?
(Please Check One)

The following refuge uses are appropriate because they have been administratively determined as appropriate uses by statute or policy [603 FW 1.11(A)(1); 603 FW 1.6(A)(3)].

________ This use is a wildlife-dependent recreational use.
Hunting, Fishing, Wildlife Observation, Wildlife Photography, Environmental Education, or Interpretation.

________ This use involves the take of fish and wildlife under state/territorial regulations.
Including other forms of state-regulated take beyond hunting and fishing.

✔ This use HAS NOT been administratively determined as appropriate by statute or policy.
Proceed to evaluate the use under Part C.

If the use meets one of the two qualifying definitions above, then it is appropriate. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

C. Is the use appropriate because it contributes to the refuge's purpose(s), goals, or objectives or Refuge System mission?
(Please check one.)

Refuge managers, in their sound professional judgement, may determine a refuge use to be appropriate if it contributes to fulfilling the refuge purpose(s), goals, or objectives described in the refuge's comprehensive conservation plan, or the Refuge System mission [603 FW 1.11 (A)(2)]. Urban wildlife refuges have the additional goal of fostering environmental awareness through outreach programs and activities that develop an informed and involved populace that supports fish and wildlife conservation [110 FW 1.5].

✔ This use contributes to the refuge purpose(s), goals, or objectives, or Refuge System mission.
Provide a written justification of how the use contributes to the qualifying purpose(s), goals, or objectives or Refuge System mission. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

______ This use DOES NOT contribute to refuge purpose(s), goals, objectives, or Refuge System mission.
Proceed to evaluate the use under Part D.

D. Is this use appropriate?

Decision Criteria:	**YES**	**NO**
(1) Does the use comply with applicable laws and regulations (Federal, State/Territorial, tribal,and local)?		
(2) Is the use consistent with applicable Executive orders and Department and Service policies?		
(3) Is the use consistent with public safety?		
(4) Is the use consistent with the goals and objectives of approved management plans or other management document?		
(5) If this is the first time the use has been proposed or if it was previously found appropriate, check Yes. If the use was previously analyzed but denied, check No.		
(6) Is the use manageable within available budget and staff?		
(7) Will the use be manageable in the future with existing resources? [603 FW 1.11 (A)(3)(h)].		
(8) Does the use contribute to the public's understanding and appreciation of the refuge's natural and cultural resources?		
(9) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality [603 FW 1.6 (D)], compatible, wildlife-dependent recreation into the future?		
(10) Is the use on an urban wildlife refuge [110 FW 1.15] and/or will it help new audiences become familiar and comfortable with fish, wildlife and their habitats?		

If the answer is "NO" to (1), (2), or (3), mark the use as "Not Appropriate" under Part G. If the answer is "NO" to any of (4) through (10), the use will generally be "Not Appropriate." Refuge managers may, however, check one or more of boxes (4) through (10) and still find the use "Appropriate" by providing a written justification of the finding and how the factor(s) are mitigated or of minimal effect.

Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

E. Consultation with State/Territorial Fish and Wildlife Agency
(Please check one.)

Refuge managers must consult with the applicable State/Territorial fish and wildlife agency when a request for a use could affect fish, wildlife, or other resources that are of concern to a State fish and wildlife agency [603 FW 1.7E(3) and 1.12].

__✔__ Consultation WAS required.

Consultation took place on: ________
(Month/Date/Year)

Proceed to Part F.

_______ Consultation WAS NOT required.
Proceed to Part F.

F. Is the use significantly complex or potentially controversial?
(Please check one.)

__✔__ Yes

If Yes, date the Regional Chief was briefed: ________
(Month/Date/Year)

Proceed to Part G.

_______ No
Proceed to Part G.

G. Finding

Based on my review of all relevant factors, I find the refuge use identified above:

_______ Exempted _______ Not Appropriate __✔__ Appropriate*

[* Includes findings that a use is administratively determined as appropriate (Section B and C) or is found appropriate through the use of the decision tool (Section D).]

Refuge Manager ________________ Date ________

H. Concurrence

The Refuge Supervisor MUST concur and sign a finding of "Not Appropriate" for an EXISTING use if the designation is made OUTSIDE of the Comprehensive Conservation Plan process. The Refuge Supervisor MUST concur and sign a finding of "Appropriate" for any proposed NEW use. Signature from the Refuge Supervisor WILL NOT be necessary for a finding of "Not Appropriate" with a proposed NEW use.

Refuge Supervisor ________________ Date ________

Any use found to be "Appropriate" will require the development of a compatibility determination before the use may be allowed on Refuge lands.

A.4 FINDING OF APPROPRIATENESS OF A REFUGE USE: SUPPLEMENT TO FWS FORM 3-2319

FURTHER EXPLANATION OF ANSWERS PROVIDED FOR THE DECISION CRITERIA:

PROJECT: COOPERATIVE GRAZING

JUSTIFICATION OF HOW THIS USE CONTRIBUTES TO THE REFUGE'S PURPOSE(S), GOALS, OR OBJECTIVES OR REFUGE SYSTEM MISSION:

The purpose of Hanalei National Wildlife Refuge (NWR or Refuge) is to benefit species listed under the Endangered Species Act of 1973 (ESA). At Hanalei NWR, the management focus includes supporting the recovery of five federally-listed Hawaiian waterbird species: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*); endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*); and threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

The use evaluated herein involves cooperative grazing of Refuge lands by domestic livestock, which may include cattle, sheep, or goats. Grazing on the Refuge would meet the definition of cooperative agriculture because (1) it is conducted in support of resource management objectives for restoring or enhancing rotational managed wetlands and riparian habitat to satisfy life history requirements of threatened and endangered Hawaiian waterbirds (Objectives 1.2 and 2.2 in the draft Wetlands Management and Waterbird Conservation Plan [dWMWCP]) and (2) it involves substantial involvement between the Service and the cooperator, as defined by 620 U.S. Fish and Wildlife Service Manual 2 and 505 U.S. Department of the Interior Department Manual 2.9.

The cooperative grazing program would be specifically designed for two distinct purposes.

1. In conjunction with heavy equipment (e.g., mowing) and herbicides, livestock grazing could be used as an initial (time-limited) strategy for reducing plant biomass and controlling or removing invasive plants (e.g., six- to eight-foot tall, dense California grass [*Urochloa mutica*]) to clear areas in preparation for long-term habitat management (i.e., either restoration of rotational managed wetland units or maintenance of short grass habitat).
2. Livestock grazing could also be used as a long-term strategy for seasonally managing and maintaining short grass conditions (e.g., grasses four to six inches in height) conducive to foraging (grazing) and nesting by threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

Grazing can cause a variety of impacts, including damage to vegetation and soils as a result of overgrazing, vegetation trampling, soil compaction, and erosion; wildlife disturbance, potentially including destruction of threatened nēnē eggs, or injury or death to young birds through trampling; and increased sedimentation and nutrient loading of waterways and wetlands, which could alter microbial communities and conditions for avian botulism. Livestock can also facilitate the introduction of alien, including pest, species (e.g., through seeds carried in hair, on vehicles and farm machinery, and in feces).

Based on the reasons for using cooperative grazing, different stipulations regarding duration, timing, and monitoring would apply. For example, livestock grazing for area clearing could be conducted at any time of year with baseline monitoring, whereas grazing for short-grass habitat management would only be permitted seasonally during the non-peak threatened and endangered waterbird breeding period (e.g., approximately May–September because nēnē peak breeding is from October–April) and would be associated with a more intensive monitoring program. In either case, additional stipulations are included to minimize adverse impacts to threatened and endangered species, soils, and aquatic resources. Pastures would be fenced to contain livestock, focus their grazing efforts, and keep them out of riparian areas and river corridor. In-pasture water and salt would be made available to better manage grazing intensity and locations. Biosecurity measures would be implemented to prevent the introduction and spread of pest species. Biological monitoring, including establishment of baseline conditions, and adaptive management based on measurable and meaningful criteria are important for ensuring that cooperative grazing remains appropriate and compatible over time.

At least initially, the cooperative grazing program would be conducted on a short-term, experimental basis (with one-year special use permit and cooperative agriculture agreement) to determine whether the program could create the habitat conditions and associated wildlife benefits being sought while minimizing impacts to threatened and endangered species and aquatic resources. Grazing program parameters (timing, frequency, intensity, or other elements) would be developed with the assistance of the Natural Resources Conservation Service (NRCS), the University of Hawaiʻi, Hawaiʻi Department of Land and Natural Resources, livestock grazers, Hawaiian waterbird biologists, and others. The end result of this effort would be a grazing plan for the Refuge and associated best management practices (BMP) for grazing.

Overall, the proposed use would contribute to the achievement of the Refuge's purpose and the National Wildlife Refuge System mission. The proposed use evaluated herein is more fully described and evaluated in the compatibility determination for this use and the documents referenced there (Appendix B).

FINDING OF APPROPRIATENESS OF A REFUGE USE

Use of this form is required for documenting all appropriate use findings (603 FW 1)

Refuge Name: Hanalei National Wildlife Refuge, County of Kaua‘i, Hawai‘i

Use: Research and Scientific Collections

This is a: ________ New Use ✔ Existing Use

A. Does this use qualify for an appropriateness review exemption?
(Please Check One)

Some refuge uses are exempted from an appropriateness review [603 FW 1.2; 603 FW 1.2(A)]. Appropriate use finding exemptions are documented through the use of this form.

________ This use is "protected," "conditioned," or otherwise provided for under law or regulation.
Examples include the use of snow machines, airplanes, or motorboats on Alaska refuges under certain conditions per the ANILCA. Provide a written justification as to how this use qualifies for this particular exemption.

________ The Service does not have jurisdiction over the use
This could be as a result of treaty rights, court orders, consent decrees, pre-existing rights (such as subsurface Non-Federal oil and gas or mineral rights, grandfathered easements, etc.). Provide a written justification as to how this use qualifies for this particular exemption.

________ This is a Right-of-Way Permit request
Right-of-way requests are subject to 340 FW 3 and compatibility determinations (603 FW 2). Attach a brief explanation as to how this use qualifies for this particular exemption.

✔ This use DOES NOT qualify for an appropriateness review exemption.
Proceed to evaluate the use under Part B.

If the use meets one of the three qualifying exemptions above, then it is exempt from an appropriate use determination. Skip Parts B, C, D and E and complete Parts F and G, sign and date, and submit a copy to the Refuge Supervisor.

B. Is the use administratively determined as appropriate in law or policy?
(Please Check One)

The following refuge uses are appropriate because they have been administratively determined as appropriate uses by statute or policy [603 FW 1.11(A)(1); 603 FW 1.6(A)(3)].

________ This use is a wildlife-dependent recreational use.
Hunting, Fishing, Wildlife Observation, Wildlife Photography, Environmental Education, or Interpretation.

________ This use involves the take of fish and wildlife under state/territorial regulations.
Including other forms of state-regulated take beyond hunting and fishing.

✔ This use HAS NOT been administratively determined as appropriate by statute or policy.
Proceed to evaluate the use under Part C.

If the use meets one of the two qualifying definitions above, then it is appropriate. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

C. Is the use appropriate because it contributes to the refuge's purpose(s), goals, or objectives or Refuge System mission?
(Please check one.)

Refuge managers, in their sound professional judgement, may determine a refuge use to be appropriate if it contributes to fulfilling the refuge purpose(s), goals, or objectives described in the refuge's comprehensive conservation plan, or the Refuge System mission [603 FW 1.11 (A)(2)]. Urban wildlife refuges have the additional goal of fostering environmental awareness through outreach programs and activities that develop an informed and involved populace that supports fish and wildlife conservation [110 FW 1.5].

✔ This use contributes to the refuge purpose(s), goals, or objectives, or Refuge System mission.
Provide a written justification of how the use contributes to the qualifying purpose(s), goals, or objectives or Refuge System mission. Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

____ This use DOES NOT contribute to refuge purpose(s), goals, objectives, or Refuge System mission.
Proceed to evaluate the use under Part D.

D. Is this use appropriate?

Decision Criteria:	**YES**	**NO**
(1) Does the use comply with applicable laws and regulations (Federal, State/Territorial, tribal,and local)?		
(2) Is the use consistent with applicable Executive orders and Department and Service policies?		
(3) Is the use consistent with public safety?		
(4) Is the use consistent with the goals and objectives of approved management plans or other management document?		
(5) If this is the first time the use has been proposed or if it was previously found appropriate, check Yes. If the use was previously analyzed but denied, check No.		
(6) Is the use manageable within available budget and staff?		
(7) Will the use be manageable in the future with existing resources? [603 FW 1.11 (A)(3)(h)].		
(8) Does the use contribute to the public's understanding and appreciation of the refuge's natural and cultural resources?		
(9) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality [603 FW 1.6 (D)], compatible, wildlife-dependent recreation into the future?		
(10) Is the use on an urban wildlife refuge [110 FW 1.15] and/or will it help new audiences become familiar and comfortable with fish, wildlife and their habitats?		

If the answer is "NO" to (1), (2), or (3), mark the use as "Not Appropriate" under Part G. If the answer is "NO" to any of (4) through (10), the use will generally be "Not Appropriate." Refuge managers may, however, check one or more of boxes (4) through (10) and still find the use "Appropriate" by providing a written justification of the finding and how the factor(s) are mitigated or of minimal effect.

Complete Parts E, F, and G, sign and date, and submit a copy to the Refuge Supervisor.

E. Consultation with State/Territorial Fish and Wildlife Agency
(Please check one.)

Refuge managers must consult with the applicable State/Territorial fish and wildlife agency when a request for a use could affect fish, wildlife, or other resources that are of concern to a State fish and wildlife agency [603 FW 1.7E(3) and 1.12].

✔ Consultation WAS required.

Consultation took place on: ________
(Month/Date/Year)

Proceed to Part F.

_______ Consultation WAS NOT required.
Proceed to Part F.

F. Is the use significantly complex or potentially controversial?
(Please check one.)

✔ Yes

If Yes, date the Regional Chief was briefed: ________
(Month/Date/Year)

Proceed to Part G.

_______ No
Proceed to Part G.

G. Finding

Based on my review of all relevant factors, I find the refuge use identified above:

_______ Exempted _______ Not Appropriate ✔ Appropriate*

[* Includes findings that a use is administratively determined as appropriate (Section B and C) or is found appropriate through the use of the decision tool (Section D).]

Refuge Manager ________________ Date ____________

H. Concurrence

The Refuge Supervisor MUST concur and sign a finding of "Not Appropriate" for an EXISTING use if the designation is made OUTSIDE of the Comprehensive Conservation Plan process. The Refuge Supervisor MUST concur and sign a finding of "Appropriate" for any proposed NEW use. Signature from the Refuge Supervisor WILL NOT be necessary for a finding of "Not Appropriate" with a proposed NEW use.

Refuge Supervisor ________________ Date ____________

Any use found to be "Appropriate" will require the development of a compatibility determination before the use may be allowed on Refuge lands.

A.6 Finding of Appropriateness of a Refuge Use: Supplement to FWS Form 3-2319

Further Explanation of Answers Provided for the Decision Criteria:

Project: Research and Scientific Collections

Justification of how this use contributes to the Refuge's purpose(s), goals, or objectives or Refuge System mission:

This use involves research and scientific collections conducted by non-National Wildlife Refuge System (Refuge System) parties on Hanalei National Wildlife Refuge (NWR or Refuge).

Research refers to a planned, organized, and systematic investigation of a scientific nature. Such studies are designed to determine the cause(s) of observed biotic or abiotic phenomenon over a finite time period, where cause and effect relationships usually can be inferred through statistical analyses.

Scientific collecting involves gathering of Refuge natural resources or cultural artifacts for scientific purposes. Examples include collection of vegetation, small mammals, and soils; contaminant sampling; and collection and curation of cultural resources.

Refuge staff periodically receive requests from outside parties (e.g., universities, state agencies, other federal agencies, and nongovernmental organizations) to conduct research and scientific collections on Refuge lands. These project requests can involve a wide range of natural and cultural resources as well as public use management issues, including collection of new species for identification, habitat use and life history requirements for specific species and species groups, practical methods for habitat restoration, extent and severity of environmental contaminants, techniques to control or eradicate pest species, effects of climate change on environmental conditions and associated habitat and wildlife response, modeling of wildlife populations, bioprospecting, and assessing response of habitat and wildlife to disturbance from public uses. Projects may be species-specific, Refuge-specific, or evaluate the relative contribution of Refuge lands to larger landscape (ecoregion, region, flyway, national, and international) issues and trends.

Use of the Refuge to conduct research or scientific collecting would generally provide information of benefit to native fish, wildlife, plants, and their habitats; or to cultural resources. Scientific findings gained through these projects could provide important information regarding life history needs of species and species groups, as well as identify or refine management actions to achieve the Refuge's natural or cultural resource management goals and objectives. Reducing uncertainty regarding wildlife and habitat responses to Refuge management actions undertaken in order to achieve desired outcomes (objectives) is essential for adaptive management (522 Department Manual 1).

Suitable research and scientific collections on refuges are inherently valuable to the U.S. Fish and Wildlife Service (Service) when they expand scientific information available for resource management decisions about fish, wildlife, plants, and their habitats; cultural resources; and/or public use. In many cases, if it were not for the Refuge staff providing access to Refuge lands and waters along with some support, the project would never occur and less scientific information would be available to aid the Service in managing and conserving Refuge resources.

The Service's Research and Management Studies (4 Refuge Manual 6) and Appropriate Refuge Uses

(603 U.S. Fish and Wildlife Service Manual 1) policies indicate priority for scientific investigatory studies that contribute 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 needs for resource management goals and objectives, where applicable, would be given a higher priority over other requests. Likewise, projects that materially interfere with or detract from the fulfillment of the National Wildlife Refuge System mission or the refuge purposes would be denied.

The proposed use evaluated herein is more fully described and evaluated in the compatibility determination for this use and the documents referenced there (Appendix B).

APPENDIX B. DRAFT COMPATIBILITY DETERMINATIONS

B.1 DRAFT COMPATIBILITY DETERMINATION - USE: COOPERATIVE KALO FARMING; RESIDENCES AND FARM STORAGE AREAS (RESIDENTIAL [OTHER] AND FARMING)

REFUGE NAME: HANALEI NATIONAL WILDLIFE REFUGE, COUNTY OF KAUAʻI, HAWAIʻI

ESTABLISHING AND ACQUISITION AUTHORITY(IES):

Endangered Species Conservation Act of 1969, as amended (16 United States Code [U.S.C.] 668aa)

REFUGE PURPOSE(S):

"… to conserve (A) fish or wildlife which are listed as endangered species or threatened species…or (B) plants…" (ESA; Endangered Species Act of 1973) (16 U.S.C. 1531–1544)

NATIONAL WILDLIFE REFUGE SYSTEM (REFUGE SYSTEM OR NWRS) MISSION:

"The mission of the [National Wildlife 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–668ee)

B.1.1 DESCRIPTION OF USE(S)

COOPERATIVE AGRICULTURE

Cooperative agriculture is when a person or entity uses agricultural practices on National Wildlife Refuge System (NWRS or Refuge System) lands in support of objectives for target species or their associated habitats that represent the biological outcomes the U.S. Fish and Wildlife Service (Service) desires, and there is substantial involvement (i.e., collaboration, participation, or intervention) between the Service and the person or entity. The Service uses cooperative agriculture agreements (CAAs) as the legal instruments to formalize the cooperative agreement between the Service and the cooperator. CAAs describe the objectives, roles, responsibilities, terms, and conditions of cooperative agriculture on Refuge System land and must be documented on a Commercial Activities Special Use Permit (SUP), Form 3-1383-C.

COOPERATIVE KALO FARMING

This use involves cooperative farming of kalo (taro, *Colocasia esculenta*) in loʻi (an impounded terrace or field) on Hanalei National Wildlife Refuge (NWR or Refuge). Before being allowed on the Refuge, this use would first need to be found appropriate (see 603 U.S. Fish and Wildlife Service Manual [FW] 1) and determined compatible (see 603 FW 2). Farming is also an economic use of refuge lands under relevant Code of Federal Regulations (see 50 CFR 29.1). Per the Cooperative Agricultural Use policy (620 FW 2) approved on August 3, 2017, cooperative kalo farming activities on the Refuge would be authorized under CAAs and documented on Commercial Activities SUPs.

Kalo farming on the Refuge meets the definition of cooperative agriculture because (1) it is conducted in support of a biological objective for managing shallow-water habitat to satisfy life history requirements of threatened and endangered Hawaiian waterbirds (Objective 1.1 in the draft Wetlands Management and Waterbird Conservation Plan [dWMWCP]) and (2) there is substantial involvement between the Service and the cooperator, as defined by 620 FW 2 and U.S. Department of the Interior (DOI) 505 Department Manual (DM) 2.9. Examples of Service involvement in support of kalo farming include, but are not limited to, coordination and technical assistance (particularly in relation to avian botulism and providing wetland habitat for threatened and endangered waterbirds); installation, operation, and maintenance of the main irrigation system; drainage ditch cleaning; maintenance of primary access roads on the Refuge; invasive species management (including feral pigs, feral cats, rats, chickens, Guinea grass [*Megathyrsus maximus*], California grass [*Urochloa mutica*], *Paspalum* grasses, and *Albizia* trees); construction and maintenance of over two miles of perimeter fence; coordination and implementation of best management practices (BMP) for sustainable farming and prevention and control of avian disease outbreaks; ensuring compliance and coverage for pesticide and fertilizer application; coordination of disposal of waste related to farming and houses; equipment sharing; and assistance with controlling trespassing, theft, poaching, trash dumping, and other illegal activities.

Kalo farming has continued to be used as a refuge management economic activity since its establishment in 1972. Kalo may have been farmed in the Hanalei Valley for more than 1,000 years prior to the establishment of Hanalei NWR (Schilt 1980). At present, approximately 160 acres (approximately 17 percent of the 917-acre Refuge) are devoted to kalo farming. This includes both acreage in lo‘i and kalo-associated banks, ditches, and dikes. The dWMWCP describes kalo farming as a component of the overall management of lowland/wetland habitats on the Refuge. Under the dWMWCP, available lowland/wetland acreage on the Refuge would be allocated among rotational managed wetlands, lo‘i kalo, fallow, or upland habitat based on a decision flowchart (Figure B-1) and re-evaluated periodically using an adaptive management framework.

Kalo farming is currently conducted by nine cooperators (individuals or families) whose operations range in size from approximately 5–48.5 acres each. Compared to modern agricultural operations elsewhere in the United States, these are small farming operations. Much of the farm work (e.g., planting, weeding, and harvesting) is conducted by hand (NRCS 2009).

The Hanalei Valley’s warm and wet climate allows kalo farming to occur year-round. The full production cycle (from planting to harvest) is approximately 12–16 months (Gutscher-Chutz 2011; NRCS 2009; Gee 2007). Successful kalo farming involves numerous actions, including mowing or other means of removing unwanted vegetation; disking or tilling of the soil; amending the soil by cover cropping or adding nutrients as needed, such as fertilizer and lime; and flooding to prepare lo‘i for planting; planting of cut kalo plants (huli) or underground shoots (‘oha); dewatering and reflooding with cool, clean water; harvesting of kalo corms (swollen underground plant stems), stalks, and leaves; and dry and wet fallowing before starting the cycle again. Fallowing helps increase yield per acre by resting lo‘i, improving soil health, and breaking disease and pest cycles (NRCS 2009). The length of time a lo’i is in each kalo habitat category during the kalo agricultural cycle is as follows: recently planted 4–6 weeks; early growth 6–8 weeks and mature growth 5–9 weeks; medium to dense growth 20–36 weeks; being harvested 1–4 weeks; unvegetated or vegetated wet fallow up to four weeks; unvegetated dry fallow up to one week; and vegetated dry fallow typically up to 12 weeks (Gee 2007).

Kalo farmers also mow dikes and clear loʻi, ditch banks, and ditches of unwanted vegetation by hand weeding, mowing, and use of herbicides. Pest control costs can account for almost one-tenth to one-third of kalo production expenses and hand-weeding can account from one-fifth to more than three-quarters of those costs (Fleming 1994; Ooka and Brennan 2000; Hanalei NWR kalo farming permittees 2017, pers. comm.). Like many agricultural crops, kalo are also plagued by pests such as the nonnative apple snail (*Pomacea canaliculata*), root and corm rot caused by *Pythium* spp., and a leaf blight caused by *Phytophthora colocasiae.* Kalo farmers on the Refuge use water level drawdowns, disking or tilling, and hand-collection in an attempt to control snails (Gutscher-Chutz 2011) and use dry fallowing in an attempt to control snails and kalo diseases. These practices, along with waterbirds feeding on snails, have greatly reduced snail abundance.

Kalo is grown for its food and cultural value. Its corm, stalk (huli), leaves (lūʻau), and flowers (pua) are all eaten. If eaten raw, calcium oxalate crystals contained in these plant parts are irritants that can cause swelling to the throat and mouth. Therefore, the corm and leaves are cooked or otherwise processed to reduce the calcium oxalate, and then eaten in a variety of forms. The corms provide starch and sugar and are boiled or steamed, then pounded to make poi; roasted; baked; or deep fried. Poi is a complex carbohydrate that is easily digestible and hypoallergenic, low in fat and protein and contains vitamins (A, B_6, B_{12}, and C), calcium, iron, potassium, magnesium, phosphorus, and zinc (Cho et al. 2007; Lo 2006). The leaves are good sources of vitamins (A, B_1, B_2, and C), calcium, iron, phosphorus, fiber, and protein and are eaten like cooked greens or used to wrap and cook other foods (Cho et al. 2007). Kalo also has cultural and medicinal values (see cultural resources section) and is used as a dye and glue (Kāne 1997).

The dWMWCP describes other management strategies relevant to kalo farming or related practices. The following are not stipulations required to ensure compatibility; however, they may be incentivized and/or incorporated into future stipulations. The list below is not exhaustive.

- Permittees would be encouraged to allow low-growing native or desirable naturalized herbaceous wetland plants, including *Fimbristylis dichotoma*, *Bacopa monnieri*, *Cyperus polystachyos*, and *Echinochloa crus-galli*, to germinate and grow on at least 25 percent of loʻi banks and at least 75 percent of ditch banks in each permit area (that does not significantly impede the ability to drain areas effectively). This would reduce erosion, help filter discharge water, and increase the foraging and breeding values of these banks for threatened and endangered Hawaiian waterbirds.
- Applying slow-release and organic fertilizers as potential alternatives to traditional farm fertilizers would be encouraged. Based on a study conducted in 2011–2012 (Deenik et al. 2013), the use of slow-release or organic fertilizers provided a long-term reservoir of plant-available nitrogen in the root zone for kalo and reduced nitrogen export to the river system. By comparison, the use of conventional fertilizers did not store applied nitrogen in the soil, but rather showed an increased export of nitrogen to the river. There are better slow-release fertilizer products designed for use in water that are available now, and the Refuge will work with cooperative farmers to explore options for pilot implementation.
- The Refuge would initiate a study of the relative effectiveness of different diameter nest buffers (e.g., 12-foot versus 18-foot diameter buffers in vegetated and unvegetated wet fallow loʻi) on nest and fledging success of threatened or endangered Hawaiian waterbirds. In addition, the study will look at the effects of other farming and management practices on nest success for threatened or endangered waterbirds. Depending upon the results of this study, nest buffer requirements or other requirements in the harvest stage could be modified if there is a need to prevent incidental take (e.g., mortality, reproductive failure) of Hawaiian waterbirds.

- Permittees would be encouraged (and incentivized) to transition over the next 15 years towards farming practices which minimize threatened and endangered waterbird mortality due to avian botulism and also improve water quality within the watershed. The Refuge would engage the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and others, as appropriate, to provide technical and financial assistance with this transition. Shifting to organic production would eliminate reliance on petrochemical farming and would be expected to increase the economic value of kalo produced on the Refuge while reducing farming-related contaminant loads being discharged into the Hanalei River and, as such, practices such as these would be incentivized and encouraged.
- The Refuge would work cooperatively with the NRCS, University of Hawai‘i, Hawai‘i Department of Health, kalo farmers, and others to develop BMPs appropriate for kalo farming and consistent with recovery of threatened and endangered waterbirds and improvements in the quality of discharge waters. BMPs could potentially be integrated into integrated pest management (IPM); use of longer fallowing periods to restore soil fertility and break disease and pest cycles; less-intensive farming practices (such as allowing nonpest native or beneficial, naturalized wetland plants to grow interspersed within the lo‘i); use of native, beneficial, naturalized plants, legumes, or other nitrogen-fixing plants as cover crops; transitioning to organic kalo farming; installing energy dissipaters and filters at select water discharge locations. These BMPs may become required stipulations for Refuge kalo farming or be implemented using an incentive program. The NRCS or others might be able to provide technical and/or financial assistance with implementation and evaluation of BMPs.
- The Refuge may work with the kalo farmers to establish and maintain a program within their farming SUP areas to exclude and remove introduced vertebrate predators that prey on threatened and endangered Hawaiian waterbirds and kalo such as feral chickens, feral pigs, and rats. The Refuge would explore options for a cooperative predator control program. This program could include Refuge perimeter fencing, live-trapping, or shooting and would also benefit kalo farmers and farming.

INTEGRATED PEST MANAGEMENT FOR COOPERATIVE KALO FARMING

The DOI and Service policies require that all farming on a refuge, whether conducted with in-house resources or by private farmers, be conducted consistent with the principles of IPM (Integrated Pest Management, 517 DM 1 and Integrated Pest Management, 569 FW 1). Implementation of IPM helps ensure that all potential pest management strategies were considered for use (including physical, cultural, biological, and chemical), and that the method(s) chosen for use was based on human safety, environmental integrity, effectiveness, and cost.

CULTIVATION OF GENETICALLY MODIFIED CROPS (GMCS)

In accordance with Biological Integrity, Diversity, and Environmental Health (BIDEH) policy (601 FW 3), the Service would not allow cultivation of genetically modified crops (GMCs) on the Refuge unless their use is essential to accomplishing the Refuge purpose and the Director approves the use. Additionally, several other factors may prevent approval of the use of GMCs such as State or local laws. Currently, GMCs are not cultivated on Hanalei NWR. The use of GMCs is not essential for accomplishing the Refuge's purpose and consequently it is not proposed within the dWMWCP. In order to consider GMC use, an Eligibility Questionnaire for Genetically Modified Crops must be completed, and applicable refuge compliance documents (e.g., Appropriate Use (603 FW 1), Compatibility Determination (603 FW 2), National Environmental Policy Act (NEPA), and ESA Section 7) must be updated.

RESIDENCES AND FARM STORAGE AREAS (RESIDENTIAL [OTHER] AND FARMING).

The cooperative farming use evaluated in this compatibility determination (CD) includes residences, farm facilities, and the lands adjacent to these properties that support kalo farming. Before being allowed on the Refuge, this use would first need to be found appropriate (603 FW 1) and then be determined compatible (603 FW 2). Because these facilities are related to efficient cooperative farming on the Refuge, the occupancy, use, and maintenance of residences and farm facilities would be authorized through CAA and regulated through Commercial Activities SUP along with its associated cooperative kalo farming. It is also an economic use of refuge lands under relevant federal regulation (see 50 CFR 29.1).

Currently on Hanalei NWR, there are six residences that are owned and occupied by five of the nine operators (individuals or families) who farm kalo on the Refuge. These farmers also use the areas immediately surrounding their residences for storing vehicles, farm equipment, and supplies; landscaping; fruit and vegetable gardening; and keeping livestock and pets. Structures associated with these activities include outbuildings, storage sheds, chicken coops, and pig pens. The resident farmers are responsible for maintenance of these facilities and immediately surrounding areas. The lands occupied by these residences and surrounding areas vary in size in relation to each authorized farm acreage.

In addition to the residences, there are three storage sheds on the Refuge that were constructed and are used by Refuge kalo farmers who reside off the Refuge. These nonresident farmers also use the areas immediately surrounding their storage sheds for storage of equipment and supplies. The nonresident farmers are responsible for the maintenance of these storage sheds and immediately surrounding areas. The lands occupied by these storage facilities and surrounding areas vary in size in relation to the amount of authorized farm acreage.

The kalo farming-related residences, storage sheds, and outbuildings on the Refuge are the personal property of each kalo farmer (DOI Office of the Solicitor 1986). Most of these buildings were constructed prior to Service acquisition of the Refuge. At the time of their construction, it was common practice for landowners to lease kalo, rice, or other farmlands to farmers and allow those farmers to construct dwellings on or adjacent to the lease lands. The lands underlying and surrounding the residences and other buildings are deeded real estate owned by the Service. The permittees/cooperators have no legal interest in or rights to the surface land or subsurface resources. See the attached map for the location of farm residences, farm storage sheds, surrounding areas, and kalo farming lands and associated structures, such as dikes, canals, and ditches (Figure B-2).

This CD has been developed and made publicly available concurrent with the dWMWCP and associated environmental assessment (EA) for Hanalei NWR. Much of the information and some of the analyses contained in this CD are addressed in greater detail in the dWMWCP and EA, which are incorporated by reference herein.

B.1.2 ADMINISTRATION OF THE USE

COOPERATIVE AGRICULTURE AGREEMENTS

Cooperative kalo farming and associated use of residences and farm facilities would be authorized under CAAs and documented in Commercial Activities SUPs. Permittees/cooperators would be entered into CAAs through an open and competitive process. The process for awarding CAAs includes the following:

- The Service would provide the public with a notice of cooperative agricultural opportunities. This would include publication of a Notice of Funding Opportunity on Grants.gov, notification on the national Service website (https://www.fws.gov/refuges/whm/cooperativeAgriculture.html) and local outreach. The notice would include details on the cooperative agricultural opportunity such as the objective criteria that would be used to rank and score applications.
- Applicants would apply directly to the Kaua‘i NWR Complex using the application guidance provided in the CAA prospectus.
- The Kaua‘i NWR Complex Project Leader, along with a selection panel, would score and rank all applicants and notify each applicant regarding whether they were awarded the CAA and the reasoning for the panel’s decision. Unsuccessful applicants have the right to appeal the decision in accordance with 50 CFR 25.45.
- Once the CAA has been awarded, each cooperator and the Service will work together to finalize the specific terms and conditions of each CAA, including an annual plan of operations for each designated unit.

DIRECT AND INDIRECT REFUGE COSTS TO IMPLEMENT THE USES

Kaua‘i National Wildlife Refuge Complex staff would directly administer CAAs for the cooperative kalo farming program. Direct and indirect costs to administer this use include the following:

- Costs associated with construction, repair, operation, and maintenance of associated facilities (e.g., residence septic system and the Kuna-side road);
- Salaries and associated employee expenses related to evaluation of the proposed use (including appropriateness finding, CD, and compliance with applicable laws, regulations, and policies such as NEPA, ESA, and National Historic Preservation Act [NHPA]), and development of the SUP or agreement;
- Salaries and associated employee expenses related to monitoring of this use to ensure that SUP/agreement requirements are followed and that the use remains compatible over time. This includes evaluation of these use effects on the Refuge’s natural and cultural resources, and compatible, especially wildlife-dependent, public use;
- Use-related supplies, equipment, and travel; and
- An applicable portion of Refuge overhead costs.

Over the past few decades, the Refuge has expended substantial time and money developing, repairing, operating, and maintaining an extensive water delivery system that is used to manage rotational managed wetland (moist-soil) units and to farm kalo. The Refuge has also repaired dike breaches; helped farmers recover from flooding; maintained some Refuge roads used by the farmers; monitored and managed avian botulism epizootics in lo‘i kalo to alleviate botulism and improve kalo production; managed invasive species (e.g., feral pigs, feral cats, rats, chickens); monitored and controlled trespassing, theft, poaching, and other illegal activities; shared equipment with the farmers; constructed and maintained miles of fence line; conducted drainage ditch cleaning which helped associated farmers; repaired septic systems for farmers’ residences; and conducted extensive invasive tree removal which has helped to protect a farmer’s residence and ensure proper irrigation flow in the main supply ditch.

Following is an estimate of annual costs associated with administering Cooperative Kalo Farming; Residences and Farm Storage Areas (Residential [other] and Farming) on the Refuge.

TABLE B-1. ESTIMATE OF ANNUAL COSTS FOR ADMINISTERING COOPERATIVE KALO FARMING

Tasks	*Estimated Costs per Year*[1]
1. Permit/agreement administration and oversight by GS-13 project leader (3%), GS-12 refuge deputy project leader (5%), GL-09 law enforcement officer (10%), GS-7 wildlife refuge specialist permit coordinator (40%), WG-10 maintenance and facilities worker (10%), WG-6 mechanic/facilities worker (5%), and WG-6 maintenance and facilities worker (10%)	$64,948
2. Permit/agreement and biological monitoring by GS-11 biologist (25%), GS-7 biological technician (50%), and GS-5 biological technician (50%)	$83,353
3. Supplies, equipment, and facility maintenance and repair	$25,833
4. Contracting	$1,250
5. Refuge overhead costs associated with the above-listed work[2]	$51,906
Total Costs	**$227,290**

[1] Annual personnel costs = 2019 step 5 salary for appropriate GS or GL level (including locality payment of 18.43%) x 35% for benefits. For WG, 2019 step 3 hourly rate x 35% for benefits.
[2] Overhead costs (management capability) = salary + benefit costs x 0.35. Overhead expenses include building rent, utilities, equipment and supplies, and support personnel, and do not include salary-related benefits.

COST-SHARING

Per the cooperative agricultural use policy (620 FW 2), cost-sharing is defined as the portion of the costs for cooperative agriculture on Refuge System lands that are borne by the cooperator. Cost-sharing can vary depending on the needs and objectives of the particular refuge land. For example, the Service may provide the cooperator with the right to perform agricultural practices on Refuge land and a percentage of any resulting crop yield, as well as the ability to use Service water, equipment, or Refuge staff. In exchange, the cooperator may provide the Service with labor, equipment, and materials; a percentage of any resulting crop yield; or maintenance, rehabilitation, or reestablishment of specific habitat conditions on Refuge lands.

The Service policy on the administration of specialized uses (5 Refuge Manual [RM] 17) requires that specialized uses, which include economic, recreational, right-of-way, and other privileged uses, must be accompanied by a fee or cooperative exchange to recover the costs of administering the special use permit and use and/or the fair market value of the benefit received.

Under this cooperative kalo farming program, farmers must provide all materials and labor needed to establish the kalo crop. The Service is working cooperatively with kalo farmers to describe and quantify the costs of the goods and services the Service provides to the farmers, the benefits the Service receives as a result of allowing kalo farming on the Refuge, and the fair market value for kalo farming (including evaluation of land rents for comparable agriculture-related residential and farm-storage uses) to develop a fair and rational cost-sharing program related to kalo farming. This study would facilitate collaboration between the Service and the kalo farmers by providing cost-benefit analysis and illustrating both parties' responsibilities and contributions towards kalo farming on the Refuge. Following from this study, the Service may, for example, evaluate opportunities through the kalo farming CAAs to cost-share water infrastructure maintenance, improvements related to avian botulism and water quality, other maintenance, and/or biological and compliance monitoring. Cost-sharing will be required in order to ensure that there are adequate resources to support the administration of this use to full compliance.

Providing waterbird habitat and aiding in the recovery of the species is the justification for allowing farming as a management tool. Kalo farming on the Refuge can satisfy some of the life history requirements of threatened and endangered Hawaiian waterbirds. Kalo farming on Hanalei NWR operates by providing for the needs of the birds in lieu of farming techniques optimized for kalo production. For example, there is an understanding that there will occasionally be some loss or damage to young kalo plants that results from some of the threatened or endangered waterbirds sporadic feeding or roosting habits within the lo‘i kalo, and that farmers are currently required to maintain a 3-foot radius (6-foot diameter) buffer of unharvested kalo around nesting waterbirds (the dWMWCP proposes a 6-foot radius [12-foot diameter buffer]) and retain lo‘i kalo in wet fallow status for at least 30 days following harvest. Therefore, kalo farming on the Refuge is a cooperative venture. Cost-sharing through the CAAs will attempt to ensure that fair market value is taken into account.

B.1.3 ANTICIPATED IMPACTS OF THE USES

REFUGE GOALS AND NWRS MISSION

As currently practiced, kalo farming and supporting subject residences, storage sheds, and surrounding areas on the Refuge directly or indirectly supports Refuge Goal 1 from the dWMWCP.

- Cultivation of kalo supports Goal 1 by satisfying some of the life history needs of threatened and endangered Hawaiian waterbirds and supplements the native and naturalized habitats provided by the rotational wetland (moist-soil) management units on the Refuge; and
- Current kalo farming practices directly support Goal 1 by creating a diverse, year-round mosaic of wetland habitats that satisfy some of the life history needs of threatened and endangered Hawaiian waterbirds. Conversely, some management practices reduce food and cover, and cause disturbance to threatened and endangered breeding birds. Implementation of permit/agreement conditions as identified in the CD stipulations would increase the value of lo‘i kalo to threatened and endangered Hawaiian waterbirds, helping to ensure this practice remains compatible with the Refuge purpose.

To the extent that kalo farming provides habitat to support the recovery of threatened and endangered Hawaiian waterbirds, it is consistent with the Refuge System statutory 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" and with the establishment purpose of the Refuge to aid in the recovery of threatened and endangered species.

BIOLOGICAL INTEGRITY, DIVERSITY, AND ENVIRONMENTAL HEALTH

Historically, migratory and nonmigratory native waterbirds had access to more available and higher quality habitat. However, because many historical wetlands have been degraded, filled, and converted to agriculture or other land uses, endangered Hawaiian waterbirds must satisfy all of their daily resource requirements (e.g., foraging and roosting habitat) and seasonal life history requirements (e.g., breeding and molting) within a more restricted range. Agricultural wetlands, such as the lo‘i kalo on Hanalei NWR, provide wetland habitat for waterbirds. Thus, at the Refuge scale, BIDEH is negatively impacted by permitting cooperative kalo farming. However, at the larger landscape scale, kalo farming contributes to BIDEH by supporting the maintenance of threatened and endangered waterbird populations.

FISH, WILDLIFE, PLANTS, AND THEIR HABITATS

As noted earlier, the purpose of the Refuge is to benefit species listed under the ESA. At Hanalei NWR, the management focus is supporting the recovery of five federally-listed Hawaiian waterbirds: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*); endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*); and threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

Cooperative Kalo Farming
Taken as a whole, Hanalei NWR, including lo‘i kalo, rotational managed wetlands, and associated upland and riverine habitats, represents 70 percent of the core habitat on Kaua‘i designated as essential to the recovery and delisting of four endangered waterbirds (USFWS 2005). Kalo farming provides a majority of the wetland acreage on Hanalei NWR. Excluding dikes, canals, and ditches, there is currently approximately 126 acres of lo‘i kalo versus 86 acres of rotational wetland (moist-soil) management units, respectively.

Across the Refuge year-round, lo‘i are in various stages of kalo production, including dry fallow (vegetated and nonvegetated), wet fallow (vegetated and nonvegetated), planting, flooded young plants, fully mature plants, and harvesting. In many cases, lo‘i also include native or beneficial, naturalized wetland plants. This provides a diversity of habitats, including water, vegetation, and invertebrates, and satisfies several of the life history requirements for the Refuge’s threatened and endangered Hawaiian waterbirds (Gutscher-Chutz 2011; Gee 2007).

For example, previous studies and observations from ongoing research on the Refuge reveal that koloa maoli use lo‘i kalo for many of the same life history requirements—including loafing, foraging, courtship, and nesting—for which they use moist-soil wetlands (Gee 2007; Malachowski 2014; Malachowski and Dugger 2018). This is important, because the Refuge is the most important protected site for this species and it hosts a large portion of the few remaining non-hybridized koloa maoli, and therefore the Refuge may have the best opportunity in the state of supporting recovery of this species.

The threatened and endangered Hawaiian waterbirds and other Refuge wildlife feed on vegetation, seeds, invertebrates, and small fishes and tadpoles in lo‘i in all stages of kalo production. Koloa maoli use kalo farms predominantly for resting (primarily on dikes) and foraging (primarily in lo‘i kalo, feeding on aquatic invertebrates as well as on plants) (Malachowski and Dugger 2018). ‘Alae ke‘oke‘o and ‘alae ‘ula sporadically feed on kalo shoots, and use young and mature kalo for cover, nest sites, or nest materials (Gee 2007; NRCS 2009). This behavior is uncommon but has occurred prior to breeding in extremely dry years when the waterbirds might be seeking calcium found in the kalo when regular sources (snails, crustaceans, insects) are unavailable. Wet fallows and providing additional food sources such as moist soil vegetation should provide alternate food resources to meet annual lifecycle needs of birds and reduce feeding on kalo. Threatened nēnē and endangered waterbirds use vegetated dry fallow and recently planted lo‘i for foraging and roosting. Dry fallow lo‘i that are unvegetated or mudflats are used for roosting by kōlea (Pacific golden plover, *Pluvialis fulva*) and other migratory shorebirds. Vegetated dry fallow lo‘i are heavily used by ‘alae ‘ula, ‘alae ke‘oke‘o, and koloa maoli in the initial growing stages (Gee 2007; Michael Mitchell 2011, pers. comm.). Lo‘i water levels are drawn down prior to kalo harvest and this stimulates production of wetland plants and invertebrates that are readily fed upon by Hawaiian waterbirds. Dry fallowing lo‘i for at least a few weeks is recommended between harvesting and replanting to improve soil conditions, restore fertility and reduce fertilizer use and costs (NRCS 2009). In addition, this practice helps to reduce the incidence of botulism outbreaks by drying out and aerating the soils (Egelhoff 2017).

Lo‘i kalo in post-harvest wet fallow are heavily used by Hawaiian waterbirds, in part because this stage generates substantial invertebrate biomass, its shallowly flooded sediments are easily accessed by wildlife, and potential predators are clearly seen (Broshears and Parrish 1980; Gutscher-Chutz 2011). Studies of lo‘i kalo use by ‘alae ‘ula and koloa maoli reveal the highest densities of their use in wet fallow and during harvest (Gutscher-Chutz 2011). Ae‘o use unvegetated wet fallow, and ‘alae ke‘oke‘o and koloa maoli prefer vegetated wet fallow (Gee 2007). Considering the high value of wet fallow to the Hawaiian waterbirds, Refuge kalo farming CAA/SUPs would require that following harvest, lo‘i be kept in wet fallow for a minimum of 30 days. Field observations reveal that this is not always occurring (Gee 2007).

Without adherence to stipulations designed to ensure compatibility, kalo farming practices could conflict with the establishment purpose of Hanalei NWR and other legal mandates such as the ESA. Lo‘i kalo on the Refuge has often historically been managed primarily to meet kalo production goals. Potentially conflicting practices include fertilization schedules and flooding and drying cycles timed to benefit kalo, rather than threatened and endangered Hawaiian waterbirds, their nesting requirements, or production of invertebrate and plant food sources. Kalo farming often involves control of non-kalo plants and invasive species through hand-weeding, mowing, dewatering lo‘i, or application of pesticides. Many of these non-kalo, wetland plants which may be unwanted by farmers (e.g., *Fimbristylis littoralis*, *Cyperus spp.*, *Eleocharis spp.*, *Ludwigia spp.*, and *Schoenoplectus juncoides*) provide waterbirds with vegetative forage, cover, enhance the production of invertebrates, and, for ‘alae ‘ula and ‘alae ke‘oke‘o, provide nesting structure or materials (Gee 2007). In less intensively managed lo‘i and fallow lo‘i where non-kalo emergent vegetation was present, koloa maoli engaged in foraging behaviors similar to those used in managed wetlands (Chris Malachowski 2019, pers. obs. cited in Malachowski and Dugger 2018).

Many of the activities associated with kalo farming disturb or have the potential to disturb wildlife, including threatened and endangered Hawaiian waterbirds that use the lo‘i and surrounding areas as habitat (Gee 2007). The Hanalei Valley’s warm and wet climate allows kalo farming to occur year-round, so lo‘i kalo and associated features (e.g., dikes, ditches, and banks) are manipulated year-round. This includes numerous farm production activities, such as plowing, tilling, fertilizing and liming, planting, weeding, mowing, applying pesticides, managing water levels, and harvesting. Some of these activities (e.g., flooding and dewatering, weeding, and application of fertilizer and lime) are repeated multiple times throughout the production cycle (Gee 2007). During nonbreeding periods, nēnē, ae‘o, and ‘alae ke‘oke‘o appear to be fairly tolerant of disturbance. However, when birds are breeding or in heavy molt, they are all more susceptible to disturbance and more vulnerable to predation. Koloa maoli and ‘alae‘ula are very wary and often flush or move quickly into dense cover when disturbed (Gutscher-Chutz 2011). Flushing of birds or even raising their alert levels creates stress and requires expending energy that would otherwise be invested in essential life history activities such as foraging, mating, nesting, brood-rearing, and predator avoidance. Disturbance can cause nest desertion; affect survival of individual birds, eggs, nestlings, or broods; and alter behavior of nonbreeding waterbirds. Overall, koloa maoli were disturbed less often in rotational managed wetlands than in kalo farms; however, the differences in human-related disturbances between wetland types was comparatively small (10 percent vs. 14 percent) and of questionable biological significance (Malachowski and Dugger 2018).

Lo‘i water levels are fluctuated and kalo corms, stalks, and leaves are harvested during times when some waterbirds are nesting over water in mature kalo plants. This can increase nest flooding, nest desertion, and increase the vulnerability of nesting waterbirds, their eggs, and their chicks to predation. Gee (2007) followed ‘alae ‘ula nests that were primarily found during kalo harvest on the Refuge. These nests experienced average nest success, but low fledging success. Nest failure was attributed to predation, abandonment, and flooding.

Complaints about suspected reduced kalo yields due to threatened and endangered waterbird depredation resulted in two of nine permittees being allowed to temporarily place fences around three lo‘i kalo during March–May 2013. Monitoring showed that the fences created obstacles that resulted in collisions for waterbirds (Dugger, Unfried, and Malachowski 2015). The frequency of high impact collisions was highest for ‘alae ‘ula. Because of the negative impacts to the threatened and endangered waterbirds, fencing and other barriers are not permitted within the kalo farming permit areas.

Some kalo farming on the Refuge includes management or removal of unwanted vegetation from lo‘i, banks, ditches, and dikes. Dike top mowing allows easy travel across dikes, good access to short vegetation, enhanced predator visibility, and provides loafing, preening, and foraging habitat for ‘alae ke‘oke‘o, ‘alae ‘ula, koloa maoli, and nēnē (Gee 2007). Removal of vegetation from lo‘i and ditch banks results in loss of some native and beneficial naturalized plants (e.g., *Fimbristylis dichotoma*, *Bacopa monnieri*, *Cyperus polystachyos*, and *Echinochloa crus-galli*), reduction in invertebrates, and accompanying loss in potential loafing, foraging, breeding, and nesting habitat. These management practices are also expensive, create wildlife disturbance, and potentially enhance sedimentation while reducing vegetative filtering of discharge water.

Residences and Farm Storage Areas (Residential [other] and Farming)
Resident farmers are allowed to keep some domesticated animals on the lands they occupy associated with their houses (their permit areas). Because Hawai‘i’s threatened and endangered waterbirds evolved in the absence of mammalian predators and some birds nest directly on the ground, domestic animals, especially cats and dogs, running loose (i.e., feral animals) or being kept in areas that waterbirds use regularly on the Refuge, pose a significant threat to recovery of these waterbirds.

Refuge staff has observed that storage and personal use areas surrounding some residences have grown in size over the years. These areas are used for landscaping, fruit and vegetable gardens, outbuildings, and storage of equipment and other materials. This unauthorized expansion consumes actual or potential wildlife habitat and increases the human footprint and zone of wildlife disturbance.

In addition, within or adjacent to some permit areas, there has been a growing accumulation of abandoned motor vehicles, abandoned farming equipment, and other abandoned equipment; supplies that are not being actively used in kalo farming or in maintenance, repair, or other legal use of permit areas; and other refuse and piles of excess or unused materials. Storage of this equipment and other materials can attract pests, such as rats, that can prey on threatened and endangered Hawaiian waterbirds and vector disease; violates Service policy on the management of nonhazardous solid waste on Refuges (561 FW 5); and is unsightly.

Although not solely related to kalo farming and associated activities, vehicle traffic along ʻŌhiki Road threatens threatened and endangered waterbirds. From 2003 to 2008, the Service documented on average four threatened or endangered bird deaths each year on this road (Letter from M. Hawkes to W. Kudo, June 25, 2008). From 2013 to 2015, we documented on average 14 threatened or endangered and migratory bird deaths each year on this road, including 22 ʻalae ʻula, 11 ʻalae keʻokeʻo, seven nēnē, and two kōlea. During the first six months of 2016, 15 additional threatened or endangered birds have already been recorded as struck by vehicles on the same road, nearly three birds per month. These numbers indicate an increasing trend in threatened and endangered bird deaths on ʻŌhiki Road (Letter from H. Tonneson to L. Tabata, July 29, 2016). Along with the general public, kalo farming permittee/cooperators would need to comply with the posted speed limit (15 miles per hour) and use pullouts as appropriate to halt the loss of threatened and endangered species from vehicle strikes and resolve other issues, including public safety.

WATER QUALITY

In recognition of its scenic beauty, rich biological resources, cultural significance, and recreational and economic values, the Hanalei River was designated an American Heritage River (under Executive Order [EO] 13061) in 1998. Among other things, the river provides habitat for native fishes and invertebrates, including five species of ʻoʻopu (Hawaiian gobies), pinao ʻula (damselflies), and ʻōpae ʻoehaʻa (shrimp). The American Heritage River Executive Order charges federal agencies with assisting local communities in protecting and restoring designated rivers.

Because of elevated levels of *Enterococci* and turbidity (total suspended solids), the State of Hawaiʻi Department of Health (HDOH) identified the Hanalei Bay Watershed as water quality limited under section 303(d) of the Clean Water Act (HDOH 2008). Elevated levels of nutrients (total nitrogen and total phosphorus) were also identified as a concern (Tetra Tech and HDOH 2008). The Hanalei River flows through Hanalei NWR and is the largest tributary in this watershed. In an effort to address constituents of concern in these waterbodies, HDOH established total maximum daily loads (TMDL) for the Hanalei River and Hanalei Estuary (HDOH 2008). The HDOH identified no dischargers with National Pollutant Discharge Elimination System permits or other point sources of pollution in the Hanalei River Watershed, so the TMDL address non-point sources. Hanalei NWR's native and exotic wildlife, and loʻi kalo were identified as sources of constituents of concern to the Hanalei River (Tetra Tech and HDOH 2008).

Water quality concerns related to kalo farming include the additional inputs of fertilizer and herbicides and the prevalence of wet tilling and other soil disturbances during kalo production, which can cause turbid water to flow back into the river. Ditch cleaning and the removal of vegetation along ditch banks (i.e., grinding vegetation or removing vegetation by digging) can also adversely affect water quality. As noted above, kalo farmers routinely control unwanted vegetation using, among other methods, application of herbicides. Glyphosate is the only herbicide currently approved for use per SUP and the pesticide use proposal (PUP) for the Refuge.

The Service's Water Resources Branch (WRB) continuously monitored field water quality parameters (temperature, conductivity, pH, dissolved oxygen [DO], and oxidation/reduction potential [ORP]) in areas of the Refuge for various periods from 2015 to 2017. Monitoring was done in loʻi selected randomly from the northeast and southeast kalo farms and in rotational managed wetland units from all areas of the Refuge; loʻi kalo within the northwest part of the Refuge were not monitored. Inflows to these areas had lower temperature, conductivity, and turbidity and higher pH, DO and ORP. Comparing managed wetlands to loʻi kalo, temperatures were either the same or slightly warmer in the wetlands. DO was low in wetlands but not nearly as low as in lo‘i kalo and the upper range of concentrations was higher in wetlands. pH in the wetlands was slightly acidic (6.0–7.0) and similar to the lo‘i kalo. ORP was always positive. Conductivity was slightly lower in the wetlands compared to the lo‘i kalo but in general, conductivity was very low everywhere on the refuge so this difference may not be significant. There were occasional higher spikes in conductivity observed in the lo‘i kalo in the northeast.

Comparing field water quality parameters in the lo‘i kalo in the northeast versus the southeast, the differences were usually small or non-existent. For most sampling periods, water temperatures were slightly cooler in the northeast versus the southeast (contrary to what was expected). Conductivity was slightly lower and pH was usually slightly higher in the southeast. DO concentrations were low in both areas but usually higher in the southeast, with the exception of summer 2015, when they were lower. There was a lot of variability in field water quality parameters, especially DO and pH, at the scale of the individual lo‘i kalo (comparing one lo‘i kalo to another from the same area or farmer). This variability was so great that it is hard to generalize about comparisons between areas or farmers.

Comparisons of field water quality parameters between recently fertilized versus unfertilized lo‘i kalo were inconclusive. One might expect that fertilization, and the drawdowns that accompany them, would lead to consistent differences in DO and pH but this was not observed. In the summer 2015, we observed no differences in DO or pH in recently fertilized lo’i kalo compared to lo’i kalo that had not been fertilized recently. In the winter 2016, we observed lower pH and DO in recently fertilized lo’i kalo in the northeast. In the summer 2017, we monitored the same lo’i kalo before and after they were fertilized and observed an increase in DO following fertilization and drawdown, but little change in pH.

The Service’s WRB also conducted nutrient sampling from July to September 2015 and from January to March 2016 in the same areas as described above. Concentrations of total nitrogen, total phosphorus, and ammonia nitrogen were lowest in the inflows and higher in the lo‘i kalo compared to managed wetland units. Bioavailable nitrogen was in the form of ammonia nitrogen at all sites; nitrate nitrogen was non-detectable in all samples. Considering all samples from both seasons combined, total nitrogen, total phosphorus, and ammonia nitrogen concentrations were highest in the northeast lo‘i kalo. Occasionally, there were very high concentrations of ammonia nitrogen in the northeast lo‘i kalo; Similar nutrient spikes were not observed in the southeast lo‘i kalo or managed wetlands. There was almost no ammonia nitrogen in the managed wetlands. Finally, there was no statistical difference in nutrient concentrations between summer and winter in the northeast lo‘i kalo. All the other areas showed much lower nutrient concentrations in the winter compared to the summer. Nutrient concentrations appear to be very high in the northeast lo‘i kalo throughout the year.

In winter 2016, the WRB also sampled the Hanalei River upstream and downstream of the Refuge for total nitrogen, total phosphorus, ammonia nitrogen, and nitrate nitrogen. Samples were collected weekly for eight weeks. Nitrogen was almost always non-detectable at both sites. Phosphorus was slightly higher downstream. It was mostly non-detectable upstream and at low concentrations downstream. Samples were not collected during the summer, when nutrient concentrations are known to be higher and river flows lower.

Additional water quality concerns related to kalo farming are the prevalence of wet tilling and other soil disturbance during kalo production, which can cause turbid water to flow back into the river. Results from water quality monitoring conducted during spring (March–April) and summer (June–September) 2015, winter (January–March) 2016 in randomly selected managed wetland units and lo‘i kalo in the northeast and southeast indicated differences between water quality in managed wetland units and lo'i kalo (Feddern 2016). The largest differences were DO and ORP, both of which were lower in lo'i kalo than in the managed wetland units. Additionally, a strong correlation between low DO and low ORP was observed suggesting anoxic conditions contribute to negative ORP and thus higher avian botulism risk (Feddern 2015). In both lo'i kalo and managed wetlands, summer DO was lower than winter DO. DO saturation and concentrations in the northeast lo'i kalo in winter were greatly lower than southeast lo'i kalo.

Additional observations were made regarding algal and plant abundance in lo'i compared to managed wetlands. In some lo'i, large mats of *Azolla filiculoides* (a nitrogen fixing aquatic fern) and algae were present, while in other lo'i and managed wetlands *Azolla* was absent and algal abundance was minimal. *Azolla* grows best in high phosphorus conditions and at depths of 0.5 to 0.833 ft (Uchida et al. 2008). Based on this information it was hypothesized fertilization in lo'i kalo causes *Azolla* and algal blooms in response to nutrient inputs. It is likely plant and algae die offs follow these blooms as nutrients are consumed and lo'i water depth decreases (water draw-downs typically follow kalo fertilization).

The Refuge has worked with residents to upgrade their old cesspools to modern septic systems. Some of the farm storage structures are three-sided sheds without constructed floors or drain/filtering systems. In addition, some farming and other equipment and supplies are stored directly on the ground, outdoors, and without overhead shelter where they are exposed to the Hanalei Valley's rains, intense sun, wind, and flood events. Exposure of storage containers to the weather increases the likelihood that they will develop rust and holes, and leak petroleum products or heavy metals into the underlying soil and surface and ground waters. Storage, transfer, and use of farming-related supplies such as fertilizers, pesticides, and petroleum products outdoors or in areas without impervious floors, drains, and containment/filtering systems increases the likelihood of surface and ground water contamination and of winds picking up surface dust. If not managed properly, these contaminants could adversely affect Refuge habitats and wildlife, including threatened and endangered Hawaiian waterbirds, and could contribute to the river's water quality problems. Finally, as noted above, there is evidence of unauthorized expansion of areas surrounding some residences and storage sheds. This expansion creates additional potential threats to surface and ground water through rainwater leaching, to air quality through wind-blown dust, and direct contamination during large flooding events.

The Hanalei River watershed is large and steeply sloped in many areas. Flows in the lower river—which the Refuge straddles—are flashy, and the Refuge lands used for residences, storage sheds, other facilities, and storage of equipment and supplies are subject to periodic flooding. This increases the risks to soil and water quality associated with flooding and transfers of fertilizer, pesticide, and petroleum residues across the ground surface into lo'i kalo and rotational managed wetland units or through leaching into ground waters. This is a special concern for equipment, supplies, and other materials stored on the ground outdoors, in three-sided sheds, or in other buildings with dirt floors.

AVIAN BOTULISM

Although the first case was reported in the late 1970s, outbreaks of avian botulism type C, a paralytic disease caused by ingestion of a toxin produced by the bacterium *Clostridium botulinum*, have occurred with regularity at Hanalei NWR since November/December 2011. Between 2011–2018, 1,342 cases of avian botulism were recorded on the Refuge (Reynolds et al. 2019). These botulism outbreaks have killed individuals of all five federally-listed waterbird species occurring on the Refuge and have been particularly detrimental to koloa maoli, which represent 62 percent of birds affected (Reynolds et al. 2019). Unlike mainland avian botulism events, outbreaks on the Refuge can occur year-round due to lack of seasonal variability in temperatures; however, they have been most prevalent in the northern lo‘i kalo during the winter months.

C. botulinum occurs naturally in soil, often lying dormant until the appearance of favorable conditions for growth and toxin production. During the growth phase of *C. botulinum*, the bacterium produces potent neurotoxins. Botulinum spores can be found in wetland sediments and the tissues of aquatic invertebrates and many vertebrates, creating many pathways for outbreaks to occur once conditions for growth are favorable. One of the more common mechanisms of large avian botulism outbreaks is the carcass-maggot cycle, where fly larvae feed on an infected carcass and are in turn consumed by birds that become affected and die, leading to more sites for maggots to feed. Ingestion of the botulinum toxin by birds inhibits the neurotransmitter acetylcholine and results in eventual paralysis of the voluntary muscles. This can lead to death by drowning, starvation, or predation (Rocke and Friend 1999).

Environmental conditions associated with avian botulism outbreaks include temperatures between 20–40°C, low dissolved oxygen, pH between 7.5 and 9.0, negative redox (oxidation/reduction) potential, and sources of decaying organic matter (especially protein such as decaying fish) (Rocke and Bollinger 2007; Rocke and Samuel 1999). The hydrological infrastructure and management of the Refuge, particularly within certain areas of lo‘i kalo, might influence the abiotic growth factors for *C. botulinum*, alter the availability of growth media, or lead to buildups of the toxin in areas with less water flow to flush the toxin. Factors leading to *C. botulinum* growth might also vary naturally or with other management practices, such as lo‘i kalo drawdowns, fertilization, or pesticide application. Hotspot (density) mapping of avian botulism cases based on data from 2011–2018 indicate that the location of hotspots varied somewhat from year to year with the most severe outbreaks (i.e., highest density botulism hotspot) occurring in lo‘i kalo in the northern part of the Refuge. The kalo regions Refuge-wide had similar densities of live/healthy koloa maoli; however, the northern kalo regions (northeast and west) contained more botulism cases relative to the numbers of koloa maoli using these areas (McDonald 2016).

Since 2015, Refuge staff has worked concertedly to improve Refuge kalo farmers’ capacity to use water more effectively and to prevent and respond to avian botulism outbreaks in hotspot areas. These efforts include improving water system infrastructure to promote higher water quality and facilitate better flushing and drainage so that waterbird exposure to warm, anaerobic soil conditions with decaying protein sources is minimized. Following improvements to water infrastructure on the Refuge, there have been reductions in avian botulism outbreak severity and frequency and in associated bird deaths over the past several years.

PUBLIC USE

Due to the Refuge’s primary purpose of management for threatened and endangered species and the sensitivity of habitat and species within the Refuge, public use of the Refuge is restricted. There is public access to ‘Ōkolehao Trail from a parking lot and trailhead along ‘Ōhiki Road, as well as some environmental education and limited guided hikes along the main roads that occur. Kalo farming is managed via SUP over 160 acres of the Refuge lowlands (including dikes and ditches but excluding buildings and farm storage areas). Resident farmers and their families, nonresident farmers, and kalo farming employees travel and haul equipment and other materials along the narrow ‘Ōhiki Road. The scenic valley in the heart of the Refuge is a popular subject of photographers on Kaua‘i and is often best captured from above at the Hanalei Valley Scenic Overlook along Kūhiō Highway.

Most of the residences and storage sheds lie along roads adjacent to the Hanalei River, which bisects the Refuge.

Currently, this use has negligible to minor impacts to the limited amount of public use occurring on the Refuge. Continuation of this use would not be expected to reduce the potential for high-quality, compatible, wildlife-dependent recreation into the future.

CULTURAL RESOURCES

Farming on Hanalei NWR represents a substantial portion of kalo acreage and production statewide (40–60 percent; Gutscher-Chutz 2011; NASS 2012; Cho, Yamakawa, and Hollyer 2007). Kalo farming on Hanalei NWR is of cultural interest and importance to Native Hawaiians across the state and the public at large.

Kalo plays a prominent role in the Hawaiian origin and traditional stories. It is revered as a divine ancestor and for its mana (supernatural or divine power, life force). Kalo was brought to the Hawaiian Islands by Polynesian voyagers more than 1,000 years ago and has been a staple of the Hawaiian diet ever since. It has been used for food, for religious and medicinal purposes, as well as for bait, glue, and dye (Kāne 1997). Kalo is also closely tied to traditional Native Hawaiian concepts of family, responsibility, personal health, a healthy environment, sustainability, and perpetuation of cultural values (Lo 2006). Today, efforts are underway to help Native Hawaiians reconnect with traditional cultural values and practices by locating and restoring historic lo‘i kalo and cultivating and processing kalo for food and other purposes.

The Hanalei Valley, which includes Hanalei NWR, contains a number of historic and pre-contact resources. Farmers living in modest residences adjacent to the lo‘i kalo where they work is representative of a traditional, tenant-farming system that has mostly disappeared in Hawai‘i. During the 1980s the Hanalei Valley was identified by the National Trust for Historic Preservation (NTHP) as an important site for rural preservation. One structure located on the Refuge among the residences, the Haraguchi Rice Mill, is listed on the National Register of Historic Places. This structure is privately owned, is not a residence, is not used for kalo farming, is no longer a functioning mill, and is not addressed in this CD.

As noted earlier, the residences, farm storage sheds, other facilities, and surrounding areas were constructed and used by individuals and families to support kalo farming on the Refuge.

B.1.4 PUBLIC REVIEW AND COMMENT

Public availability of this draft CD has been widely announced together with the announcement of the availability of the Refuge's dWMWCP and EA. The review and comment period were concurrent with the dWMWCP and EA.

B.1.5 DETERMINATION

____________ Use is Not Compatible

_____X_____ Use is Compatible with Following Stipulations

B.1.6 STIPULATIONS NECESSARY TO ENSURE COMPATIBILITY

GENERAL (SPECIFIC TO KALO FARMING)

1. Kalo farming on the Refuge is officially authorized through a CAA and documented on a Commercial Activities SUP for each permittee/cooperator (hereafter referred to as permittee). The CAAs would authorize kalo farming and necessary, related activities for 1–5 years each (this includes permits for existing residences and sheds). Use of Refuge lands for other purposes would not be allowed without specific, prior written approval of the Refuge manager (for the purpose of these stipulations, the Refuge manager is the Refuge Project Leader of the Kaua'i National Wildlife Refuge Complex). In the event an existing permittee chooses to discontinue or is unable to continue kalo farming on the Refuge, the Service would evaluate whether to retain the area in lo'i kalo or assign it to other habitat types based on a management decision flowchart (Figure B-1). If the Service determines that kalo farming would continue within that particular area, an open and competitive process would determine award of the CAA.
2. Permittees are required to restrict their activities and access on the Refuge to their residences or storage sheds and the immediately surrounding areas, their lo'i kalo and associated facilities (e.g., dikes, canals, and ditches), the access roads depicted on the attached map (Figure B-2), and other areas open to the public. Access to other areas of the Refuge that are not open to the public would not be allowed without specific, prior written approval of the Refuge manager.
3. Permittees are prohibited from assigning or sub-permitting their Refuge farming authorizations. Permittees are required to personally supervise and participate in all kalo farming activities, including maintenance of irrigation ditches and roads in their permit area.
4. Permittees are required to supply labor for all ditch cleaning and maintenance and repair of roads in their permit area. Each permittee is required to keep a record of ditch cleaning and road maintenance or repair effort that is available upon request from the Refuge manager. Additionally, permittees are required to cooperatively maintain fences, gates, water control structures, signs, and other infrastructure in partnership with the Refuge staff (Figures B-3, B-4, and B-5). Specific individual and shared responsibilities for maintenance would be included in the plan of operations associated with the CAA.
5. Permittees are required to brief new employees (i.e., farm workers) about the special status of Hanalei NWR; management of the Refuge for native fish, wildlife, plants, and their habitats; the need to exercise care and caution while on the Refuge to minimize disturbance or other impacts to threatened and endangered species, other native wildlife, or Refuge visitors engaging in wildlife-dependent education or recreation; the need to minimize the likelihood that nonnative species, including domestic dogs, cats, noxious weeds, or pest plants, are brought onto the Refuge; and all of the special conditions of their CAA/SUP.
6. Permittees will be required to participate in a comprehensive Refuge water budget analysis, and subsequent implementation of recommended improvements is required to help ensure the availability of an adequate water supply throughout Hanalei NWR.

GENERAL (SPECIFIC TO RESIDENCES AND FARM STORAGE AREAS)

1. Use of Refuge lands for kalo farming-related residences, outbuildings, other structures associated with the residences, storage sheds, and surrounding areas is authorized through the same CAA and documented on the same Commercial Activities SUP as its associated

cooperative kalo farming and as such has the same terms and conditions associated, including permit length.

2. Use of Refuge lands for permittee-owned residences, storage sheds, and other facilities will be terminated if associated kalo farming CAAs and SUPs are terminated. In the event of termination, the permittees will be granted 180 days to remove their improvements (residences, storage sheds, outbuildings, and other structures), equipment, supplies, and other personal property from the Refuge. Any property remaining on the Refuge after 180 days will be considered abandoned, becomes the property of the Service, and could be disposed of.
3. Only permittees and members of their immediate family—legal parents, spouses, and children—are allowed to live in the primary residences described in the CAAs and SUPs. At least one permit holder must live in the residence. The number of people residing in a residence located within the Refuge cannot exceed the design limit or County Code for the residence and its associated septic system.
4. No new farmer residences are authorized on Refuge property. Permittees are prohibited from constructing new structures or making modifications/additions to their existing structures in their CAA/SUP area or elsewhere on the Refuge without specific, prior written approval of the Refuge manager. All residences, outbuildings, other structures associated with the residences, and the immediately surrounding areas, and all storage sheds and immediately surrounding areas are also required to be constructed, modified, and maintained consistent with relevant County and State building, electrical, plumbing, health and safety, and other similar codes, standards, and other relevant requirements. This includes securing appropriate permits and approval from the Refuge manager prior to construction or modification. Stipulations associated with this Refuge authorization could be more restrictive than county and state requirements. Permittees are required to comply with the most restrictive applicable requirement.
5. Permittees who both reside and farm kalo on-site are restricted to use of a Refuge area totaling approximately one acre in size for their existing residence and immediately surrounding areas for residential use and storage; this area is specified within the CAA/SUP. These areas will be marked with signs or through use of other appropriate means that clearly show the boundary of the CAA/SUP area. The final size limitation and the shape of individual permit areas will be based in part on an on-the-ground review by Refuge staff in consultation with Refuge kalo farmers. Permittees are prohibited from clearing or otherwise using areas of the Refuge outside their permit areas for any reason without specific, prior written approval of the Refuge manager.
6. Permittees who live off-site, but farm kalo on-site, are restricted to use of a Refuge area totaling approximately 0.06 acre (2,500 square feet) in size for their existing storage sheds and immediately surrounding areas. These CAA/SUP areas will be marked with signs or through use of other appropriate means that clearly show the boundary of the permit area. The final size limitation and the shape of individual permit areas will be determined in part on an on-the-ground review by Refuge staff in consultation with Refuge kalo farmers. Permittees are prohibited from clearing or otherwise using areas of the Refuge outside of their permit areas without specific, prior written approval of the Refuge manager.
7. Permittees who live on-site are allowed to store and use a number (specified within their CAA/SUP) of personal vehicles and equipment that are used in farming or maintenance and repair of their homes, storage sheds, or permit areas. However, permittees are prohibited from storing abandoned or unusable motor vehicles and farming equipment or supplies that are not being actively used in kalo farming on the Refuge or in maintenance, repair, or other legal use of their permit areas.

8. Permittees who live on-site are allowed to plant and maintain fruit and vegetable gardens/orchards immediately adjacent to residences, in consultation with the Refuge manager, and keep a total of no more than the following numbers of pets or livestock inside each of their CAA/SUP areas: two dogs (must be fully contained in a kennel or fenced area near residence or kept indoors) and one horse, if used in kalo farming operations. Young animals cannot be kept on the Refuge after they have been weaned. Neither indoor nor outdoor pet cats are allowed. One pig and ten adult chickens may be raised for personal consumption only (not for sale), but they must be confined to pens at all times.

   Other than horses used in farming operations, these animals are prohibited from roaming freely on the Refuge, or from accompanying resident farmers or their employees, family members, and guests to kalo fields or in any other part of the Refuge. Any dog observed harassing wildlife on the Refuge is subject to immediate removal.
9. Permittees and their employees who live off-site are prohibited from planting or maintaining fruit or vegetable plants, gardens, or orchards; or from bringing or keeping any animals on the Refuge.

GENERAL (APPLIES TO ALL KALO FARMING AND RELATED RESIDENTIAL/STORAGE USES)

The following stipulations apply to permittees, their family members, employees, and guests.

1. In the absence of specific, prior written approval of the Refuge manager, permittees, their family members, their employees, and their guests are prohibited from collecting and removing any abiotic or biological specimens or samples, or mementos from the Refuge.
2. Consistent with Service policy regarding management of nonhazardous solid waste on refuges (Resource Conservation and Recovery Act of 1976 [RCRA], as amended (42 U.S.C. 6901–6992k)—Solid Waste (Nonhazardous); 50 CFR 27.93, Abandonment of Property; 50 CFR 27.94, Disposal of Waste; and 561 FW 5, Managing, Recycling, and Disposing of Non-Hazardous Solid Waste), permittees are prohibited from dumping or disposing of refuse/trash, debris, litter, or abandoned, excess, or unused materials, building materials, and supplies on the Refuge, including permit areas. These must be removed by permittees on at least a quarterly (90 day) basis. Permittees are prohibited from dumping or disposing of noncomposted organic material on the Refuge without specific, prior written approval of the Refuge manager (see Farming, Fish and Wildlife, and Water Quality, #7, below).
3. Permittees are required to hold the United States Government harmless from any damages or injury to the permittee or members of the public in areas and facilities accessed via the terms of their permit.
4. In addition to the stipulations listed here and the Commercial Activities SUP conditions and requirements, permittees, their family members, their employees, and their guests are required to comply with Refuge System-related and other applicable laws, regulations, and policies including "Prohibited Acts" listed in 50 CFR 27.
5. Permittees or their representatives are required to participate in meetings or workshops with Refuge management at least twice annually. The purposes of such meetings would be to share new information, discuss results of monitoring, assist with plant identification, review compliance with these stipulations, and address other issues. Other meetings will be scheduled as needed.
6. No changes can be made to any of these stipulations without specific, prior written approval of the Refuge manager.

FARMING, FISH AND WILDLIFE, AND WATER QUALITY

1. All lo‘i are required to be kept in kalo farming at all times, subject to the normal practice of keeping the land fallow at intervals for soil conservation (i.e., 4–8 weeks). Permittees are allowed to keep up to 25 percent of the total lo‘i area in dry fallow for a period not to exceed 180 days. The area in cultivation and the area in dry fallow must be alternated. In avian botulism prone areas, permittees are required to drain, harvest, and dry fallow lo‘i for ≥30 days pending Refuge manager request.
2. Permittees are required to keep lo‘i in wet fallow for a minimum of 30 days, with a water depth of 6–8 inches, following the complete harvest of kalo in that lo‘i. All exceptions to the wet fallow time requirement must be approved in writing by the Refuge manager prior to replanting. The Refuge manager may extend or reduce the required wet fallow period with advance notice. Permittees are required to maintain a record of dates and locations of wet and dry fallow periods and provide those records to the Refuge manager annually.
3. After the 30-day minimum wet fallow, permittees are required to thoroughly drain and aerate each lo‘i kalo prior to replanting.
4. Permittees are required to manage either:
   a. ≥10 percent cover of beneficial non-kalo emergent plants (≥3 species of low-growing annuals, <6–12 inches tall; e.g., *Fimbristylis littoralis*, *Cyperus* spp., *Eleocharis* spp., *Ludwigia* spp., *Schoenoplectus juncoides*) in understory within each lo‘i;
   b. ≥20 percent cover of beneficial non-kalo emergent plants in understory on ≥50 percent of lo‘i; or
   c. ≥10 percent of total lo‘i acreage in vegetated wet fallow to promote growth of non-kalo emergent plants.

   These native or naturalized wetland plants would increase the habitat value of lo‘i to threatened and endangered Hawaiian waterbirds. Some of these native or naturalized plants, for instance kāmole (*Ludwigia octovalvis*), which are efficient at oxidizing root zones could even enhance the growth of surrounding plants (Ernst 1990), potentially including kalo.
5. Permittees are required to maintain grasses, leafy forbs, and other vegetation at 4–6 inches in height through mowing, brush cutting, or other means on at least 75 percent of dike tops in each permit area. This would provide foraging and loafing habitat for ‘alae ke‘oke‘o, ‘alae ‘ula, and nēnē, and allow these threatened or endangered waterbirds to more easily see any approaching predators (Gee 2007). This practice would also help control pest plants.
6. Pesticide, herbicide, fungicide, and/or insecticide use must be approved in advance each year by the Service and only occur per terms of approved PUPs and other terms of the IPM program (see Appendix D). Approved PUPs would authorize application for specific pesticide products for a period of one year. These pesticides must be applied by qualified applicators and consistent with pesticide label restrictions and approved PUPs or as modified by a special needs restriction approved by the U.S. Environmental Protection Agency. Permittees are required to maintain accurate, written records of pesticide and fertilizer use (e.g., dates, types, and amounts) and provide those records to the Refuge manager annually.

   The Service’s approval process begins with a request submitted by the permittee which must include documentation of the pest problem, proposed application dates, amounts, methods, and chemicals requested for use. The request would need to be submitted at least 90 days prior to proposed use to allow adequate time for PUP evaluation and processing. A fertilizer and an herbicide use plan must be developed by each permittee and approved by Refuge manager within two years.

7. Permittees may use compost (defined as the product resulting from the controlled biological decomposition of organic wastes) or similar organic materials or cover cropping (Refuge pre-approved plant species and time periods only) as soil amendments in their lo‘i. However, without specific, prior written approval of the Refuge manager, dumping or disposing of any noncomposted organic materials, including animal waste (manure), green waste from outside sources, or other organic materials such as peelings or other residues from kalo/poi mills elsewhere on the Refuge, is prohibited. Following harvest, permittees are prohibited from discarding excess kalo harvesting byproduct on lo‘i dikes. These byproducts are to be left within the lo‘i.
8. Permittees are required to report the nests of threatened and endangered Hawaiian waterbirds found within their permit area to their farm workers and the Refuge manager or Refuge biologist within 24 hours of discovery. On the same day as the nest discovery is made, farmers are required to place a minimum 6-foot tall bamboo, or other wooden pole, vertically and securely in the ground on a dike at the end of the row in which the nest was found. Those same lo‘i must remain flooded to a depth of 3–6 inches and if in a field being harvested, a minimum 6-foot radius area of unharvested kalo plants must be maintained around each active waterbird nest until the young birds fledge or leave the lo‘i on their own accord. Farmers must coordinate with Refuge staff to minimize impacts or take of birds by implementing additional protective measures as needed, such as delaying harvest in areas where nests are known to occur until the young birds fledge or leave the lo‘i of their own accord.

   Permittees would plant and maintain lo‘i in a way that would distribute kalo at different stages of maturity among different lo‘i, so that harvesting of all lo‘i at one time would not occur. This would allow farmers the continued ability to harvest in lo‘i that do not have a nest present.
9. Permittees are required to participate in relevant aspects of the Avian Botulism Prevention and Response Protocol as part of their CAA and SUP. If a given kalo patch is identified as an avian botulism hotspot, then permittees must work with Refuge staff to change environmental conditions. This includes implementing BMPs such as improving water circulation in lo‘i (i.e., cross-flow irrigation) or reconfiguring pipelines to remove all flow-through (i.e., lo‘i-to-lo‘i) drains.
10. Farmers are required to report dead or sick waterbirds found on the Refuge to the Refuge biologist or Refuge management as soon as possible, but no more than within 24 hours of discovery.
11. Permittees are required to report stray dogs or cats found on the Refuge to the Refuge manager or Refuge biologist within eight hours of discovery.
12. Consistent with applicable federal regulations (see 50 CFR 27.52), permittees are prohibited from introducing plants, animals (including pets), plants, or invertebrates onto the Refuge without specific, prior written approval of the Refuge manager.
13. No new kalo hybrid (non-GMC) varieties would be considered by the Refuge manager for introduction to Hanalei NWR without written proof or certification of the hybrid’s method of origin.
14. Permittees are prohibited from erecting or maintaining fences or barriers that exclude or are flying hazards/obstacles to threatened and endangered Hawaiian waterbirds from lo‘i kalo or other permitted areas. Permittees are also prohibited from erecting or maintaining scarecrows, raptor effigies, or similar devices designed to scare birds away from lo‘i kalo, or to haze birds away from their permit areas.

15. While on the Refuge, including within their permit area, permittees are required to store, label, maintain, use, and dispose of hazardous materials such as pesticides, herbicides, fungicides, fertilizers, and petroleum products consistent with applicable county, state, and federal requirements. Permittees will be required to cooperate with periodic governmental environmental compliance audit and safety inspections (see 560 FW 7) for the Refuge, with a focus on the management of hazardous and nonhazardous materials in kalo farming and related permit areas, especially areas surrounding residences and storage sheds. Such an audit would generate findings and recommendations for complying with application laws, regulations, and policies. The audit recommendations could provide the basis for new or modified permit stipulations. Permittees would have 90 days to come into compliance with such new or modified stipulations.
16. Permittees shall work cooperatively with the Refuge on priority research and monitoring (e.g., soil and water testing) and provide any data collected to Refuge management annually.

CULTURAL RESOURCES

1. In the absence of specific, prior written approval of the Refuge manager, permittees, their family members, their employees, and their guests are prohibited from disturbing or otherwise adversely impacting any pre-contact, historic, or other cultural resources on the Refuge. In the event such resources are inadvertently disturbed in the course of conducting otherwise permitted activities, the disturbing activity must be immediately discontinued, and the Refuge manager must be notified within 24 hours. If iwi (skeletal human remains) are encountered, the activity must be immediately stopped and the Refuge manager, police, and Hawaiʻi Department of Land and Natural Resources must be notified. Collecting and removing any pre-contact or historic artifacts is prohibited.

2. Collecting and removing any prehistoric, pre-contact, or historic artifacts is prohibited.

B.1.7 JUSTIFICATION

Like moist-soil wetland management, kalo farming is labor intensive. If conducted by kalo farmers under a CAA, it would be an alternative method for providing Refuge wetland habitat that satisfies several of the life history requirements for the Refuge's threatened and endangered Hawaiian waterbirds (Gee 2007; Gutscher-Chutz 2011; Malachowski 2014; Malachowski and Dugger 2018) and assists in controlling the spread of pest plant species that otherwise would quickly create large monotypic habitat patches of little or no value to wildlife. Consequently, cooperative kalo farming and supporting subject residences, storage sheds, and surrounding areas support the Refuge purpose, two of the Refuge goals, and the Refuge System mission. Where it continues to contribute to the threatened and endangered species recovery purpose of the Refuge, allowing kalo farming on the Refuge is also consistent with previous official correspondence on this subject (for example, see DOI 1974a, 1974b, 1974c; USFWS 1972).

Regulations in 50 CFR 29.1 require that the Service only authorize economic uses of refuge natural resources where a determination has been made that the use contributes to the achievement of the Refuge purpose or the Refuge System mission. The regulations define an economic use to include "cultivating areas," so kalo farming at Hanalei NWR qualifies as an economic use subject to these regulations. The subject existing residences, storage sheds, and surrounding areas are supportive of kalo farming on the Refuge. By extension, these uses qualify as economic uses subject to these regulations, and also contribute to achieving the Refuge purpose and the Refuge System mission.

As described earlier, cultivation and use of kalo play important roles in Hawaiian culture. Because kalo produced on the Refuge represents a substantial portion of statewide production, continued kalo farming on the Refuge would measurably support perpetuation of these traditional cultural values. Additionally, the kalo farming landscape on the Refuge has been officially recognized as of historic importance.

Cooperative kalo farming and its supporting subject residences, storage sheds, and surrounding areas have the potential to generate effects on wildlife, their habitats, public use, and cultural resources. The stipulations enumerated above, including specific prohibitions, would minimize adverse effects and help enhance potential beneficial effects.

The Refuge would undertake monitoring to determine, among other things, whether the stipulations are being properly implemented and are resulting in desired outcomes. Violation of any of these stipulations may result in citations, notice of violation or noncompliance, suspension of permit, or temporary or permanent withdrawal by appropriate Refuge personnel of official permission to continue this use on the Refuge. Permits could be revoked by the Refuge manager within 30 days of written notice of noncompliance with these stipulations.

The Refuge would also monitor habitat quantity and quality; wildlife use and productivity; water quality; conditions and uses of residences, storage sheds, and other buildings; conditions and uses of immediately surrounding areas; ditch and road conditions in areas near the permit areas; public use; and other relevant attributes to determine if stipulations are resulting in expected and desirable outcomes. In consultation with permittees/cooperators, the Refuge would apply adaptive management to modify stipulations or adjust objectives, as necessary, to achieve desirable results.

The Refuge reserves the right to add to or otherwise modify the stipulations listed herein in order to ensure the continued compatibility of this use. New or modified stipulations could be instituted as a result of new information generated by ongoing or new studies (especially in regards to factors influencing avian botulism), audits, or reviews; new legal, regulatory, or policy requirements; significant changes to the Refuge environment or status of native fish, wildlife, plants, or their habitats; changes to uses of residences, storage sheds, or immediately surrounding areas; changes to kalo farming or related practices; mutual agreement with the kalo farmers; or for other legitimate reasons. Except in the case of emergencies, farmers would be advised of new or significantly modified stipulations at least 90 days prior to becoming effective.

B.1.8 COMPATIBILITY STANDARD

In order to continue to utilize cooperative kalo farming on Hanalei NWR as a management tool along with the related residences, facilities, and immediate surrounding areas, compatibility would need to be determined. By allowing these uses to occur under the stipulations described above, it is anticipated that wildlife disturbance would be minimized, and most wildlife disturbed by this use would find sufficient food resources and resting places so their abundance and use would not be measurably lessened on the Refuge. Additionally, it is anticipated that the required monitoring associated with this use would help prevent unacceptable or irreversible impacts to fish, wildlife, plants, and their habitats; cultural resources; and public use. For the several reasons stated above, continued kalo farming and its related residences, facilities, and immediate surrounding areas, consistent with the stipulations described herein, would provide wetland habitat and not materially interfere with or detract from maintenance of the Refuge's biological integrity, diversity, and environmental health; fulfillment of the Hanalei NWR purpose; or the Refuge System mission.

B.1.9 MANDATORY RE-EVALUATION DATE:

_____________ Mandatory 15-year re-evaluation date (for wildlife-dependent public uses)

______X_____ Mandatory 10-year re-evaluation date (for all uses other than wildlife-dependent public uses)

B.1.10 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

This compatibility determination has been developed and issued concurrently with the WMWCP and EA for Hanalei NWR.

B.1.11 COMPATIBILITY DETERMINATION: KALO FARMING; RESIDENCES AND FARM STORAGE AREAS (RESIDENTIAL [OTHER] AND FARMING)

REFUGE DETERMINATION:

Refuge Manager,
Hanalei National
Wildlife Refuge: ________________________________ _______________

(Signature) (Date)

CONCURRENCE:

Regional Chief,
National Wildlife Refuge
System, Pacific Region: ________________________________ _______________

(Signature) (Date)

B.1.12 References Cited

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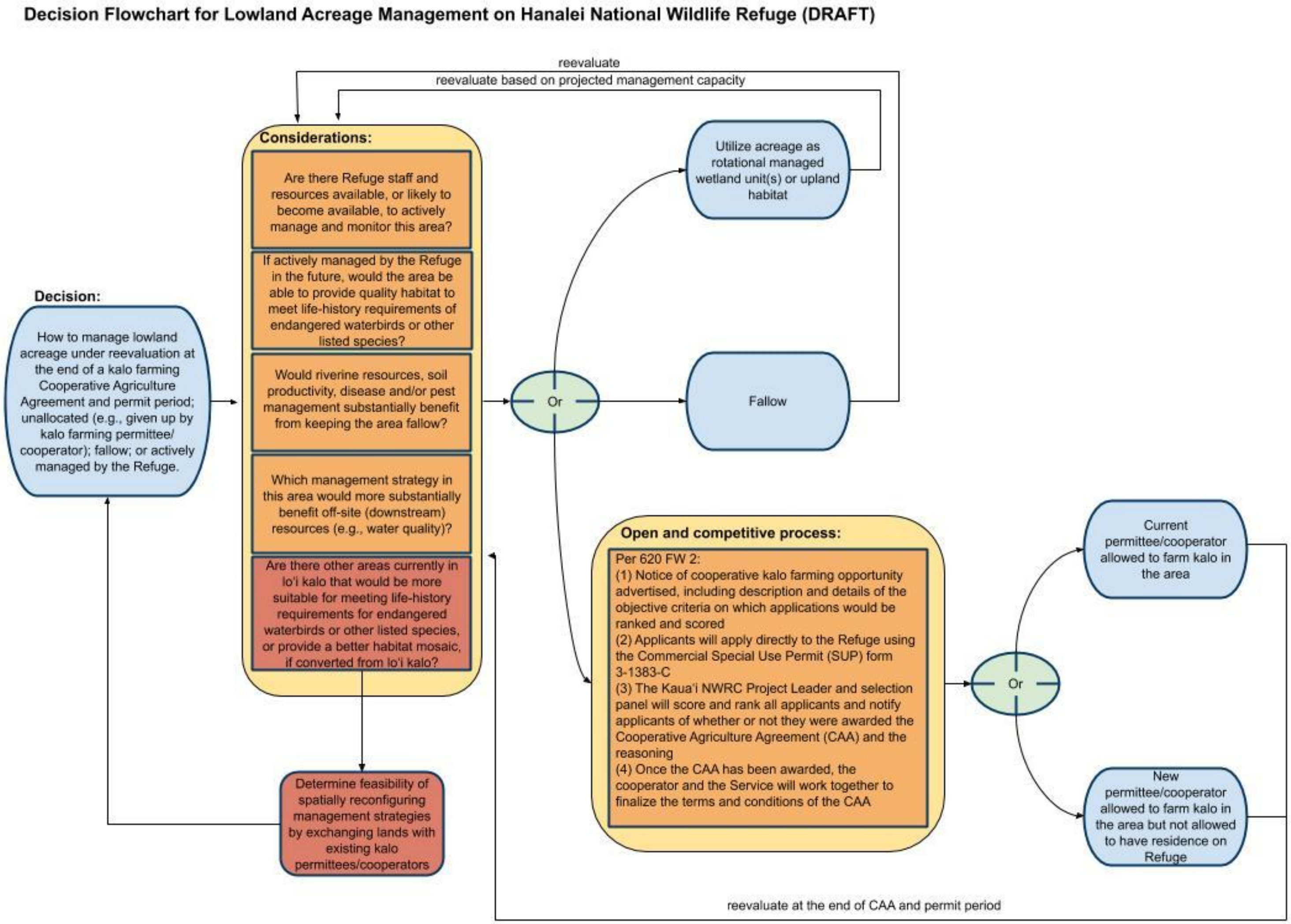
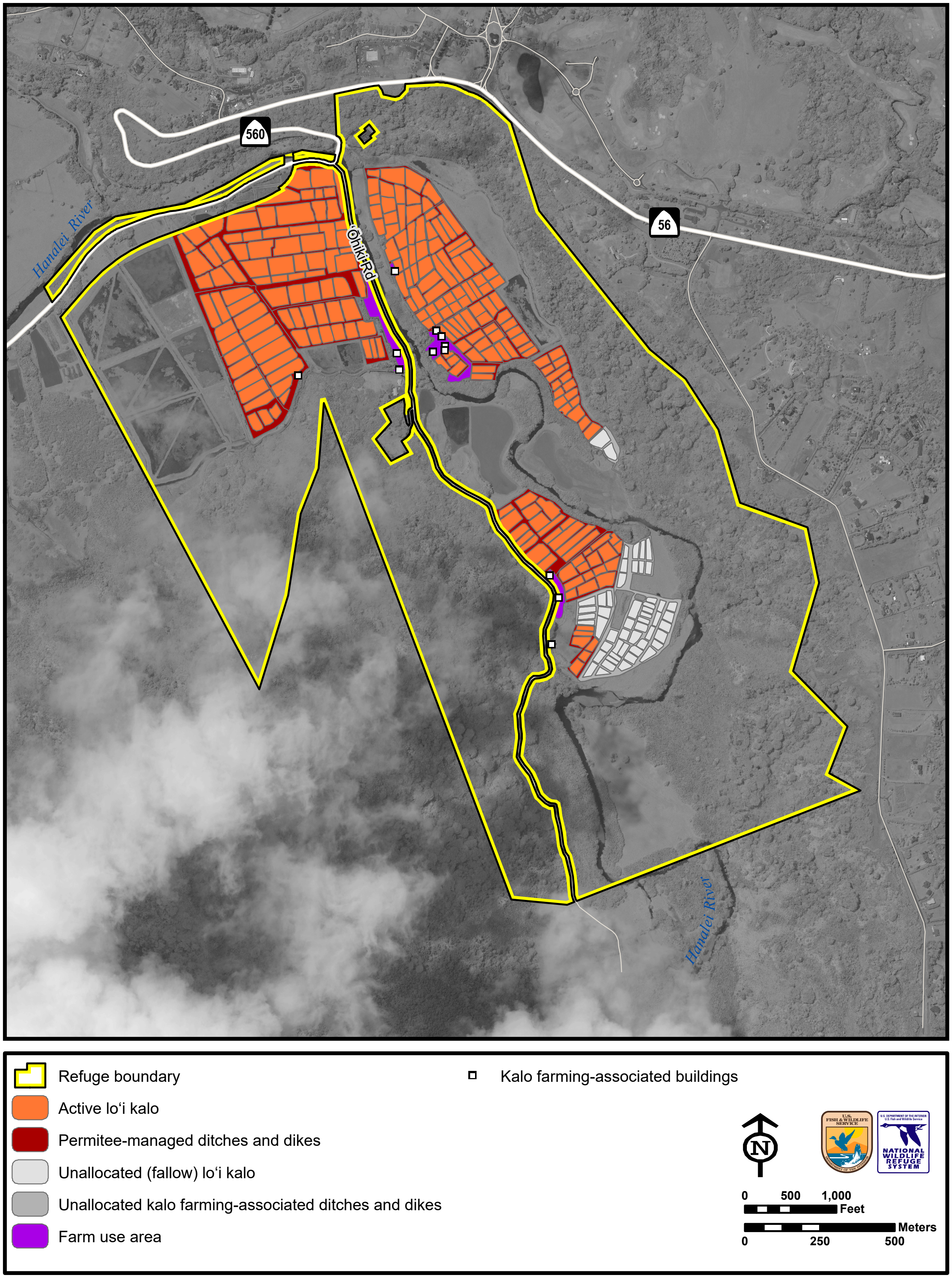


Figure B-1. Active management flowchart, Hanalei NWR

Figure B-2. Current kalo farming lands, residences, storage areas, and associated areas



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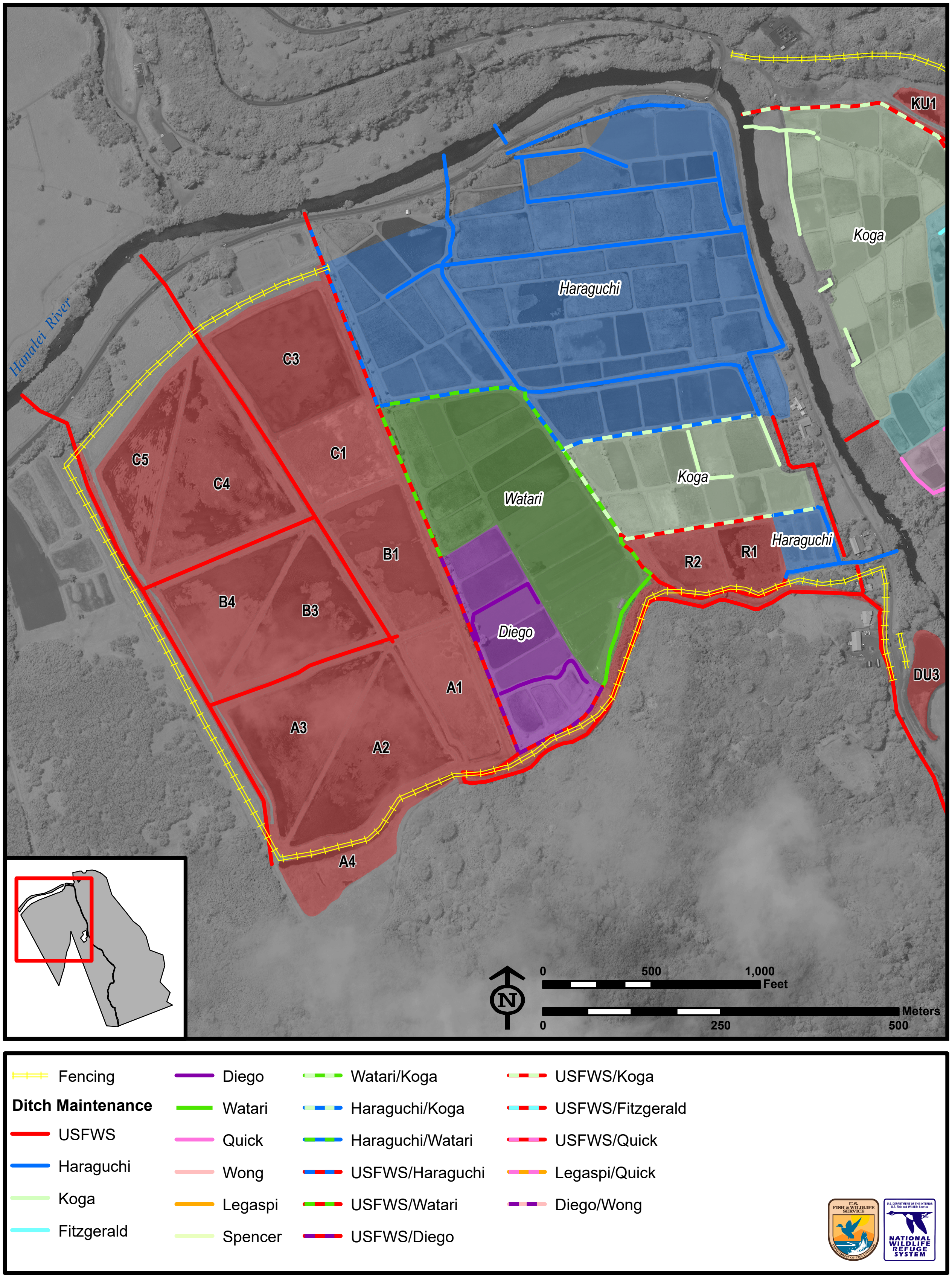
Data Source: USFWS 2019; Imagery from DigitalGlobe 6/3/2019
USFWS R1 Refuge Inventory and Monitoring Branch

Figure B-3. Ditch maintenance responsibilities, northwestern Hanalei NWR



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Data Source: USFWS 2019; Imagery from DigitalGlobe 6/3/2019

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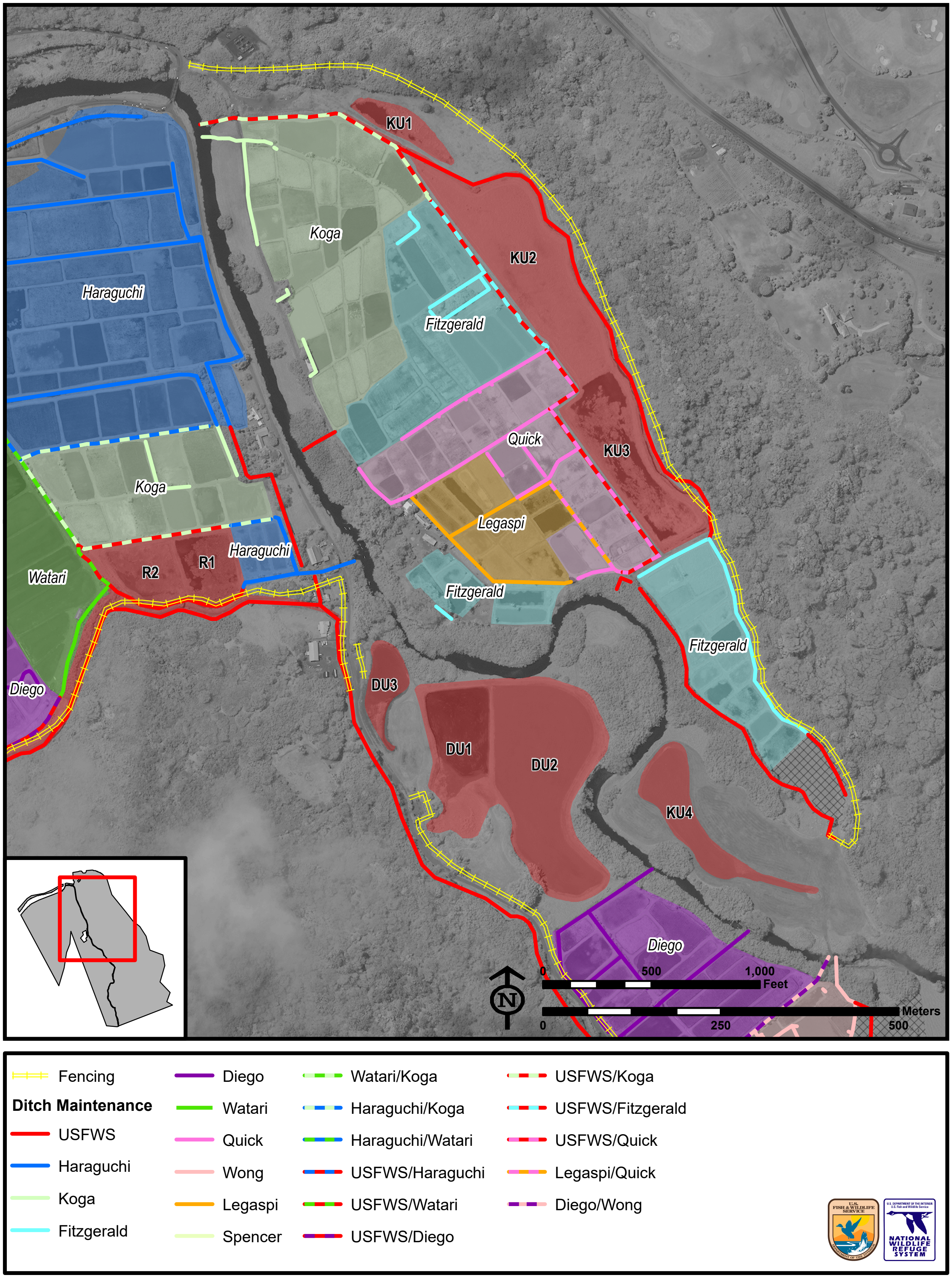
Figure B-4. Ditch maintenance responsibilities, northeastern Hanalei NWR



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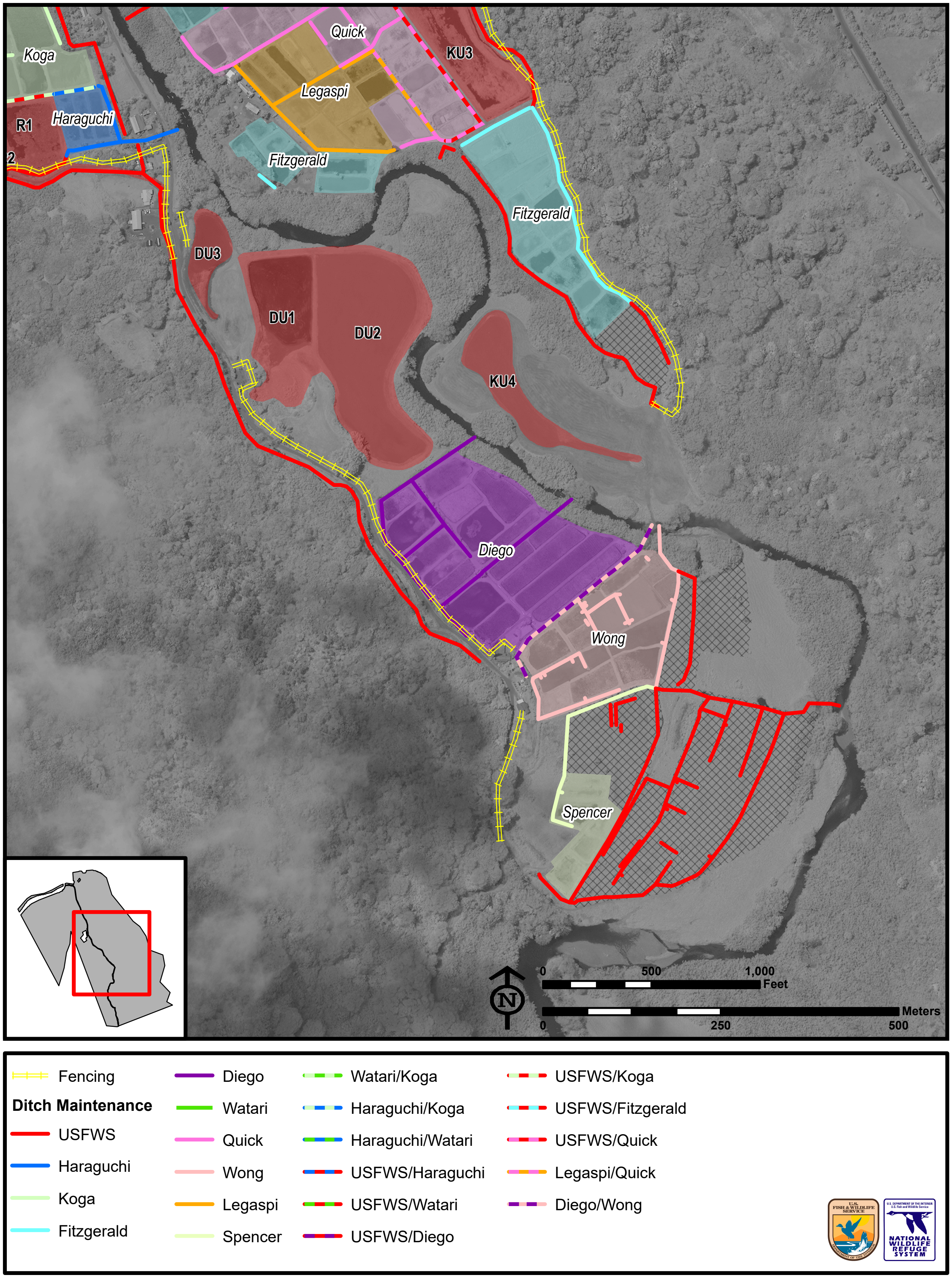
USFWS R1 Inventory and Monitoring Branch

Figure B-5. Ditch maintenance responsibilities, southern Hanalei NWR



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USFWS R1 Inventory and Monitoring Branch

B.2 DRAFT COMPATIBILITY DETERMINATION - USE: COOPERATIVE GRAZING

REFUGE NAME: HANALEI NATIONAL WILDLIFE REFUGE, COUNTY OF KAUAʻI, HAWAIʻI

ESTABLISHING AND ACQUISITION AUTHORITY(IES):

Endangered Species Act of 1973, as amended (16 United States Code [U.S.C.] 1531–1544)

REFUGE PURPOSE(S):

"… to conserve (A) fish or wildlife which are listed as endangered species or threatened species…or (B) plants…" (ESA; Endangered Species Act of 1973)

NATIONAL WILDLIFE REFUGE SYSTEM (REFUGE SYSTEM OR NWRS) MISSION:

"The mission of the [National Wildlife 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 [Refuge Administration Act], as amended) (16 U.S.C. 668dd–668ee).

B.2.1 DESCRIPTION OF USE(S)

COOPERATIVE AGRICULTURE

Cooperative agriculture is when a person or entity uses agricultural practices on National Wildlife Refuge System (NWRS or Refuge System) lands in support of objectives for target species or their associated habitats that represent the biological outcomes the U.S. Fish and Wildlife Service (USFWS or Service) desires, and there is substantial involvement (i.e., collaboration, participation, or intervention) between the Service and the person or entity. The Service uses cooperative agriculture agreements (CAAs) as the legal instruments to formalize the cooperative agreement between the Service and the cooperator. CAAs describe the objectives, roles, responsibilities, terms, and conditions of cooperative agriculture on Refuge System land and must be documented on a Commercial Activities Special Use Permit (SUP), Form 3-1383-C.

COOPERATIVE GRAZING

This use involves cooperative grazing of Hanalei National Wildlife Refuge (NWR or Refuge) lands by domestic livestock, which may include cattle, sheep, or goats. Before being allowed on the Refuge, this use would first need to be found appropriate (see 603 U.S. Fish and Wildlife Service Manual [FW] 1) and determined compatible (see 603 FW 2). Farming is also an economic use of refuge lands under relevant Code of Federal Regulations (CFR; 50 CFR 29.1). Per the Cooperative Agricultural Use policy (620 FW 2) approved on August 3, 2017, cooperative grazing on the Refuge would be authorized under CAAs and documented on Commercial Activities SUPs.

Grazing on the Refuge would meet the definition of cooperative agriculture because (1) it is conducted in support of resource management objectives for restoring or enhancing rotational managed wetlands and riparian habitat to satisfy life history requirements of threatened and endangered Hawaiian waterbirds (Objectives 1.2 and 2.2 in the draft Wetlands Management and Waterbird Conservation Plan [dWMWCP]) and (2) it involves substantial involvement between the Service and the cooperator, as defined by 620 FW 2 and 505 Department Manual (DM) 2.9.

At Hanalei NWR, the cooperative grazing program would be specifically designed for two distinct purposes.

1. In conjunction with heavy equipment (e.g., mowing) and herbicides, livestock grazing could be used as an initial (time-limited) strategy for reducing plant biomass and controlling or removing invasive plants (e.g., 6- to 8-foot tall, dense California grass [*Urochloa mutica*]) to clear areas in preparation for long-term habitat management (i.e., either restoration of rotational managed wetland units or maintenance of short grass habitat).
2. Livestock grazing could also be used as a long-term strategy for seasonally managing and maintaining short grass conditions (e.g., grasses 4–6 inches in height) conducive to foraging (grazing) and nesting by threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

Based on the reasons for using cooperative grazing, different stipulations regarding duration, timing, and monitoring would apply. For example, livestock grazing for the former purpose could be conducted at any time of year with baseline monitoring whereas grazing for the latter purpose would only be permitted seasonally during the non-peak threatened and endangered waterbird breeding period (e.g., approximately May–September since nēnē peak breeding is October–April) and would be associated with a more intensive monitoring program. In either case, fencing would be erected around the pastures to focus the grazing where desired and keep livestock from riparian areas, steep banks, and the Hanalei River. An in-pasture water supply and salt blocks would also be made available and used to deter livestock from riparian areas and river corridor and, as necessary, encourage livestock to graze in areas of particular interest. Monitoring and adaptive management based on measurable and meaningful criteria are important for ensuring that cooperative grazing remains compatible over time.

At least initially, the cooperative grazing program would be conducted on a short-term, experimental basis (with 1-year SUP and CAA) to determine whether the program could create the habitat conditions and associated wildlife benefits being sought while minimizing impacts to threatened and endangered species and aquatic resources. Grazing program parameters (timing, frequency, intensity, or other elements) would be developed with the assistance of the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the University of Hawai‘i, Hawai‘i Department of Land and Natural Resources, livestock grazers, Hawaiian waterbird biologists, and others. The end result of this effort would be a grazing plan for the Refuge and associated best management practices (BMP) for grazing.

PROPOSED AREAS OF USE

There are currently 3–18 acres of lowlands that are not currently in rotational managed wetlands or actively farmed lo‘i kalo and could be restored to functional wetland units for the benefit of threatened and endangered and migratory waterbirds. Specifically, the areas include three acres in between the KU4 wetland unit on the south and lo‘i kalo on the north, five acres bordered on the west and south by fallow lo‘i kalo and to the east by a hau (*Hibiscus tiliaceus*) dominated area, and also 10 acres located near a riparian grassland and adjacent hau dominated area by the Hanalei River diversion (Figure B-6). These areas would need to be opened up to bare mineral soil using heavy equipment, herbicides, and/or grazing (to remove California grass) as a first step in restoration.

Following area clearing, water delivery systems and water control structures would need to be installed. Subsequently, moist-soil management techniques would be used within these rotational managed wetland units to manipulate native and naturalized beneficial non-native vegetation to provide important structure for threatened and endangered waterbird nesting, foraging, brooding, loafing, and thermal/escape cover.

Within an approximately 14–24-acre riparian grassland and adjacent hau-dominated area near the southern boundary of the Refuge (Figure B-6), grazing would be used to create and maintain a short grass habitat 4–6 inches in height for foraging (grazing) and nesting by nēnē. The fenced area outside the grazed area would include a relatively undisturbed riparian zone with taller and denser vegetation that could be used for nesting by endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*) and ʻalae ʻula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*). It is expected that other native wildlife could also benefit from the grazed area and adjacent riparian zone. Within the 10-acre hau-dominated area, following the removal of hau, grazing would maintain the cleared area (e.g., control/removal of invasive species such as California grass) prior to completing wetland habitat restoration.

In managing short grass habitat, grazing could supplement, and be used in conjunction with mowing by Refuge staff. Regardless of the management technique employed, treatments would need to occur regularly because the grass grows quickly and year-round. The costs, habitat benefits, and other effects of grazing and mowing would be evaluated over time. As data are generated and monitoring results become available, the Service would implement adaptive management principles to refine grazing prescriptions. If results were favorable, this program could be extended to a more long-term basis.

This draft compatibility determination (CD) has been developed and made publicly available concurrent with the dWMWCP and associated environmental assessment (EA) for Hanalei NWR. Much of the information and some of the analyses contained in this draft CD are addressed in greater detail in the dWMWCP and EA, which are incorporated by reference herein.

B.2.2 ADMINISTRATION OF THE USE

COOPERATIVE AGRICULTURE AGREEMENTS

As mentioned above, cooperative grazing would be authorized under CAAs and documented on Commercial Activities SUPs. Permittees/cooperators would be entered into CAAs through an open and competitive process. The process for awarding CAAs includes the following:

- The Service would provide the public with a notice of cooperative agricultural opportunities. This would include publication of a Notice of Funding Opportunity on Grants.gov, notification on a national Service website (https://www.fws.gov/refuges/whm/cooperativeAgriculture.html), and local outreach. The notice would include details on the cooperative agricultural opportunity such as the objective criteria that would be used to rank and score applications.
- Applicants would apply directly to the Kauaʻi NWR Complex using the application guidance provided in the CAA prospectus.
- The Kauaʻi NWR Complex Project Leader, along with a selection panel, would score and rank all applicants and notify each applicant regarding whether they were awarded the CAA and the reasoning for the panel's decision. Unsuccessful applicants have the right to appeal the decision in accordance with 50 CFR 25.45.

- Once the CAA has been awarded, the cooperator and the Service would work together to finalize the specific terms and conditions of the CAA, including a plan of operations.

DIRECT AND INDIRECT REFUGE COSTS TO IMPLEMENT THE USE

Kaua'i National Wildlife Refuge Complex staff would directly administer CAAs for the cooperative grazing program. Direct and indirect costs to administer this use include the following:

- Costs associated with construction, repair, operation, and maintenance of associated facilities;
- Salaries and associated employee expenses related to evaluation of the proposed use (including appropriateness finding, CD, and compliance with applicable laws, regulations, and policies such as National Environmental Policy Act [NEPA], ESA, and National Historic Preservation Act [NHPA]), and development of the grazing SUP and CAA;
- Salaries and associated employee expenses related to monitoring of this use to ensure that SUP/agreement requirements are followed and that the use remains compatible. This includes evaluation of grazing's effects on the Refuge's natural and cultural resources, and compatible, especially wildlife-dependent, public use;
- Use-related supplies, equipment, and travel; and
- An applicable portion of Refuge overhead costs.

TABLE B-2. ONE-TIME COSTS ASSOCIATED WITH COOPERATIVE GRAZING (PART OF WHICH COULD BE COST-SHARED)

Tasks	*Estimated Costs*
1. Erection of fences and gates	$5,000
2. Infrastructure for in-pasture water supplies	$1,500
Total Costs	**$6,500**

TABLE B-3. ESTIMATE OF ANNUAL COSTS FOR ADMINISTERING COOPERATIVE GRAZING

Tasks	*Estimated Costs per Year*[1]
1. Permit/agreement administration and oversight by GS-12 refuge deputy project leader (2%), GS-7 wildlife refuge specialist permit coordinator (10%), and WG-10 maintenance and facilities worker (2%)	$10,811
2. Permit/agreement and biological monitoring by GS-11 biologist (5%) and GS-7 biological technician (25%)	$21,353
3. Supplies, equipment, and facility maintenance and repair	$1,000
4. Refuge overhead costs associated with the above-listed work[2]	$11,258
Total Costs	**$44,422**

[1] Annual personnel costs = 2019 step 5 salary for appropriate GS or GL level (including locality payment of 18.43%) x 35% for benefits. For WG, 2019 step 3 hourly rate x 35% for benefits.
[2] Overhead costs (management capability) = salary + benefit costs x 0.35. Overhead expenses include building rent, utilities, equipment and supplies, and support personnel, and do not include salary-related benefits.

COST-SHARING

Per the cooperative agricultural use policy (620 FW 2), cost-sharing is defined as the portion of the costs for cooperative agriculture on Refuge System lands that are borne by the cooperator. Cost-sharing can vary depending on the needs and objectives of the particular refuge land. For example, the Service may provide the cooperator with the right to perform agricultural practices on Refuge land and a percentage of any resulting crop/feed yield, as well as the ability to use Service- delivered water, equipment, or Refuge staff. In exchange, the cooperator may provide the Service with labor, equipment, and materials; a percentage of any resulting crop/feed yield; or maintenance, rehabilitation, or reestablishment of specific habitat conditions on Refuge lands.

The Service policy on the administration of specialized uses (5 Refuge Manual [RM] 17) requires that specialized uses, which include economic, recreational, right-of-way, and other privileged uses, must be accompanied by a fee or cooperative exchange to recover the costs of administering the special use permit and use and/or the fair market value of the benefit received.

Grazing would be required to meet some of the life history requirements of threatened and endangered Hawaiian waterbirds. Because management for waterbirds could conflict with practices optimized for forage and livestock production, grazing on the Refuge is a cooperative venture. Cost-sharing through the CAAs will attempt to ensure that fair market value is taken into account. The Service may explore cost-sharing under the CAA to support biological and compliance monitoring.

B.2.3 ANTICIPATED IMPACTS OF THE USE(S)

The proposed cooperative grazing program would directly or indirectly support Goals 1 and 2 in the dWMWCP. To the extent that grazing provided habitat to support the recovery of threatened and endangered Hawaiian waterbirds, it would be consistent with the Refuge System mission.

FISH, WILDLIFE, PLANTS, AND THEIR HABITATS

As noted earlier, the purpose of the Refuge is to benefit species listed under the ESA. At Hanalei NWR, the management focus is supporting the recovery of five federally-listed Hawaiian waterbirds: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula; endangered koloa maoli; and threatened nēnē.

As mentioned previously, livestock grazing can be used as a valuable tool to (1) clear areas in advance of habitat management (e.g., wetland restoration) and (2) manage and maintain grassland habitats. To illustrate the latter use: at present, the southern riparian grassland is completely overgrown by tall and dense California grass and thus, provides low value for Hawaiian waterbirds (Gutscher-Chutz 2011). After initial control/removal of invasive plants, grazing this area to the desired grass height (4–6-inches) would be expected to provide foraging habitat for nēnē. The riparian areas could be used for nesting by koloa maoli and ‘alae ‘ula. Other native wildlife could also benefit from the grazed pasture and fenced riparian zones. Ae‘o, ‘alae ke‘oke‘o, ‘alae ‘ula, and koloa maoli actively fed and loafed in grazed management units at Hanalei NWR in the past (USFWS 1994).

However, unless properly managed, livestock grazing can cause a variety of undesirable effects (Kirby et al. 1992). Livestock are drawn to water and grazing directly adjacent to riparian areas can cause vegetation trampling; soil compaction and erosion; and reduced recruitment of shrubs and trees, the latter of which is actually consistent with desired management of these areas. The proposed grazing program would minimize erosion and undesirable impacts to riparian areas by erecting and maintaining fences and gates between pastures and riparian areas. Fences would be set back approximately 150 feet or more from the Hanalei River to protect this waterway from adverse effects of grazing and to provide adequate, undisturbed habitat for nesting by koloa maoli and ‘alae ‘ula.

Where stocking rates are too high, livestock can overgraze pastures causing long-term damage to vegetation and soils. Livestock can also graze pastures unevenly. Grazing pressure within a pasture can be influenced by the availability of water and salt. The provision of an in-pasture water supply and salt blocks would deter livestock from riparian areas and encourage more consistency in grazing pressure. Additionally, in-pasture water supplies will be necessary since direct livestock access to the river would be blocked by fencing. Cross-fencing and pasture rotations would also be considered and used, as appropriate. Livestock can also facilitate the introduction of alien, including pest, species (e.g., through seeds carried in hair, on vehicles and farm machinery, and in feces).

Grazing-related activities, such as transporting livestock, moving water and salt, fence and gate maintenance and repair, and monitoring, would be sources of potential wildlife disturbance. During nonbreeding periods, nēnē, ae‘o, and ‘alae ke‘oke‘o appear to be fairly tolerant of disturbance. However, when birds are breeding or in heavy molt, they are all more vulnerable to disturbance. Koloa maoli and ‘alae‘ula are very wary and often flush or move quickly into dense cover when disturbed (Gutscher-Chutz 2011). Flushing of birds or even raising their alert levels creates stress and requires animals to expend energy that would otherwise be invested in essential life history activities such as foraging, mating, nesting, brood-rearing, and predator avoidance. Disturbance can cause nest desertion; affect survival of individual birds, eggs, nestlings, or broods; and alter behavior of nonbreeding waterbirds. Disturbance levels would be expected to be highest when the livestock program was initially established and when turn-outs or round-ups occurred. These events would be short-lived. In the absence of human and other activity, the waterbirds could acclimate, during their nonbreeding periods, to the presence of low-intensity livestock grazing. Nēnē are ground nesters, usually hiding their nests in the shade of a shrub or other vegetation (USFWS 2004). Livestock could destroy nēnē eggs or injure or kill young birds by stepping on them. If threatened or endangered waterbirds are nesting in an area, such as nēnē in a given paddock, then grazing would only be allowed seasonally during non-peak breeding periods, or grazing would not be permitted in that area. This would be addressed through the monitoring program.

WATER QUALITY

Because of elevated levels of *Enterococci* and turbidity (total suspended solids), the State of Hawai‘i Department of Health (HDOH) identified the Hanalei Bay Watershed as water quality limited under section 303(d) of the Clean Water Act (HDOH 2014). Elevated levels of nutrients (total nitrogen and total phosphorus) were also identified as a concern (Tetra Tech and HDOH 2008). The Hanalei River flows through Hanalei NWR and is the largest tributary in this watershed. In an effort to address constituents of concern in these waterbodies, HDOH established total maximum daily loads (TMDL) for the Hanalei River and Hanalei Estuary (Tetra Tech and HDOH 2008). HDOH identified no dischargers with National Pollutant Discharge Elimination System permits or other point sources of pollution in the Hanalei River Watershed, so the TMDL address non-point sources. Hanalei NWR was identified as a source of constituents of concern to the Hanalei River (Tetra Tech and HDOH 2008).

As noted above, livestock are drawn to water and riparian areas. They can increase sedimentation in waterways from bank erosion associated with trails to streams and from stirring up bottom sediments through wading. Nutrient loading can also increase as a result of livestock defecation on stream banks that is later washed into the water, or direct urination or defecation into water. Cattle may also carry leptospirosis. Additional water quality degradation could result from grazers and other personnel crossing the river in vehicles for other grazing-related management purposes. The proposed grazing program would address these issues by erecting and maintaining fences and gates between pastures, riparian areas, and waterways. Fences would be set back approximately 150 feet from the Hanalei River to protect this waterway from adverse effects of grazing.

PUBLIC USE

Due to limited public access and its management for threatened and endangered species, public use of the Refuge is restricted. Kalo farming occurs adjacent to the narrow, single-lane public road (‘Ōhiki Road) that bisects the Refuge. Although farmers and their employees travel and haul equipment and other materials along this narrow road, it does not appear to conflict with public use. Grazing permittees would likely use trucks and/or trailers to transport livestock into and out of the Refuge, with the primary access route being via Burma Road. This traffic would be infrequent but would need to move slowly and be watchful for other vehicles, public and commercial users (e.g., kalo farmers), and threatened and endangered waterbirds. This requirement is included as a stipulation.

CULTURAL RESOURCES

The Hanalei Valley, including the Refuge, contains a number of historic and pre-contact resources. During the 1980s the Hanalei Valley was identified by the National Trust for Historic Preservation (NTHP) as an important site for rural preservation.

There is potential that grazing permittees could adversely affect the Refuge’s cultural resources. Permittees would be provided clear maps depicting areas they were authorized to access and use, and they would be made aware of prohibitions related to cultural resources. As a result, impacts to these resources would not be expected.

B.2.4 PUBLIC REVIEW AND COMMENT

Public availability of this draft CD has been widely announced concurrent with the availability of the Refuge’s dWMWCP and associated EA. The review and comment period were concurrent with the draft plan.

B.2.5 DETERMINATION

_________ Use is Not Compatible

____X____ Use is Compatible with Following Stipulations

B.2.6 STIPULATIONS NECESSARY TO ENSURE COMPATIBILITY

GENERAL

1. Permission to graze on the Refuge will be officially authorized through a CAA and documented on a Commercial Activities SUP, one to each permittee/cooperator (hereafter referred to as permittee). Initially, the CAA would authorize grazing for a maximum of 1 year. Additional CAAs for additional years would depend on the results of monitoring data demonstrating the value of the grazing program for threatened and endangered Hawaiian waterbirds. Future CAAs could be issued on a short-term basis or for up to five years each. Use of Refuge lands for other purposes or the introduction of plants, animals, or invertebrates onto the Refuge is not allowed without specific, prior written approval of the Refuge manager. For the purpose of these stipulations, the Refuge manager is the Project Leader of the Kauaʻi National Wildlife Refuge Complex.
2. Permittees are required to restrict their activities and access on the Refuge to their SUP areas, the access roads identified, and other areas open to the public.
3. Permittees are prohibited from transferring, assigning, or sub-permitting their Refuge grazing authorizations.
4. Permittees or their representatives are required to participate in meetings or workshops with Refuge management annually. The purposes of such meetings would be to share new information, discuss results of monitoring, review compliance with these stipulations, and address other issues. Other meetings would be scheduled as needed.
5. With the exception of livestock fences, associated gates, and other grazing-related structures specifically described in the grazing plan (see below), permittees are prohibited from constructing new or maintaining existing structures on the Refuge without specific, prior written approval of the Refuge manager.
6. In the absence of specific, prior written approval of the Refuge manager, permittees and their employees are prohibited from collecting and removing any archaeological or historic artifacts, abiotic or biological specimens or samples, or mementos from the Refuge.
7. Consistent with Service policy regarding management of nonhazardous solid waste on refuges (Resource Conservation and Recovery Act of 1976 [RCRA], as amended (42 U.S.C. 6901–6992k)—Solid Waste (Nonhazardous); 50 CFR 27.93, Abandonment of Property; 50 CFR 27.94, Disposal of Waste; and 561 FW 5, Managing, Recycling, and Disposing of Non-Hazardous Solid Waste), permittees are prohibited from dumping or disposing of refuse/trash, debris, litter, or abandoned, excess, or unused materials, building materials, and supplies on the Refuge, including permit areas. These would need to be removed by permittees on at least a quarterly (90 day) basis.
8. Permittees are required to hold the United States Government harmless from any damages or injury to the permittee or members of the public in areas and facilities accessed via the terms of their SUP.
9. In addition to the stipulations listed here, the Commercial Activities SUP conditions and requirements, permittees and their employees are required to comply with Refuge System-related and other applicable laws, regulations, and policies including “Prohibited Acts” listed in 50 CFR 27.
10. No changes can be made to any of these stipulations without specific, prior written approval of the Refuge manager.

GRAZING, FISH AND WILDLIFE, AND WATER QUALITY

1. The Refuge will work cooperatively with the NRCS, University of Hawaiʻi, grazers, Hawaiian waterbird biologists, and others to develop a grazing plan for the Refuge and associated BMPs for grazing that is consistent with recovery of threatened and endangered Hawaiian waterbirds. Once adopted, the plan's elements (grazing timing, frequency, intensity, contingencies during high water events, or other elements) and BMPs would automatically become required conditions of Refuge grazing SUP and agreements. The NRCS or others might be able to provide technical or financial assistance with implementation and evaluation of BMPs.

   Permittees will be provided with a prescribed grazing plan for the pasture(s). Among other things, this plan will spell out expectations from the grazing program, including grass height and evenness of grazing. Permittees must manage their livestock, and grazing facilities and supplies (e.g., water and salt) to achieve plan objectives. Permittees are required to maintain accurate written records on livestock numbers in each field and turn-in–turn-out dates and provide those records to the Refuge manager upon request.
2. If the purpose of grazing within a specified area is for the clearing of unwanted vegetation in preparation for long-term habitat management, then cooperative grazing may be conducted at any time of year according to BMPs and with baseline monitoring as articulated in an approved grazing plan. If threatened or endangered waterbirds are nesting in an area, such as nēnē in a given paddock, then grazing will only be allowed seasonally outside of the peak threatened and endangered waterbird breeding period (e.g., approximately May–September because nēnē peak breeding is October–April), or grazing will not be permitted in that area.
3. If the purpose of grazing within a specified area is to maintain short grass conditions (e.g., grasses 4–6 inches in height) for the benefit of nēnē foraging (grazing) and nesting, then cooperative grazing will be conducted seasonally during the nēnē nonbreeding season (May–September) according to BMPs and with intensive, prescriptive monitoring as articulated in an approved grazing plan. If threatened or endangered waterbirds are nesting in an area, such as nēnē in a given paddock, then grazing would not be permitted in that area.
4. Permittees are required to report the nests of threatened and endangered Hawaiian waterbirds found within their SUP area to the Refuge manager or Refuge biologist within 24 hours of discovery.
5. Grazing permittees are required to have proof of ownership of livestock used in the Refuge grazing program. Each animal must be branded or otherwise permanently marked.
6. Permittees are required to satisfy and maintain compliance with state and local government requirements regarding livestock health and sanitation.
7. Pesticide, herbicide, fungicide, and/or insecticide use must be approved in advance each year by the Service and only occur per terms of approved Pesticide User Proposals (PUPs) and other terms of the integrated pest management (IPM) program (see Appendix D). Approved PUPs authorize application for specific pesticide products for a period of 1 year. These pesticides must be applied by qualified applicators and consistent with pesticide label restrictions and approved PUPs or as modified by a special needs restriction approved by the U.S. Environmental Protection Agency. Permittees are required to maintain accurate, written records of pesticide use and provide those records to the Refuge manager annually.

   The Service's approval process begins with a request submitted by the permittee which must include documentation of the pest problem, proposed application dates, amounts, methods, and chemicals requested for use. The request must be submitted at least 90 days prior to proposed use to allow adequate time for PUP evaluation and processing.

8. Permittees are required to follow biosecurity measures, as specified in the prescribed grazing plan, to prevent weed seed transport on animals, humans, or equipment.
9. When traveling on any Refuge roads, permittees are required to drive slowly and be watchful for other vehicles, public and commercial users (e.g., kalo farmers), and threatened and endangered Hawaiian waterbirds. The primary access route for grazing operations is via Burma Road.
10. Grazed pastures must be fenced and gated. Grazing permittees are responsible for ensuring that gates are closed, and livestock do not roam across the Refuge or onto neighboring lands outside the pasture fences. Permittees are responsible for locating and removing livestock that have strayed outside fenced pastures within 24 hours of notification by Refuge staff. Permittees are responsible for any kalo (taro, *Colocasia esculenta*) damage.
    Permittees are responsible for surveying fences and gates to identify breaks or other problems. Responsibilities for maintenance and repair of these facilities will be described through the CAA and plan of operations. Regardless of who constructed them, all grazing-related facilities on the Refuge are the property of the Service.
11. In-pasture water supplies will be provided by the permittee. If these are mobile facilities, grazing permittees are responsible for moving them to achieve objectives of the grazing plan.
12. The Refuge will work with the permittees to establish and maintain a program within their SUP areas to exclude and remove introduced vertebrate predators that prey on threatened or endangered Hawaiian waterbirds. This program may include fencing, live-trapping, shooting, and use of bait stations. Permittees will be required to report stray dogs or cats found on the Refuge to the Refuge manager or Refuge biologist within eight hours of discovery.
13. Permittees are required to report dead or sick waterbirds found on the Refuge to the Refuge manager or Refuge biologist within 24 hours of discovery.

CULTURAL RESOURCES

1. In the absence of specific, prior written approval of the Refuge manager, permittees, their family members, their employees, and their guests are prohibited from disturbing or otherwise adversely impacting any pre-contact, historic, or other cultural resources on the Refuge. In the event such resources are inadvertently disturbed in the course of conducting otherwise permitted activities, the disturbing activity must be immediately discontinued, and the Refuge manager must be notified within 24 hours. If iwi (skeletal human remains) are encountered, the activity must be immediately stopped and the Refuge manager, police, and Hawaiʻi Department of Land and Natural Resources must be notified.
2. Collecting and removing any pre-contact or historic artifacts is prohibited.

B.2.7 JUSTIFICATION

REFUGE GOALS AND THE REFUGE SYSTEM MISSION

The proposed cooperative grazing program would directly or indirectly support Goals 1 and 2 identified in the dWMWCP. To the extent that grazing provided habitat to support the recovery of threatened and endangered Hawaiian waterbirds, it would be consistent with the Refuge System mission.

FISH, WILDLIFE, PLANTS, AND THEIR HABITATS; AND WATER QUALITY

It is expected that grazing could be used as a management technique to convert existing areas on the Refuge that are overgrown with exotic vegetation and of low value to wildlife into productive wetlands or short grass habitats for threatened and endangered Hawaiian waterbirds. The pastures would be fenced, and outside riparian areas should provide nesting habitat for koloa maoli and ‘alae ‘ula.

However, grazing can cause a variety of impacts, including damage to vegetation and soils as a result of overgrazing, vegetation trampling, soil compaction and erosion, and reduced recruitment of shrubs and trees in riparian areas; wildlife disturbance, potentially including destruction of nēnē eggs, or injury or death to young birds through trampling; and increased sedimentation and nutrient loading of waterways and wetlands, which could alter microbial communities and conditions for avian botulism.

Stipulations are included to specifically address these concerns. Pastures would be fenced to contain livestock, focus their grazing efforts, and keep them out of riparian areas and streams. In-pasture water and salt would be supplied to better manage grazing intensity and locations. Based on the purpose of the cooperative grazing, different stipulations regarding duration, timing, and monitoring would apply.

The Refuge would establish a program to monitor compliance with the stipulations, including BMPs enumerated herein. Violation of any of these stipulations could result in temporary or permanent withdrawal of official permission to continue grazing on the Refuge. The SUP could be revoked by the Refuge manager immediately for noncompliance with these stipulations.

Management parameters of the Refuge grazing program, including timing, frequency, intensity, or other elements, would be developed with the assistance of the NRCS, the University of Hawai‘i, livestock grazers, endangered Hawaiian waterbird biologists, or others. The Refuge would monitor habitat quantity and quality, wildlife use and productivity, water quality, and other relevant attributes to determine if grazing was resulting in expected and desirable outcomes. Monitoring would assess, grassland condition (e.g., height, vigor, and species diversity) and wildlife use (e.g., foraging and nesting use, and nest success). Findings would be evaluated against habitat and wildlife objectives to determine whether the grazing program was achieving desired results. In consultation with permittees, the grazing program would be altered as needed until the grazing program was achieving objectives.

The Refuge reserves the right to add to or otherwise modify the stipulations listed herein in order to ensure the continued compatibility of this use. New or modified stipulations could be instituted as a result of new information generated by ongoing or new studies, audits, or reviews; new legal, regulatory, or policy requirements; significant changes to the Refuge environment or status of native fish, wildlife, plants, or their habitats; changes to grazing or related practices; mutual agreement with the grazers; or for other legitimate reasons. Except in the case of emergencies, permittees would be advised of new or significantly modified stipulations at least 90 days prior to their becoming effective.

PUBLIC USE AND CULTURAL RESOURCES

Grazing permittees would likely use trucks and/or trailers to transport livestock into and out of the Refuge along the narrow, single-lane ‘Ōhiki Road. This traffic would be infrequent, but drivers would need to move slowly and be watchful for other vehicles, public and commercial users (e.g., kalo farmers), and threatened and endangered waterbirds.

Clear maps depicting areas they are authorized to access and use, and prohibitions related to cultural resources should greatly reduce the likelihood that impacts would occur to these resources as a result of grazing.

ECONOMIC USES

Regulations in 50 CFR 29.1 require that the Service only authorize economic uses of refuge natural resources where a determination has been made that the use contributes to the achievement of Refuge purpose or the Refuge System mission. The regulations define an economic use to include “grazing livestock;” this proposal is subject to these regulations.

As discussed above, it is the intent of the proposed grazing program to convert Refuge habitats of low use to wildlife into valuable habitats for threatened and endangered Hawaiian waterbirds, including nēnē, koloa maoli, and ‘alae ‘ula. However, if not properly managed, grazing can have some adverse side effects. With the stipulations described herein, the beneficial aspects of this use should increase, and its detrimental effects should diminish. Overall, the proposed use would contribute to achievement of the Refuge’s purpose and the Refuge System mission.

B.2.8 COMPATIBILITY STANDARD

The areas proposed for cooperative grazing currently provide low value to wildlife. Grazing would be used as a management tool for clearing areas of undesirable vegetation and also maintaining short grass habitat conditions. Following clearing, 14–24 acres of overgrown, rank riparian grassland could be converted and maintained as a short grass pasture which would benefit nēnē foraging and nesting, and adjacent riparian areas would provide nesting habitat for koloa maoli and ‘alae ‘ula. Following clearing and with the availability of resources to install a water delivery system and water control structures, 3–18 acres of lowland could be converted to rotational managed wetlands which would provide for threatened and endangered waterbird nesting, foraging, brooding, loafing, and thermal/escape cover.

A properly managed livestock grazing program could also be used to achieve these habitat and wildlife objectives. When conducted under a SUP and CAA, livestock grazing by a non-Refuge party would be a cost-effective management technique to achieve desired results. As proposed, this would be an experimental program, and incorporate monitoring and adaptive management. Stipulations would reduce potential adverse effects and enhance beneficial effects.

In order to be allowed on the Refuge, grazing would need to be determined compatible. By allowing the use to occur under the stipulations described above, it is anticipated that wildlife disturbance would be minimized, and wildlife disturbed by this use would find sufficient food resources and resting places so their abundance and use would not be measurably lessened on the Refuge. Additionally, it is anticipated that monitoring, as needed, would prevent unacceptable or irreversible impacts to fish, wildlife, plants, and their habitats; cultural resources; and public use. For the several reasons stated above, cooperative grazing, consistent with the stipulations described herein, would not materially interfere with or detract from maintenance of the Refuge’s biological integrity, diversity, and environmental health; fulfillment of the Hanalei NWR’s purpose; or the Refuge System mission.

B.2.9 MANDATORY RE-EVALUATION DATE:

__________ Mandatory 15-year re-evaluation date (for wildlife-dependent public uses)

____X____ Mandatory 10-year re-evaluation date (for all uses other than wildlife-dependent public uses)

B.2.10 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

This compatibility determination has been developed and issued concurrently with the dWMWCP and EA for Hanalei NWR.

B.2.11 COMPATIBILITY DETERMINATION: COOPERATIVE GRAZING

REFUGE DETERMINATION:

Refuge Manager,
Hanalei National
Wildlife Refuge: ______________________________ ____________
(Signature) (Date)

CONCURRENCE:

Regional Chief,
National Wildlife Refuge
System, Pacific Region: ______________________________ ____________
(Signature) (Date)

B.2.12 REFERENCES CITED

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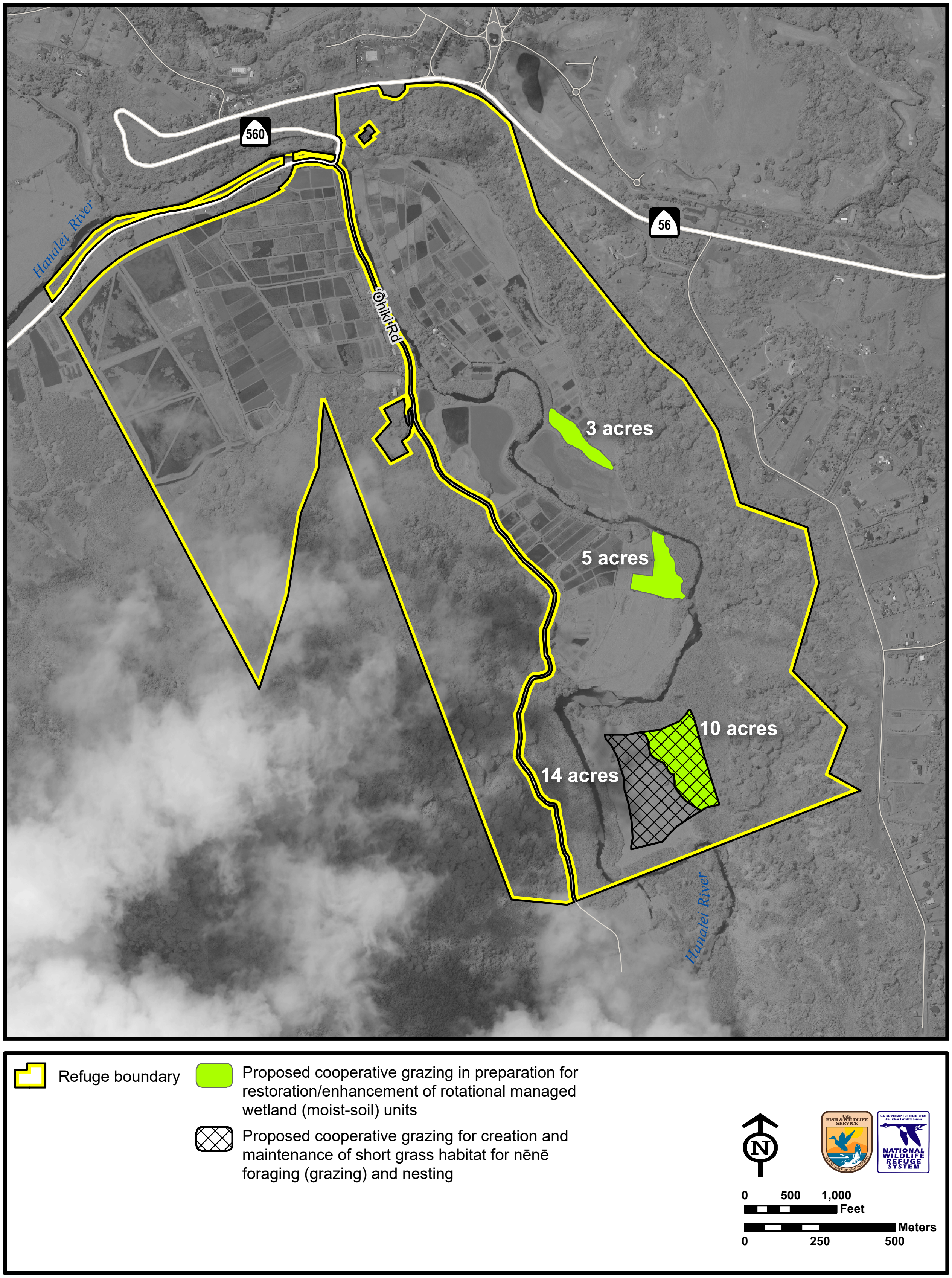
USFWS. 2004. *Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose (Branta Sandvicensis)*. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service. https://ecos.fws.gov/docs/recovery_plan/040924a.pdf.

Figure B-6. Proposed cooperative grazing areas, Hanalei NWR



Map Date: 7/1/2019 File: 11-102-1_grazing.mxd
Data Source: USFWS 2019; Imagery from DigitalGlobe 6/3/2019

USFWS R1 Refuge Inventory and Monitoring Branch

B.3 DRAFT COMPATIBILITY DETERMINATION - USE: RESEARCH AND SCIENTIFIC COLLECTIONS

REFUGE NAME: HANALEI NATIONAL WILDLIFE REFUGE, COUNTY OF KAUAʻI, HAWAIʻI

ESTABLISHING AND ACQUISITION AUTHORITY(IES):

Endangered Species Act of 1973, as amended (16 United States Code [U.S.C.] 1531–1544)

REFUGE PURPOSE(S):

"… to conserve (A) fish or wildlife which are listed as endangered species or threatened species…or (B) plants…" (ESA; Endangered Species Act of 1973)

NATIONAL WILDLIFE REFUGE SYSTEM (REFUGE SYSTEM OR NWRS) MISSION:

"The mission of the [National Wildlife 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 [Refuge Administration Act], as amended) (16 U.S.C. 668dd–668ee).

B.3.1 DESCRIPTION OF USE(S)

This use involves research and scientific collections conducted by non-National Wildlife Refuge System (Refuge System) parties on Hanalei National Wildlife Refuge (NWR or Refuge).

Research refers to a planned, organized, and systematic investigation of a scientific nature. Such studies are designed to determine the cause(s) of observed biotic or abiotic phenomenon over a finite time period, where cause and effect relationships usually can be inferred through statistical analyses.

Scientific collecting involves gathering of Refuge natural resources or cultural artifacts for scientific purposes. Examples include collection of vegetation, small mammals, and soils; contaminant sampling; and collection and curation of cultural resources.

Refuge staff periodically receive requests from outside parties (e.g., universities, state agencies, other federal agencies, and nongovernmental organizations) to conduct research and scientific collections on Refuge lands. These project requests can involve a wide range of natural and cultural resources as well as public use management issues, including collection of new species for identification, habitat use and life history requirements for specific species and species groups, practical methods for habitat restoration, extent and severity of environmental contaminants, techniques to control or eradicate pest species, effects of climate change on environmental conditions and associated habitat and wildlife response, modeling of wildlife populations, bioprospecting, and assessing response of habitat and wildlife to disturbance from public uses. Projects may be species-specific, Refuge-specific, or evaluate the relative contribution of Refuge lands to larger landscape (ecoregion, region, flyway, national, and international) issues and trends.

The U.S. Fish and Wildlife Service's (USFWS' or Service's) Research and Management Studies (4 Refuge Manual [RM] 6) and Appropriate Refuge Uses (603 U.S. Fish and Wildlife Service Manual

[FW] 1) policies indicate priority for scientific investigatory studies that contribute 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 needs for resource management goals and objectives, where applicable, would be given a higher priority over other requests. Attached to this compatibility determination (CD) are examples of high-priority research and scientific collection topics for Hanalei NWR (see attached).

Research and scientific collections on the Refuge would generally be authorized through individual special use permits (SUPs) consistent with Service policy (Administration of Specialized Uses, 5 RM 17).

Projects that represent public or private economic use of the natural resources of the Refuge would need to comply with relevant Federal regulations for such uses (50 Code of Federal Regulations [CFR] 29.1). In such cases, the Refuge would need to first determine that the use contributes to the achievement of Refuge purposes or the Refuge System mission prior to making a determination regarding the project's compatibility.

This CD has been developed and made publicly available concurrent with the draft Wetlands Management and Waterbird Conservation Plan (dWMWCP) and associated environmental assessment (EA) for Hanalei NWR. Much of the information and some of the analyses contained in this CD are addressed in greater detail in the dWMWCP and EA, which are incorporated by reference herein.

AVAILABILITY OF RESOURCES

Refuge staff responsibilities for research and scientific collections by non-Refuge System entities are primarily limited to the following: review of proposals, preparation of an SUP(s) and other appropriate compliance documents (pursuant to the National Environmental Policy Act (NEPA), ESA, National Historic Preservation Act, etc.), and monitoring project implementation to ensure that impacts and conflicts remain within acceptable levels (remain compatible) over time. Additional administrative, logistical, and operational support could also be provided depending on each specific request. Estimated costs for one-time and annually recurring tasks by Refuge staff would be determined on a project-by-project basis. Sufficient funding in the Refuge's general operating budget would need to be available to cover expenses for these projects. The terms and conditions for funding and staff support necessary to administer each project on the Refuge would be clearly stated in the SUP(s).

The Refuge has the following staffing and funding to administratively support and monitor research and scientific collections that are currently taking place on Hanalei NWR (see table below). Any substantial increase in the number of projects would create a need for additional resources to satisfy administrative and monitoring needs to ensure the projects were implemented in a compatible manner. Any substantial additional costs above those itemized below could result in determining a project not compatible unless expenses were offset by the investigator, sponsoring organization, or other party. Table B-4 summarizes annual costs.

TABLE B-4. ESTIMATE OF ANNUAL COSTS FOR ADMINISTERING RESEARCH AND SCIENTIFIC COLLECTIONS

Tasks	*Estimated Costs per Year*[1]
1. Permit/agreement administration and oversight by GS-12 refuge deputy project leader (1%) and GL-09 law enforcement officer (1%)	$1,970
2. Permit/agreement monitoring by GS-11 biologist (3%)	$2,884
3. Supplies, equipment, and travel	$1,000
4. Refuge overhead costs associated with the above-listed work[2]	$1,699
Total Costs	**$6,554**

[1] Annual personnel costs = 2019 step 5 salary for appropriate GS or GL level (including locality payment of 18.43%) x 35% for benefits. For WG, 2019 step 3 hourly rate x 35% for benefits.
[2] Overhead costs (management capability) = salary + benefit costs x 0.35. Overhead expenses include building rent, utilities, equipment and supplies, and support personnel, and do not include salary-related benefits.

B.3.2 ANTICIPATED IMPACTS OF THE USE(S)

Use of the Refuge to conduct research or scientific collecting would generally provide information of benefit to native fish, wildlife, plants, and their habitats or cultural resources. Scientific findings gained through these projects could provide important information regarding life history needs of species and species groups, as well as identify or refine management actions to achieve natural or cultural resource management objectives. Reducing uncertainty regarding wildlife and habitat responses to Refuge management actions undertaken in order to achieve desired outcomes (objectives) is essential for adaptive management (522 Department Manual [DM] 1).

Potentially, some project's methods could impact or conflict with Refuge-specific natural or cultural resources, priority wildlife-dependent public uses, other research, or Refuge management programs. In such cases, in order for the project to be determined compatible, it would need to be clearly demonstrated that the project's scientific findings would contribute to Refuge management and that the project could not be conducted off-Refuge. The investigator(s) would need to identify methods/strategies in advance to eliminate or minimize potential impacts and conflicts. If unacceptable impacts, including long-term and cumulative impacts, could not be avoided, then the project could not be determined compatible.

REFUGE GOALS AND NWRS MISSION

It is likely that most proposed research or scientific collection projects would support one or more of the Refuge goals, but each would need to be evaluated separately. Projects that were determined supportive of Refuge goals and the Refuge System mission would have a greater chance of being found appropriate, determined compatible, and authorized for implementation.

FISH, WILDLIFE, PLANTS, AND THEIR HABITATS

Impacts would be project- and site-specific and would vary depending upon the nature and scope of the fieldwork. Data collection techniques would generally have no or minimal 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 would at least have short-term, localized impacts.

As noted earlier, the purpose of the Refuge is to benefit species listed under the ESA. At Hanalei NWR, the management focus is supporting the recovery of five federally-listed Hawaiian waterbirds: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*); endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*); and threatened nēnē (Hawaiian goose, *Branta sandvicensis*).

Disturbance would likely be one of the greatest wildlife effects caused by research and scientific collections. Disturbance would be possible where users penetrate the interior of the Refuge, particularly near rotational managed wetland (moist-soil) units that are in greatest use by federally-listed Hawaiian waterbirds. During nonbreeding periods, nēnē, ae‘o, and ‘alae ke‘oke‘o appear to be fairly tolerant of disturbance. However, when birds are breeding or in heavy molt, they are all more vulnerable to disturbance. Koloa maoli and ‘alae‘ula are very wary and often flush or move quickly into dense cover when disturbed (Gutscher-Chutz 2011). Flushing of birds or even raising their alert levels creates stress and requires animals to expend energy that would otherwise be invested in essential life history activities such as foraging, mating, nesting, brood-rearing, and predator avoidance. Disturbance can cause nest desertion; affect survival of individual birds, eggs, nestlings, or broods; and alter behavior of nonbreeding waterbirds.

Trulio (2005) reviewed numerous studies of the effects of recreational and other human uses on wildlife, especially waterbirds. Reviewed studies found that research can have a number of adverse effects on wildlife and can contribute to nest abandonment, increased depredation, reduction of nests near disturbed areas, lower productivity, and increased flight. These findings are consistent with studies at a seabird colony on the lower Columbia River where land-based researchers flushed large numbers of California brown pelicans (Wright et al. 2007).

Field research could also cause trampling of native plants, erosion, and introduction or spread of exotic species, including invertebrates, plants, and pest species. All of these impacts could adversely affect native fish, wildlife, plants, and their habitats.

Spread of nonnative and/or pest plants, invertebrates, and/or pathogens is possible from ground disturbance and/or transportation of project equipment and personnel. These effects would be minimized or eliminated by requiring proper cleaning of investigator equipment and clothing as well as quarantine methods and possibly restoration or mitigation plans, where appropriate (see attached).

There also could be localized and temporary effects from vegetation trampling, erosion, collecting of soil and plant samples, or trapping and handling of fish and wildlife. Impacts could also occur from infrastructure necessary to support a project (e.g., permanent transects or plot markers, exclosure devices).

All of these impacts could adversely affect native fish, wildlife, plants, and their habitats. Individual circumstances associated with specific studies would determine the degree of actual effects upon reproduction, survival of individuals, and diversity and abundance of native species (community health).

PUBLIC USE

Authorizing research or scientific collections would be expected to negligibly impact wildlife-dependent or other public uses. Permittees conducting commercial tour operations and participants in special Refuge events would be advised of any active research or scientific collections on the Refuge, and, as appropriate, warned to avoid areas under study and markers or other equipment used for study.

CULTURAL RESOURCES

Hanalei NWR is rich in pre-contact and historic resources. To the extent that the ground surface or existing structures are disturbed, research and scientific collections have the potential to affect cultural resources. The stipulations require that researchers are provided with clear maps depicting access points and use areas, and include prohibitions related to cultural resources. These provisions would greatly reduce the likelihood of impacts occurring and would reduce the degree of effect if they did occur.

B.3.3 PUBLIC REVIEW AND COMMENT

Public availability of this CD has been widely announced together with the announcement of the availability of the Refuge's dWMWCP and associated EA. The review and comment period were concurrent with the dWMWCP and EA.

B.3.4 DETERMINATION

__________ Use is Not Compatible

____X____ Use is Compatible with Following Stipulations

B.3.5 STIPULATIONS NECESSARY TO ENSURE COMPATIBILITY

GENERAL

1. Permission to use the Refuge for research or scientific collections will be officially authorized through a SUP. Generally, a permit would be issued on a year-to-year basis. SUPs cover use by a specified individual or organization and cannot be assigned or sub-permitted to others (i.e., the permit is not transferable). Annual or other short-term SUPs are preferred; however, some permits may be longer, if needed, to allow completion of the project. All SUPs will have a definite termination date in accordance with 5 RM 17.11. 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. For the purpose of these stipulations, the Refuge manager is the Refuge Project Leader of the Kaua'i National Wildlife Refuge Complex.

   Prior to potential SUP renewal, Refuge staff will meet with researchers to share new information, discuss results of monitoring, review compliance with SUP conditions, and address other issues. Other meetings may be scheduled as needed.
2. The SUP will include maps clearly depicting the areas that researchers are authorized to access and use, including the Refuge entry point(s). Travel within the Refuge is by designated road, dike, or trail. Permittees are prohibited from straying outside the areas depicted on the maps.
3. The Refuge will supply researchers with information about the Refuge; its purpose and goals; natural and cultural resources of concern; open and closed areas; rules and regulations; and any hazardous conditions. Researchers are responsible for reviewing and understanding this

information and ensuring that their colleagues also receive, review, and understand this information.

4. Researchers are prohibited from constructing new or maintaining existing structures on the Refuge without specific, prior written approval of the Refuge manager.
5. Unless it was an element included in their approved project proposal, researchers and their colleagues are prohibited from collecting and removing any archaeological or historic artifacts, abiotic or biological specimens or samples, or mementos from the Refuge.
6. Consistent with Service policy regarding management of nonhazardous solid waste on refuges (Resource Conservation and Recovery Act of 1976 [RCRA], as amended (42 U.S.C. 6901–6992k)—Solid Waste (Nonhazardous); 50 CFR 27.93, Abandonment of Property; 50 CFR 27.94, Disposal of Waste; and 561 FW 5, Managing, Recycling, and Disposing of Non-Hazardous Solid Waste), permittees are prohibited from dumping or disposing of refuse/trash, debris, litter, or abandoned, excess, or unused materials, building materials, and supplies on the Refuge, including permit areas.
7. Researchers are required to hold the United States Government harmless from any damages or injury to the permittee or members of the public in areas and facilities accessed via the terms of their SUP.
8. In addition to the stipulations listed here, the general SUP conditions and requirements, and the special SUP conditions, researchers and their colleagues are required to comply with Refuge System-related and other applicable laws, regulations, and policies including "Prohibited Acts" listed in 50 CFR 27.
9. No changes can be made to any of these stipulations without specific, prior written approval of the Refuge manager.

RESEARCH AND SCIENTIFIC COLLECTIONS

1. The Refuge will periodically issue a call for research proposals. Proposals received by the stated deadline will be evaluated and considered for approval during the next cycle.
2. At least six months before initiation of fieldwork, a researcher(s) is required to submit a detailed proposal (see attached format). Among other things, proposals must adhere to scientifically defensible protocols for data collection, where available and applicable.

   Project proposals are reviewed by Refuge staff and others, as needed. This review will assess—relative to Refuge management issues and understanding of natural systems—the potential impacts (short-term, long-term, and cumulative) relative to the benefits of the investigation. This assessment will form the primary basis for determining whether or not the project could be approved.
3. Researchers are required to submit progress reports at least annually for multiple-year projects. A list of the minimum required elements for these reports is attached. Final project reports are due 1 year after completion of the project unless negotiated otherwise with the Refuge manager. Researchers are required to provide Refuge staff with the following:
   a. An opportunity to review and comment on draft manuscripts prior to their submittal to a scientific journal for consideration for publication;
   b. Copies (reprints) of all publications resulting from a project permitted on the Refuge; and
   c. At the conclusion of the project, raw data (preferably in an electronic database format).

   In all written and oral presentations resulting from projects on the Refuge, researchers are required to appropriately cite and acknowledge the Refuge System, Hanalei NWR, and Refuge staff and other Service personnel who supported or contributed to the project.

Upon completion of the project or annually, the researcher is required to remove all equipment and physical markers (unless required for long-term projects) and restore sites to the Refuge manager's satisfaction. The SUP would specify conditions for removal and clean up.

4. Researchers must obtain all required local, state, and federal permits for collections and other purposes.
5. A Section 7 consultation under the ESA is required for all project activities that may affect a federally listed species and/or critical habitat. Only projects which would have "no effect" or would result in a" not likely to adversely affect" determination are considered for potential approval.
6. To reduce impacts, the minimum number of samples (e.g., water, soils, vegetative litter, plants, macroinvertebrates, vertebrates, and artifacts) will be collected for identification and/or experimentation and statistical analysis.

   Where possible, researchers will be required to coordinate and share collections. This may reduce sampling needed for multiple projects and any associated mortality and disturbance. For example, if one investigator collected fish for a diet study and another researcher was examining otoliths, then it could be possible to accomplish sampling for both projects with one collection effort.

   All samples collected on Refuge lands and waters are the property of the Service even while in the possession of the researcher. Any future work with previously collected samples not clearly identified in the project proposal will require submission of a subsequent proposal for Refuge review and approval. In addition, a new SUP is required for additional project work. For samples or specimens to be stored at other facilities, such as museums, a memorandum of understanding is necessary (see attached).
7. To minimize the introduction and spread of pests, sampling equipment as well as researchers' clothing and vehicles (e.g., all-terrain vehicles, boats) must be thoroughly cleaned (free of dirt and plant material) before being used on the Refuge. Depending on the project, quarantine methods may be necessary (see attached).
8. Researchers are required to secure approval from the Service prior to use of any pesticides, including uses of herbicides, fungicides, and insecticides, on the Refuge. Researchers must submit a completed Pesticide Use Proposal (PUP) for each proposed pesticide use to the Refuge manager. The PUP must be submitted at least 60 days prior to proposed use of the pesticide to allow adequate time for evaluation and processing.
9. At any time, Refuge staff may accompany researchers in the field.
10. Researchers are required to report dead or sick threatened and endangered Hawaiian waterbirds or other wildlife to Refuge staff within 24 hours of discovery.

CULTURAL RESOURCES

1. In the absence of specific, prior written approval of the Refuge manager, researchers and their colleagues are prohibited from disturbing or otherwise adversely impacting any pre-contact, historic, or other cultural resources on the Refuge. In the event such resources are inadvertently disturbed in the course of conducting otherwise permitted activities, the disturbing activity must be immediately discontinued, and the Refuge manager must be notified within 24 hours. If iwi (skeletal human remains) are encountered, the activity must

be immediately stopped and the Refuge manager, police, and Hawaiʻi Department of Land and Natural Resources must be notified.

2. Collecting and removing any pre-contact or historic artifacts is prohibited.

B.3.6 JUSTIFICATION

Suitable research and scientific collections on refuges are inherently valuable to the Service when they expand scientific information available for resource management decisions about fish, wildlife, plants, and their habitats; cultural resources; and/or public use. In many cases, if it were not for the Refuge staff providing access to Refuge lands and waters along with some support, the project would never occur, and less scientific information would be available to aid the Service in managing and conserving Refuge resources.

The Refuge would monitor compliance with the stipulations enumerated herein. Violation of any of these stipulations could result in temporary or permanent withdrawal by appropriate Refuge personnel of official permission to continue research or scientific collections on the Refuge. Permits could be revoked by the Refuge manager with 30 days' written notice of noncompliance with these stipulations.

The Refuge would also monitor habitat quantity and quality, wildlife use and productivity, water quality, cultural resources, and other relevant endpoints to determine if stipulations associated with research and scientific collections result in expected and desirable outcomes. In consultation with researchers, the Refuge would apply adaptive management principles to modify stipulations or adjust objectives, as necessary, to achieve desirable results.

The Refuge reserves the right to add to or otherwise modify the stipulations listed herein in order to ensure the continued compatibility of this use. New or modified stipulations would be instituted as a result of ongoing or new studies; new legal, regulatory, or policy requirements; significant changes to the Refuge environment or status of native fish, wildlife, plants, or their habitats; as a result of mutual agreement with researchers; or for other legitimate reason. Researchers would be advised of new or significantly modified stipulations at least 90 days prior to their becoming effective.

The Refuge also reserves the right to terminate permission for these uses if permittees violate Refuge rules or regulations; if unacceptable impacts occur to native fish, wildlife, plants, or their habitats, cultural resources or Refuge facilities, or other Refuge visitors; or for other legitimate reasons.

By allowing the use to occur under the stipulations described above, it is anticipated that wildlife which could be disturbed by this use would find sufficient food resources and resting places so their abundance and use would not be measurably lessened on the Refuge. Additionally, it is anticipated that monitoring, as needed, would prevent unacceptable or irreversible impacts to fish, wildlife, plants, and their habitats; cultural resources; and public use. Where this was not the case, the proposed project would likely not be compatible and would not be authorized for implementation. As a result, potential research and scientific collections, consistent with the stipulations described herein, would not materially interfere with or detract from maintenance of the Refuge's biological integrity, diversity, and environmental health; fulfillment of Hanalei NWR's purpose; or the Refuge System mission.

B.3.7 MANDATORY RE-EVALUATION DATE:

__________ Mandatory 15-year re-evaluation date (for wildlife-dependent public uses)

____X____ Mandatory 10-year re-evaluation date (for all uses other than wildlife-dependent public uses)

B.3.8 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

This compatibility determination has been developed and issued concurrently with the WMWCP and EA for Hanalei NWR.

B.3.9 COMPATIBILITY DETERMINATION: RESEARCH AND SCIENTIFIC COLLECTIONS

REFUGE DETERMINATION:

Refuge Manager,
Hanalei National
Wildlife Refuge: ______________________________ ____________
(Signature) (Date)

CONCURRENCE:

Regional Chief,
National Wildlife Refuge
System, Pacific Region: ______________________________ ____________
(Signature) (Date)

B.3.10 REFERENCES CITED

Gutscher-Chutz, J.L. 2011. Relationships Among Aquatic Macroinvertebrates, Endangered Waterbirds, and Macrophytes in Taro Lo‘i at Hanalei National Wildlife Refuge, Kaua‘i, Hawai‘i. Master’s Thesis. South Dakota State University, SD. http://openprairie.sdstate.edu/etd/448

Trulio, L. 2005. Understanding the Effects of Public Access and Recreation on Wildlife and their Habitats in the Restoration Project Area. San Jose State University, Department of Environmental Studies, CA.

Wright, S.K., D.D. Roby, and R.G. Anthony. 2007. Responses of California Brown Pelicans to Disturbances at a Large Oregon Roost. Waterbirds 30(4): 479-487.

B.3.11 HIGH-PRIORITY RESEARCH AND SCIENTIFIC COLLECTIONS

The following are examples of high-priority research and scientific collection topics for Hanalei NWR. They are not listed in priority order.

- Evaluate methods to control hybridization threats to koloa maoli; support completion of hybrid identification keys within 1 year.
- Identify factors most limiting koloa maoli population recovery.
- Develop survey methods to reliably estimate koloa maoli population size; refine methods for other threatened and endangered waterbirds.
- Investigate how habitat types influence ‘alae ‘ula reproductive success and ecology, including identification of factors limiting population size.
- Investigate methods to control pest fish that degrade habitat quality.
- Work with partners to investigate status and distribution of ‘ōpe‘ape‘a; identify management priorities.
- Develop water budget and conduct efficiency study.
- Conduct on-Refuge contaminant investigations relevant to threatened and endangered waterbirds.
- Investigate pest aquatic vertebrate ecology (e.g., bullfrogs, tilapia) to develop life-cycle specific control methods.
- Investigate methods to effectively control and monitor nonnative vertebrate pests that prey on threatened and endangered waterbirds.
- Identify primary predators for each life stage of the threatened and endangered waterbirds.
- Investigate the relative importance of causes of mortality for threatened and endangered waterbirds.
- Describe phenology and other life history characteristics of important wetland plants and invertebrates relative to abiotic factors.
- Investigate threatened and endangered waterbird daily and seasonal movements.
- Conduct pollen core studies to assess historical vegetation composition.
- Work with partners to conduct stream assessments.
- Conduct assessment of dike size and integrity as part of maintenance to ensure wetland management is supported sufficiently; rehabilitate, as necessary.
- Work with partners to investigate designs for ‘o‘opu-friendly river outlets to prevent ‘o‘opu entrapment in lo‘i and impoundments during river migrations.
- Conduct hydrogeomorphic investigations relevant to restoration of watershed processes and functions.

- Investigate abiotic/biotic conditions of specific lo‘i kalo with avian botulism occurrence; identify management measures.
- Determine effect of nest buffer size and cover in harvested lo‘i kalo on waterbird nest and brood success within three years.
- Support additional research to set measurable and attainable milestones for nutrient load reductions in Hanalei River.
- Determine nutrient and sediment levels in water released from Refuge wetlands and lo‘i kalo into the Hanalei River.
- Investigate efficient methods for nutrient removal and sediment control (e.g., sediment traps on major drains, floating racks of plants).
- Evaluate costs and benefits of longer wet and dry fallow periods to threatened and endangered waterbirds and kalo farming.

Format for Proposals to Conduct Research or Long-Term Monitoring on National Wildlife Refuges

A Special Use Permit (SUP) is required to conduct research and/or long-term monitoring on refuge lands. To receive a SUP, a detailed project proposal using the following format must be submitted to the Refuge manager approximately six months prior to the start of the project.

Title:

Principal Investigator(s):

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 or attach vitae 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 resource management issue and/or knowledge gap regarding ecological function that currently exists with any available background information.
- Benefit of project findings to resources associated with refuge.
- Potential consequences if the conservation issue and/or knowledge gap regarding ecological function is not addressed.

Objectives:

Provide detailed objective(s) for the proposed project.

Methods and Materials:

Provide a detailed description of the methods and materials associated with field and laboratory work (if applicable) to be conducted for the project. Methods should include the following:

- study area(s);
- number of samples;
- sampling dates and locations;
- sampling techniques; and
- data analyses including **statistical methods** 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, boats, 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 or Territorial and Federal permits required if applicable.

Potential Impacts to Refuge Resources:

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. Consider the cumulative impacts associated with this project.

Animal Welfare Plan:

If appropriate, attach a copy of the Institutional Animal Care and Use review and/or animal welfare plans that are required by the principle investigator's affiliation.

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 project is divided into phases to be accomplished separately provide separate 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 of the final report/manuscript. Draft reports/manuscripts should 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 also requires raw data for management and planning purposes for the Refuge.

Publications:

Describe the ultimate disposition of study results as publications in scientific journals, presentation at professional symposiums, or final reports.

Disposition of Samples:

If the project entails the collection of biotic and/or abiotic samples, then describe their storage. Although the samples may be in the possession of scientists for the purposes of conducting the project in accordance with the SUP, the Service 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, a new proposal must be submitted to the Refuge manager to obtain a SUP 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. If specimens will be curated at a museum, then prepare a MOU using the format provided in Attachment 3.

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:

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 witnesseth 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

ALIEN SPECIES QUARANTINE RESTRICTIONS
FOR NATIONAL WILDLIFE REFUGES

A. Introduction

Thank you for your interest in conducting research/monitoring on the refuge(s). To protect wildlife and habitat communities found on the refuge, visitation is carefully regulated and requires that each individual or group secure a Special Use Permit (SUP) to gain access to the refuge. Each SUP clearly outlines the responsibilities of each permittee, including specific quarantine policies, which may be more detailed than the policies listed within this document. Details for securing a SUP can be found by contacting the refuge manager. Prospective scientific researchers must apply for the SUP at least six months prior to their proposed study period.

One of the gravest threats to the refuge(s) is the introduction of alien plant and animal species. The practices described below are complex, but the Service has found them to be effective at greatly reducing additional introductions of invasive species on refuge(s).

B. Definitions

1. **Clothing** - all apparel, including shoes, socks, over and under garments.
2. **Soft gear** - all gear such as books, office supplies, daypacks, fannypacks, packing foam or similar material, camera bags, camera/binocular straps, microphone covers, nets, holding or weighing bags, bedding, tents, luggage, or any fabric or material capable of harboring seeds or insects.
3. **New Clothing/Soft Gear** - new retail items, recently purchased and never used.
4. **Refuge Dedicated Clothing/Soft Gear** - items that have ONLY been used at the
5. refuge(s), and which have been stored in a quarantined environment between trips to the refuge(s).
6. **Sensitive Gear** - computers, optical equipment, and other sensitive equipment.
7. **Non-Sensitive Equipment and Construction Materials** - building materials, power and hand tools, generators, misc. machinery, etc.
8. **Suitable Plastic Packing Container** - packing containers must be constructed of smooth, durable plastic which can be easily cleaned and will not harbor seeds or insects. Packing containers may be re-used for multiple trips to the refuge(s) but must be thoroughly cleaned before each trip and strictly dedicated to refuge-related projects.

a. Examples of APPROPRIATE plastic packing containers are five gallon plastic buckets and plastic totes constructed with a single layer and having a smooth surface. All appropriate packing containers must have tight-fitting plastic lids.

b. An example of an INAPPROPRIATE plastic packing container is U.S. mail totes. Mail totes are typically constructed of cardboard-like plastic that provides a porous, multi-layered surface, allowing seeds and insects to easily hitch-hike.

C. Special Use Permit (SUP)

All persons requesting use of the refuge(s) must secure a SUP, as described in Section A above, and agree to comply with all refuge requirements to minimize the risk of alien species introductions.

D. Quarantine Inspections

All personal gear, supplies, equipment, machinery, vehicles (e.g., ATVs, trucks, trailers), and vessels (e.g., planes, boats, ships, barges) will be inspected for quarantine compliance by Service staff prior to entering the refuge(s) and again before departing the refuge(s). A concerted effort will be made to ensure that alien pests are not transported. Service staff on the refuge(s) will inspect outbound cargo prior to transport.

E. Prohibited Items (Transport of the following items are strictly prohibited)

1. Rooted plants, cuttings, flowers, and seeds (raw or propagative).
2. Soil, sand, gravel, or any other material that may harbor unwanted plant and animal species.
3. Animals (no exceptions).
4. Cardboard (paper and plastic cardboard harbors seeds and insects).

F. Regulated Items (Transport of the following items are strictly regulated)

1. Food items have the potential to carry alien pests and are therefore selected, packed, and shipped with great care for consumption on the refuge(s). Foods will not be allowed on the refuge(s) without prior authorization.
2. Because wood products often harbor seeds and insects, only treated wood that has been painted or varnished may be allowed on the refuge(s). Approved wood products must also be frozen for 48 hours or fumigated as described in Section K below.

G. Packing Procedures

Ensure that the environment selected for packing has been well cleaned and free of seeds and insects. Keep packing containers closed as much as possible throughout the packing process so insects cannot crawl in before the containers have been securely closed. Quarantine procedures should be performed as close to the transportation date as possible to ensure that pests do not return as hitch-hikers on the packing containers.

H. Packing Containers

1. All supplies and gear must be packed and shipped in SUITABLE PLASTIC PACKING CONTAINERS (see Section A for definitions of packing containers). Packing containers must be constructed of smooth, durable plastic that has been thoroughly cleaned prior to use.
2. Packing containers may be re-used for multiple trips to the refuge(s) but must be thoroughly cleaned before each trip and strictly dedicated to refuge-related projects. Cardboard containers are strictly prohibited because they can harbor seeds and insects.

I. Clothing and Soft Gear

1. All persons entering the refuge(s) must have NEW or REFUGE DEDICATED clothing and soft gear (including all footwear).
    a. Freeze all clothing and soft gear for 48 hours (including both new and refuge dedicated).
    b. Fumigation under a tarp or in a large container is also an option.

J. Sensitive Equipment

All sensitive gear (e.g., optical equipment, computers, satellite phones, other electronic equipment) must be thoroughly inspected and cleaned.

K. Non-Sensitive Equipment and Construction Materials

1. All nonsensitive equipment, machinery, and construction materials that are water resistant must be steam cleaned or pressure washed to ensure the removal of all dirt, insects, and seeds from external surfaces.
2. All non-water resistant items must be tented and fumigated to kill unwanted pests or frozen for 48 hours.
3. Quarantine procedures should be performed as close to the transportation date as possible to ensure that pests do not return to the equipment or packing containers.

APPENDIX C. MANAGEMENT OF ROTATIONAL MANAGED WETLAND (MOIST-SOIL) UNITS

APPENDIX C. MANAGEMENT OF ROTATIONAL MANAGED WETLAND (MOIST-SOIL) UNITS

Given the substantially altered 'natural' conditions throughout the Main Hawaiian Islands that exist in the 21st century, wetland units require intensive management to meet the life history requirements of threatened and endangered Hawaiian waterbirds. The U.S. Fish and Wildlife (USFWS or Service) employs a technique known as moist-soil management which involves the use of seasonal water drawdowns with periodic soil disturbance (e.g., disking, rototilling) within wetland units to attempt to simulate the dynamics of seasonally flooded natural wetlands (e.g., flood events and precipitation/drying cycles). Moist-soil management oxidizes wetland bottoms and incorporates plant material into the soil increasing its fertility and producing an abundance and diversity of aquatic invertebrates as well as creates a seed bed for germination of native/naturalized wetland plants. Annual plants resulting from moist-soil management produce an abundance of seeds that are readily available and consumed by waterbirds. The energy available from these seeds is often as high as or higher than agricultural crops. As moist-soil annuals decompose, they provide substrate and forage for aquatic invertebrates which are also an important food resource for waterbirds, particularly young waterbirds and pre-laying hens.

To provide the reader with additional background information concerning Hanalei National Wildlife Refuge (NWR or Refuge) management in rotational managed wetland (moist-soil) units, the following sections are provided:

- Brief timeline summary of major management actions to date at Hanalei NWR;
- Before and after photos of areas managed;
- Desired future conditions for rotational managed wetland units; and
- Typical management activities related to wetland unit management and maintenance.

C.1 MANAGEMENT TIMELINE

TABLE C-1. BRIEF MANAGEMENT TIMELINE FOR HANALEI NWR

1972	Refuge established
1983	Irrigation system constructed
1988–1989	Work began on creating three managed wetland ponds (A, B, C ponds)
1993	An additional pond (D) was constructed
1995	The irrigation system was extended on the eastside of Hanalei River
2004	R ponds reverted back to the Refuge for management
2005–2007	Reconfigured existing wetland ponds based on soil textures and extended supply pipelines (western and eastern A, B, C, D ponds) to align with reconfiguration; created K ponds Created independent water control structures to improve individual wetland unit management
2005–2006	Established formal program to control introduced predators
2007	Developed internal draft annual habitat management plan

C.2 BEFORE AND AFTER MANAGEMENT

Before and after management: The wetland areas were overgrown with vegetation and pest species prior to management actions. Post-management actions established wetland management units where active management of soils and ponds create habitat for threatened and endangered Hawaiian waterbirds.

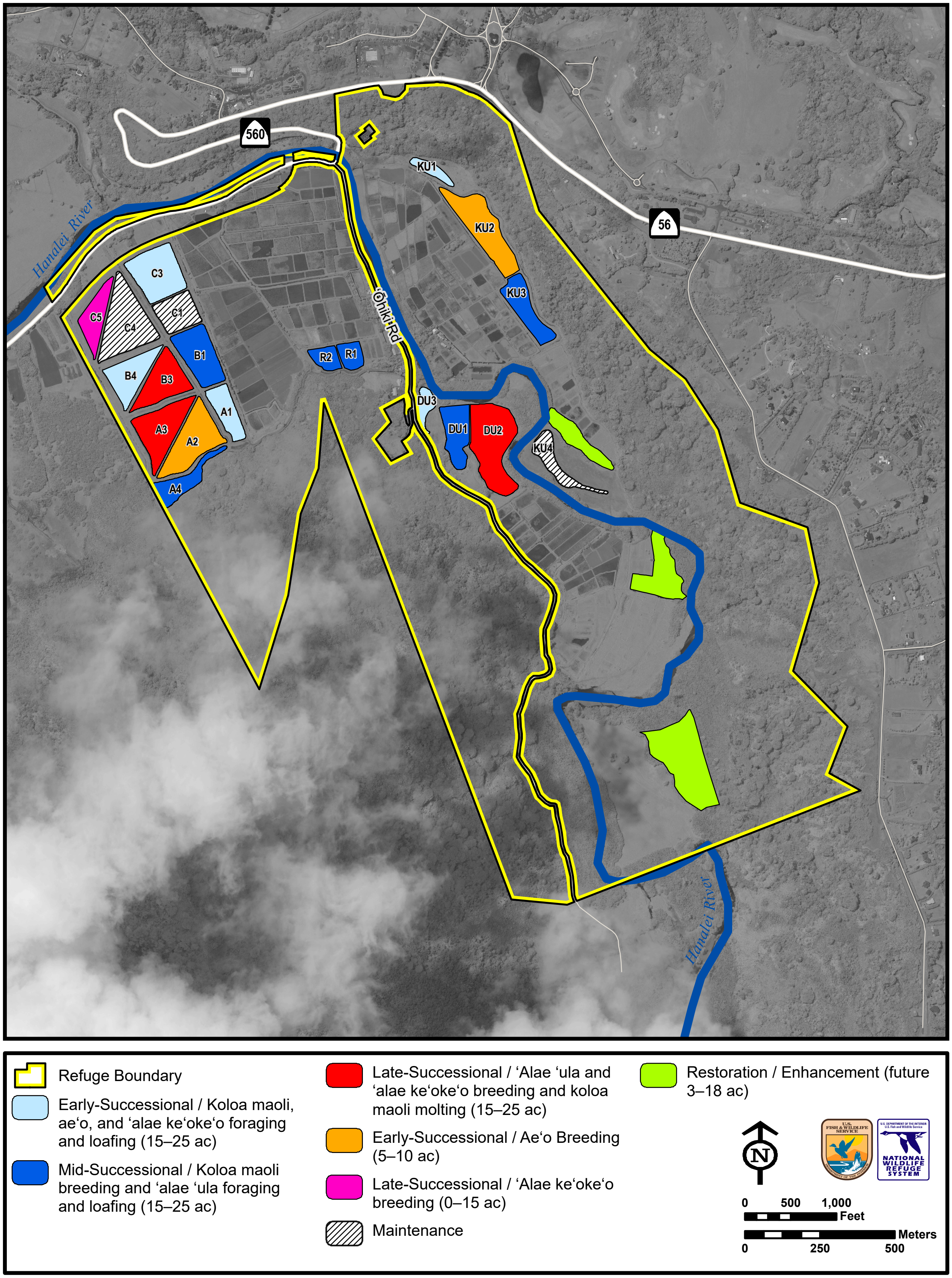
Wetland area before and after management, Hanalei NWR. Photo credit: USFWS

C.3 DESIRED FUTURE CONDITIONS FOR ROTATIONAL MANAGED WETLAND UNITS

Once rotational managed wetland units are established, they require intensive management to meet life history requirements of five federally-listed Hawaiian waterbirds: endangered ae‘o (Hawaiian stilt, *Himantopus mexicanus knudseni*); endangered ‘alae ke‘oke‘o (Hawaiian coot, *Fulica alai*); endangered ‘alae ‘ula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*); endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*); and threatened nēnē (Hawaiian goose, *Branta sandvicensis*). Moist-soil management is the primary way in which this is accomplished as it simulates the dynamics of seasonally flooded wetlands.

Sections C.3.1–C.3.3 describe three successional stages (early, mid, late) for emergent wetlands favored by ducks (e.g., koloa maoli) and rails (e.g., ‘alae ke‘oke‘o, ‘alae ‘ula) within a 18–24 month rotation. Section C.3.4 describes one successional stage (early) for a seasonal playa (e.g., Ni‘ihau ephemeral lakes) or tidal mudflat favored by shorebirds (ae‘o) within a 12–24 month rotation. Section C.3.5 describes a management regime focused on providing wetland conditions specific for the breeding life history of ‘alae ke‘oke‘o in units with coarser textured soils (e.g., C2, C5, DU2). Figure C-1 provides a snapshot illustration of the spatial configuration of rotational wetlands management.

Figure C-1. Example of rotational wetlands management, Hanalei NWR



Map Date: 7/1/2019 File: 11-102-1bc_ex.mxd
Data Source: USFWS 2019; Imagery from DigitalGlobe 6/3/2019
USFWS R1 Refuge Inventory and Monitoring Branch

C.3.1 Early-Successional Managed Wetlands for Koloa Maoli, Ae‘o, and ‘Alae ke‘oke‘o Foraging and Loafing

Guiena

Early-successional managed wetland, Hanalei NWR. Photo credit: USFWS

Attributes:

- Availability on Refuge throughout the year;
- Recently-flooded mosaic of shallow (<8 inches, mostly 3–4 inches), open water and 50–75% cover of short (<12 inches tall), non-persistent emergents (e.g., *Fimbristylis*, *Cyperus*, *Eleocharis*);
- Abundant macroinvertebrates (e.g., damselflies, crayfish, midges) for foraging;
- Minimal human disturbance year-round;
- <5% cover of pest plants (e.g., California grass [*Urochloa mutica*], *Paspalum*, Guinea grass [*Megathyrsus maximus*]);
- No feral mallards (*Anas platyrhynchos*) or their hybrids; and
- Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year cumulatively for rotational managed wetlands.

Description and Rationale:

This habitat is the first of three successional stages (early, mid, late) for emergent wetlands favored by ducks and rails within an 18–24 month rotation. These attributes are modeled after those described under koloa maoli pre-breeding habitat in the internal draft Annual Habitat Management Plan (USFWS 2007), characterized by non-persistent emergent vegetation and abundant macroinvertebrates for breeding hens. A hen has about 24 hours between ovulation and laying and must eat protein equal to what she puts into an egg every day while she is laying (koloa maoli lay 8–10 eggs). For wood ducks (*Aix sponsa*), a species comparable in size to koloa maoli, that means 0.18

ounces (5 grams) protein (dry weight) daily or about 2,400–4,300 individual invertebrates per day (Drobney 1980).

The early successional management regime involves a full treatment or setting the wetland back to mudflat. Prior to this, the unit is dewatered, dried out, and pest plants grubbed or spot-sprayed. Disking to breakup pest plant root systems is followed by tilling for finer breakup of soils and root systems. Pond bottoms are contoured for microtopography and sloughs are created to promote drainage. Prior to draining a unit, sediments and nutrients are allowed to settle to protect water quality in the river while pest and other plants decompose. The water level is gradually drawn down and the unit maintained in a moist soil condition suitable for wetland plant germination. After one to three months, when plant growth is sufficient (~12 inches height), pest plants are spot-sprayed or hand-pulled and the unit is mowed to create a mosaic of open water and vegetation. The unit is gradually inundated and water pulsed at two to four-inch increments for four to six months (Smith 2010).

Although koloa maoli is the primary benefitting species, this stage mimics an annual spring “rebirth” of a wetland and multiple bird species benefit. Initial drawdowns for wetland plant germination provide forage for grazing koloa maoli, nēnē, ‘alae ke‘oke‘o, and ‘alae ‘ula. Open grassy sedgelands also provide protected night roosts for nonbreeding nēnē and migratory shorebirds such as kōlea, and sloughs and shallow pools from freshets in variable topography provide ephemeral sources of invertebrate foods for migratory shorebirds and ae‘o. As water is gradually raised to promote plant growth, habitat becomes available for ae‘o and plants begin to provide escape cover for secretive koloa maoli and seeds for food. As the inundated plant material decomposes, it returns nutrients to the wetland and provides habitat for aquatic organisms important for breeding koloa maoli.

In addition to habitat loss, feral mallards and introduced predators are the two most serious threats to koloa maoli (USFWS 2011). Feral mallards threaten koloa maoli with extinction through hybridization which could lead to loss of koloa maoli as a unique Hawaiian species after only a few generations. The deoxyribonucleic acid (DNA) analysis indicates nonmigratory feral mallards (domesticated mallards that have escaped or been released into the wild) are cross-breeding with endangered koloa maoli (Uyehara, Engilis Jr., and Reynolds 2007; Fowler, Eadie, and Engilis Jr. 2009). Removal of the threat of hybridization is a primary recovery action in the recovery plan (USFWS 2011). Koloa maoli eggs and young are also vulnerable to introduced predators including rats, mongooses, bullfrogs, largemouth bass, dogs, cats, and cattle egrets. Adult koloa maoli are vulnerable to introduced barn owls as well. It is critical to control predators during the breeding season to reduce mortality and increase reproductive success and survival. These management techniques also benefit multiple native species, including endangered ae‘o, ‘alae ke‘oke‘o, and ‘alae ‘ula; threatened nēnē (USFWS 2011); and migratory birds and are important to achieve the Hanalei NWR purpose.

C.3.2 MID-SUCCESSIONAL MANAGED WETLANDS FOR KOLOA MAOLI BREEDING AND ‘ALAE ‘ULA FORAGING AND LOAFING

Mid-successional managed wetland, Hanalei NWR. Photo credit: USFWS

ATTRIBUTES:

- Availability on Refuge throughout the year, particularly from December–May;
- Mosaic of shallow (<8 inches, mostly 3–4 inches), open water with a 50–75% canopy cover of tall (12–60 inches) emergents (e.g., kāmole [*Ludwigia octovalvis*], millet [*Echinochloa crus-galli*], ‘ahu‘awa [sedge, *Cyperus javanicus*]) and 25% understory cover of short (<6 inches tall) non-persistent emergents (e.g., *Fimbristylis*, *Cyperus*, *Eleocharis*);
- Presence of submerged aquatic vegetation (e.g., pondweeds) enhanced by fish exclusion devices;
- Abundant macroinvertebrates (e.g., damselflies, crayfish, midges) for foraging;
- <5% cover of pest plants (e.g., California grass, *Paspalum*, Guinea grass);
- Minimal human disturbance year-round;
- No feral mallards or their hybrids; and
- Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year cumulatively for rotational managed wetlands.

DESCRIPTION AND RATIONALE:

This habitat is the second of three successional stages (early, mid, late) for emergent wetlands favored by ducks and rails within an 18–24 month rotation. These attributes are modeled after those described under koloa maoli brood-rearing habitat in the internal draft Annual Habitat Management Plan (USFWS 2007), characterized by 50–75% emergent vegetation interspersed with open water to provide cover for broods, vegetation structure for abundant macroinvertebrates, and seeds for proper duckling growth and development. The koloa maoli duckling diet has never been studied. However, mallard ducklings eat mainly animal foods for the first 25 days of life (aquatic insects especially chironomids, small crustaceans, and mollusks) spending 65–80% of daylight feeding. After 20–30 days, seeds become more prominent in the mallard duckling diet (Drilling, Titman, and McKinney 2002).

The moist-soil management regime is guided by the Quarterly Management Unit Assessment (QMUA) which monitors vegetation response to habitat manipulations and helps determine if habitat objectives (e.g., plant cover, water depth) are being met. If habitat objectives are not being met, interim treatments may include pulsing water in 2–6 inch increments to break down vegetation, and control (e.g., spot spraying, hand-pulling) pest vegetation, or drawdowns to control pest fish and stimulate plant and invertebrate growth. Slow drawdowns help to maintain nutrients and organic matter in the unit. When pest fish and tadpoles are abundant, slow drawdowns concentrate fish, tadpoles, and invertebrates to allow for more efficient foraging by birds. However, avian botulism is a concern. Therefore, even during drawdowns, water is allowed to flow through the wetland to maintain circulation, and evidence of botulism poisoning is closely monitored during drawdown periods. Drawdowns also aerate substrates allowing nutrients to turnover which stimulates plant and invertebrate production.

Although koloa maoli pairs and broods are the primary beneficiaries, this stage benefits multiple bird species, particularly ‘alae ke‘oke‘o, and ‘alae ‘ula for pre-breeding, nesting, brood-rearing, foraging, and loafing. Ae‘o would continue to forage on aquatic invertebrates in shallow open-water pools. Migratory dabbling ducks have similar habitat requirements to koloa maoli for foraging and loafing; thus, habitat management for koloa maoli would also benefit migratory ducks.

Koloa maoli ducklings are prey for all introduced vertebrate predators including rats, mongooses, bullfrogs, dogs, cats, largemouth bass, and cattle egrets. Apparent cat kills of older ducklings found on dikes suggest older ducklings and fledglings may be vulnerable to cat predation on dikes because these young birds likely spend more time preening and loafing (USFWS, unpublished data). It is critical to control predators during the breeding season to reduce mortality and increase reproductive success and survival. In addition, feral mallards continue to threaten koloa maoli with extinction through hybridization leading to loss of koloa maoli as a unique Hawaiian species. Removal of this threat of hybridization is a primary recovery action in the recovery plan (USFWS 2011). These management techniques also benefit multiple native species, including endangered ae‘o, ‘alae ke‘oke‘o, and ‘alae ‘ula; threatened nēnē (USFWS 2011); and migratory birds and are important to achieve the Hanalei NWR purpose.

C.3.3 Late-Successional Managed Wetlands ‘Alae ‘ula and ‘Alae ke‘oke‘o Breeding and Koloa Maoli Molting

Late-successional managed wetland, Hanalei NWR. Photo credit: USFWS

Attributes:

- Availability on Refuge throughout the year, particularly from March–August;
- Mosaic of open water (3–12 inches deep) with initially a 50–75% cover of tall (>24 inches) robust emergents (e.g., kāmole, nānaku [great bulrush, *Schoenoplectus tabernaemontani*], Manchurian wild rice [*Zizania latifolia*]) declining to 25–50% cover as marsh matures;
- Interspersion with sufficient vegetative edge to provide visual barriers to maximize territories available for breeding;
- Presence of submerged aquatic vegetation (e.g., pondweeds);
- Abundant macroinvertebrates (e.g., damselflies, small mollusks and crustaceans) for foraging;
- Minimal human disturbance during breeding peaks;
- <5% cover of pest plants (e.g., California grass, *Paspalum*, Guinea grass);
- No feral mallards or their hybrids; and
- Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year cumulatively for rotational managed wetlands.

Description and Rationale:

This habitat is the third of three successional stages (early, mid, late) for emergent wetlands favored by ducks and rails within an 18–24 month rotation. These attributes are modeled after those described under ‘alae ‘ula/‘alae ke‘oke‘o pre-breeding/nesting habitat in the internal draft Annual Habitat Management Plan (USFWS 2007). Fluctuating water levels are undesirable, requiring nesting adults to continually build up nests or have nests surrounded by dry ground vulnerable to mammalian predation. During brood-rearing periods, water levels are pulsed infrequently to provide greater availability of macroinvertebrates eaten by breeding adults and fed to developing chicks. These invertebrates are an important protein source necessary for survival and proper development. Additionally, invertebrates are critical for molting ducks. Both survey and tracking data indicate koloa maoli seek undisturbed wetlands with dense cover to molt, including late successional wetlands with peak in May to July (USFWS, unpublished data; C. Malachowski, unpublished data). Providing a mosaic of open water and desirable plant species promotes the greatest number of nesting and brood-rearing territories, while minimizing territorial aggression between family units.

The moist-soil management regime is guided by the QMUA which monitors vegetation response to habitat manipulations and helps determine if habitat objectives (e.g., plant cover, water depth) are being met. If habitat objectives are not being met (and there are no nests or broods) a partial treatment could be conducted. Prior to partial treatment (i.e., returning the unit to mid-succession if habitat is not responding to management), the unit is dewatered, dried out, and pest plants grubbed or spot-sprayed as needed. The unit may be kept moist with sloughs, but is maintained in moist soil conditions to allow wetland plants to germinate on mudflats. After one to four months, when plant growth is sufficient (~8–24 inches high), pest plants are spot-sprayed or hand-pulled and the unit may be mowed to create a mosaic of open water and vegetation. The unit is gradually inundated and water pulsed at 2–4-inch increments as needed (Smith 2010).

Although breeding ʻalae keʻokeʻo, and ʻalae ʻula are the primary species to benefit, this stage benefits multiple bird species, particularly aeʻo, koloa maoli, and migratory dabbling and diving ducks that use later succession habitats for foraging and loafing.

ʻAlae ʻula and ʻalae keʻokeʻo appear to be less susceptible to human disturbance compared with aeʻo and koloa maoli, which may relate to their nest location, nesting habitat, and response to disturbance. However, ʻalae keʻokeʻo, and ʻalae ʻula are vulnerable to the same introduced predators as the other threatened or endangered waterbirds. Adults are susceptible to predation by dogs, cats, mongooses, and rats. Predators of chicks or eggs include bullfrogs, common mynah, largemouth bass, and cattle egret. Native ʻaukuʻu (black-crowned night heron) are also known to take chicks (Bannor and Kiviat 2002; Pratt and Brisbin Jr. 2002). It is critical to control predators during the breeding season to reduce mortality and increase reproductive success and survival. These management techniques benefit multiple threatened and endangered and migratory waterbird species (USFWS 2011).

C.3.4 Early-Successional Managed Wetlands for Aeʻo Breeding

Attributes:

- Availability on Refuge from approximately March–August
- Recently flooded mosaic of shallow (<3 inches), open water and exposed mudflat (saturated and unsaturated) with sparse (<25% cover) of low-growing (<6 inches tall) emergent plants (e.g., *Fimbristylis,* water hyssop [*Bacopa* spp.]);
- Undulating, irregular topography creating unsaturated mudflats with gradual slopes (~15:1) during drawdown to provide nesting adjacent to foraging habitat;
- Abundant macroinvertebrates (e.g., damselflies, crayfish, midges) for foraging;
- Reproductive success of ≥2 hatchlings and ≥1 fledglings per nest;
- Minimal human disturbance year-round;
- <5% cover of pest plants (e.g., California grass, cattail [*Typha latifolia*]);
- No feral mallards or their hybrids; and

- Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year cumulatively for rotational managed wetlands.

DESCRIPTION AND RATIONALE:

This habitat is an early successional stage of a seasonal playa (e.g., Ni‘ihau ephemeral lakes) or tidal mudflat favored by shorebirds within a 12–24 month rotation. These attributes are modeled after those described under ae‘o breeding/nesting/brood-rearing in the internal draft Annual Habitat Management Plan (USFWS 2007). Ae‘o use a diversity of wetland habitats, but higher nesting densities are found on early successional wetlands with large mudflats, sparse, low-growing vegetation (USFWS 1983), and abundant macroinvertebrates. Suitable ae‘o breeding habitat is rare in the Hawaiian Islands because of altered hydrology, contaminants, and pest species (USFWS 2011). Successful breeding colonies are found almost exclusively on human-maintained wetlands (Robinson et al. 1999) managed primarily for the purpose of threatened and endangered Hawaiian waterbird recovery. Gee (2007) found ae‘o at Hanalei NWR to be responsive to wetlands management with 42 of 48 nests constructed in wetlands specifically managed for this species. Although nest (42%) and fledging (3%) success was low with ~2 chicks fledged because of predators and inundation, creating suitable habitat in larger units to increase predator detection by birds, and creating habitat in sync with the breeding season was recommended. In 2010, water level management resulted in lower nest success (33%) probably due to high rainfall/flooding but higher fledging success (44%) with at least 17 chicks fledged for Hanalei NWR.

Water level management timed to mimic seasonal inundation and evapotranspiration is beneficial to breeding ae‘o. Management should be focused on units that naturally have less robust vegetative growth. Prior to full treatment, the unit is dewatered, dried out, and pest plants grubbed or spot-sprayed. Disking to breakup pest plant root systems may be followed by a wet till (water depth ≤6 inches) for finer breakup of soils and root systems. Pond bottoms are sculpted to create a mosaic of saturated and unsaturated mudflat with gradual slopes to provide nesting adjacent to foraging habitat. If needed, the unit is maintained for a few weeks in moist soil conditions for seed germination. Two-to-three inch shoots are inundated to stimulate invertebrate foods and foraging by breeding pairs.

This pre-breeding and foraging habitat is managed starting in February or March for one to three months at 100 percent open water four to six inches deep to suppress plant growth. Initial water level drawdowns help establish unsaturated mudflats required for nest building and maximize the number of nests/breeding pairs an area can support. Mid-season water level drawdowns provide a mosaic of unsaturated and saturated mudflats required for brood-rearing. Pulsing water helps to stimulate production of invertebrate foods throughout the brood-rearing period and maximizes the number of broods an area can support. It also allows adult ae‘o with broods to establish suitable feeding territories and reduces inter-brood conflicts that can result in injury or death to young chicks.

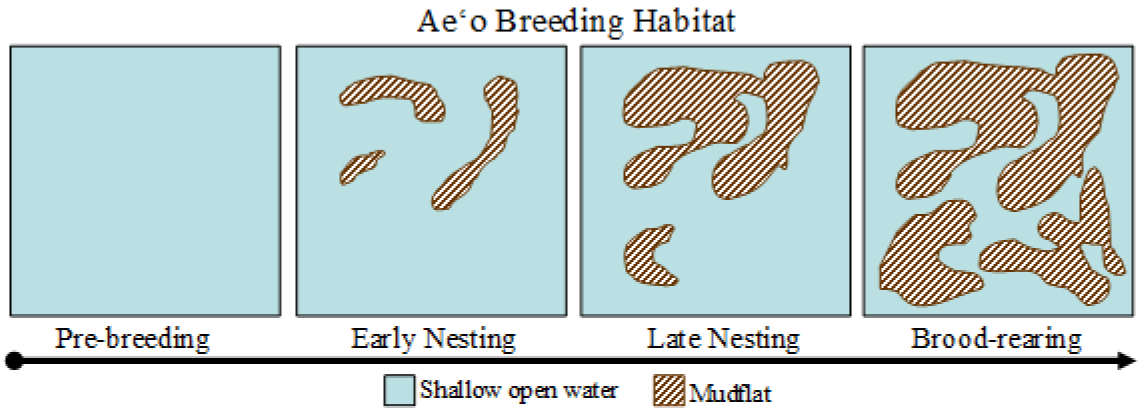


Figure C-2. Illustration of ae'o breeding habitat. Credit: USFWS

Other birds that benefit from open mudflat habitat include foraging and loafing koloa maoli, ʻalae keʻokeʻo, migratory waterfowl and shorebirds, and occasionally ʻalae ʻula. Aeʻo are easily disturbed during the breeding season. Since they nest in the open on exposed mudflats, they evolved behaviors to help protect nests and young. One adult behavior is to depart the camouflaged nest when danger is perceived. However, this behavior leaves nests or young exposed to predators and weather. Eggs can be destroyed by prolonged exposure to high temperature, wind chill, and rain, all of which occur frequently in Hawaiʻi. Chicks and nests are cryptic and can be stepped on or run-over if not seen. Human disturbance must be minimized during the breeding period to reduce the risk of increasing nest failure and chick mortality. Thus, access to the Refuge rotational managed wetlands is limited to essential activities by Refuge staff.

Aeʻo nests, eggs, and young are also vulnerable to a variety of introduced predators including rats, mice, mongooses, bullfrogs, dogs, cats, and cattle egrets. Chicks are more likely to freeze rather than flee when danger is perceived, a behavior that makes them easy prey for terrestrial predators. It is critical to control predators during the breeding season to reduce mortality and increase reproductive success and survival. These management techniques also benefit multiple native species, including endangered koloa maoli, ʻalae keʻokeʻo, and ʻalae ʻula; threatened nēnē (USFWS 2011); and migratory birds and are important to achieve the Hanalei NWR purpose.

C.3.5 Managed Wetland Habitat for ʻAlae keʻokeʻo Breeding

Attributes:

- Availability on Refuge, particularly from March–August;
- Mosaic of open water (10–14 inches) with initially a 50–75% cover of tall (>24 inches) robust emergents (e.g., kāmole, nānaku, Manchurian wild rice) declining to 25–50% cover as marsh matures;
- Interspersion with sufficient vegetative edge to provide visual barriers to maximize territories available for breeding;
- Presence of submerged aquatic vegetation (e.g., pondweeds);
- Abundant macroinvertebrates (e.g., damselflies, small mollusks and crustaceans) for foraging;
- Minimal human disturbance during breeding peaks;
- <5% cover of pest plants (e.g., California grass, *Paspalum*, Guinea grass);

- No feral mallards or their hybrids; and
- Predation levels by introduced predators (e.g., cats, barn owls, dogs, cats, rats) ≤6 individual threatened or endangered waterbirds per year cumulatively for rotational managed wetlands.

DESCRIPTION AND RATIONALE:

This habitat is the focused on providing wetland conditions specific for the breeding life history of ʻalae keʻokeʻo in units with coarser textured soils (e.g., C2, C5, DU2). Plant succession would occur over approximately six months, followed by a maintenance period. These attributes are modeled after those described under ʻalae keʻokeʻo pre-breeding/nesting habitat in the internal draft Annual Habitat Management Plan (USFWS 2007). Fluctuating water levels are undesirable, requiring nesting adults to continually build up nests or have nests surrounded by dry ground vulnerable to mammalian predation. During brood-rearing periods, water levels are pulsed infrequently to provide greater availability of macroinvertebrates eaten by breeding adults and fed to developing chicks. These invertebrates are an important protein source necessary for pre-breeding. Providing a mosaic of open water and desirable plant species promotes the greatest number of nesting and brood-rearing territories, while minimizing strife between family units.

The management regime involves a full treatment or setting the wetland back to mudflat. Prior to this, the unit is dewatered, dried out, and pest plants grubbed or spot-sprayed. Disking to breakup pest plant root systems is followed by a wet till (water depth ≤6 inches) for finer breakup of soils and root systems. Pond bottoms are contoured for microtopography and sloughs are created to promote drainage. Prior to draining a unit, sediments and nutrients are allowed to settle to protect water quality in the river while pest and other plants decompose. The water level is gradually drawn down and the unit maintained in a moist soil condition suitable for wetland plant germination. After one to four months, when plant growth is sufficient (~24 inches height), pest plants are spot-sprayed or hand-pulled and the unit is mowed to create a mosaic of open water and vegetation. The unit is flooded to a depth of 10–14 inches to begin accelerated breakdown of organic material for invertebrate production.

C.4 WETLAND UNIT MANAGEMENT AND MAINTENANCE

Management activities help to break down vegetation and stimulate invertebrate production year-round. Each pond is treated every 12–15 months due to the rapid plant breakdown.

Step 1 – After the rotational managed wetland unit is dry, vegetation that has not been broken down during the life of the unit is mowed. California and *Paspalum* grass stands may need to be grubbed or spot-sprayed with herbicide depending on density.

Rotational managed wetland unit after mowing, Hanalei NWR. Photo credit: USFWS

Step 2 – Disking is used to break up the root systems of undesired plants. When California and *Paspalum* stands become too thick, scraping with a dozer is required prior to disking. Multiple passes with the disk may be required in prepping for wet tilling, depending on the density of the root systems

Disking within a rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

Step 3 – Prior to wet tilling, the pond is flooded no deeper than six inches. Wet tilling is the most important step in achieving good success with native wetland plant germination. The wet tilling process is effective at finely breaking up the root systems of weeds such as California grass and separating them from the soil. This process also helps to supersaturate the soil which creates better conditions for quicker germination of native sedges, which gives the sedges a competitive advantage over the pest weeds and allows the formation of dense sedge beds important for breakdown and invertebrate production for foraging.

Wet tilling within a rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

Leaving water on the pond allows sediment to drop out and can further suppress invasive vegetation.

Rotational managed wetland unit after-wet tilling, Hanalei NWR. Photo credit: USFWS

Step 4 – Drawdown after tilling. After wet tilling, the sedges have a faster germination because of good soil saturation and the setback/breakup of the undesirable root systems. The sedges are able to outcompete the California and *Paspalum* grasses.

Drawdown after wet tilling in a rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

Initial sedge growth within a rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

Step 5 – Spot-spraying with glyphosate is a further tool to control pest California and *Paspalum* grasses. Doing this can significantly prolong the life of the pond and reduce subsequent treatment effort.

Rotational managed wetland unit after herbicide spot-spraying, Hanalei NWR. Photo credit: USFWS

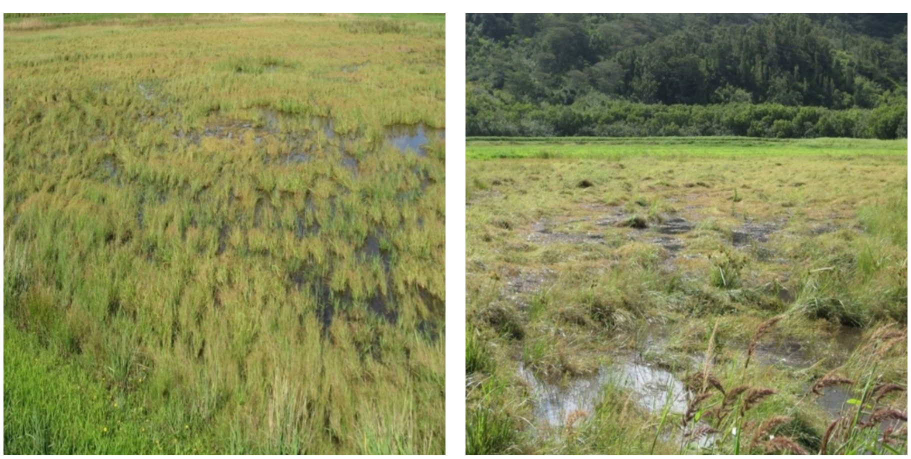
Step 6 – The growth period of one to three months is adequate to achieve the desired vegetation height so that we can flood over the top of the initial sedge growth and begin vegetation breakdown for invertebrate production.

Vegetation filling in a rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

We then mow to create a mosaic pattern for the desired ratio of open water to vegetation for pre-breeding and foraging and to create more edge.

Mowed areas for creating open water to vegetation edges, Hanalei NWR. Photo credit: USFWS

Depending on the type of waterbird use condition, a mosaic is not necessary all the time and the waterbirds do the work themselves.



Interspersion of vegetation and open water in rotational managed wetland units, Hanalei NWR. Credit: USFWS

Step 7 – Initial flooding of freshly treated rotational managed wetland units provides foraging opportunity for the federally-listed Hawaiian waterbirds. Invertebrate production is apparent shortly after flooding.

Flooded rotational managed wetland unit, Hanalei NWR. Photo credit: USFWS

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APPENDIX D. INTEGRATED PEST MANAGEMENT (IPM) PROGRAM

ADDITIONAL ABBREVIATIONS AND UNITS

These additional abbreviations are specific to this appendix; other abbreviations are provided in the cover pages to the dWMWCP.

%	percent
ae basis	highest application of an active ingredient
a.i.	active ingredient
APHIS	Animal Plant Health Inspection Service
ARS	Agricultural Research Service
BAFs	bioaccumulation factors
BCFs	bioconcentration factors
bw	body weight
CAS	Chemical Abstract Service
cm	centimeter
DT_{50}	dissipation time
EC_{50}	environmental concentration
EEC	estimated environmental concentration
ELS	early life stage
EXTOXNET	Extension Toxicology Network
ft	feet
ft^2	square feet
g	grams
gal	gallons
GUS	Groundwater Ubiquity Score
I	vapor pressure index
kg	kilograms
K_{oc}	sorption coefficient
K_{ow}	Octanol-Water
lb(s)	pound(s)
LC_{50}	Median Lethal Concentration (Toxicological Endpoint)
LD_{50}	Oral Lethal Dose (Toxicological Endpoint)
LOC	Level of Concern
LOEC	Lowest Observed Effect Concentration
LOEL	Lowest Observed Effect Level
mg	milligrams
mm HG	millimeter of mercury
NIOSH	National Institute for Occupational Safety and Health
NOAEC	No Observed Adverse Effect Concentration
NOAEC	No Observed Adverse Effect Concentration
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NPE	Nonylphenol polyethylate
oz	ounce
POEA	polyoxyethylene-amine
ppb	parts per billion
ppm	parts per million
PPQ	Plant Protection and Quarantine
PUPS	Pesticide Use Proposal System
Reg. No.	EPA Registration Number
REI	restricted entry interval
RLGIS	Refuge Lands Geographic Information System
RQ	Risk Quotient
RTECS	Registry of Toxic Effects of Chemical Substances
SARA	Superfund Amendments and Reauthorization Act
SDS	Safety Fata Sheets
S_w	water solubility
t½	half-life
T-REX	Terrestrial Residue Exposure model
TWA	time-weighted-average
v	version
wt	weight
µg	microgram

APPENDIX D. INTEGRATED PEST MANAGEMENT (IPM) PROGRAM

D.1 BACKGROUND

Integrated pest management (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. IPM is a scientifically based, adaptive management process where available scientific information and best professional judgment of the refuge staff as well as other resource experts are 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 Code of Federal Regulations (CFR) 46.145, adaptive management is 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, are 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 are considered when determining feasibility/practicality of various treatments.

The Draft Wetlands Management and Waterbird Conservation Plan (dWMWCP) includes strategies to address pests (see Chapter 4 of this dWMWCP) based on IPM techniques and adaptive management 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 dWMWCP:

- 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 in accordance with effects analyses (environmental consequences) of the Environmental Assessment (EA) associated with this dWMWCP. 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 management would be similar to the process described in this appendix for ground-based treatments of other pesticides.

D.2 Pest Management Laws and Policies

In accordance with Service policy 569 U.S. Fish and Wildlife Service Manual (FW) 1 (Integrated Pest Management), plant, invertebrate, and vertebrate pests on units of the National Wildlife Refuge System (NWRS or Refuge System) can be controlled to ensure balanced wildlife and fish populations in support of refuge-specific wildlife and habitat management objectives. Pest control on federal (Refuge) lands and waters is authorized under the following legal mandates:

- National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), as amended (16 United States Code (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 (FIFRA; 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 (EO) 13148, Section 601(a);
- EO 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 Department Manual (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 nonnative 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 dWMWCP, the terms pest and invasive species are used interchangeably because both can prevent/impede the 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 that are considered pests may be managed if the following criteria are met[1]:

- 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

[1] Note that during the life span of the WMWCP, 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.

- Control would not conflict with attainment of resource objectives or the purpose(s) for which the Refuge was established.

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, the removal of feral pigs damaging Hanalei Refuge infrastructure and/or negatively affecting habitats managed on Refuge lands may be conducted without a pest control proposal.

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 EO 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]).

D.3 STRATEGIES

To fully embrace IPM as identified in 569 FW 1, the following strategies, where applicable, are carefully considered on the Refuge for each pest species. Any pests and IPM needs identified during implementation of the dWMWCP, when and if approved, would follow these existing strategies.

D.3.1 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 uninfested 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 to 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). These prevent re-introductions by various mechanisms including vehicles, personnel, livestock, and horses. Because invasive species are frequently the first to establish in newly disturbed sites, prevention requires a reporting mechanism for early detection of new pest occurrences with quick response to eliminate any new satellite pest populations. Prevention requires 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 involves halting the spread of existing infestations to new sites (Mullin et al. 2000). The primary purpose of prevention is to keep pest-free lands or waters from becoming infested. EO 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 identify pest species on-site or within reasonably expected potential invasion vicinity. Where possible, the refuge staff begin project activities in uninfested areas before working in pest-infested areas.
- The refuge staff locate and use pest-free project staging areas. They avoid or minimize travel through pest-infested areas, or restrict to those periods when spread of seed or propagules of invasive plants is least likely.
- The refuge staff determine the need for and, when appropriate, identify sanitation sites where equipment can be cleaned of pests. Where possible, the refuge staff 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 need to be collected, where practical. The refuge staff remove mud, dirt, and plant parts from project equipment before moving it into a project area.
- The refuge staff clean all equipment, before leaving the project site, if operating in areas infested with pests. The refuge staff determine the need for and, when appropriate, identify sanitation sites where equipment can be cleaned.
- Refuge staff, their authorized agents, and refuge volunteers, 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 evaluate options, including closure, to restrict the traffic on sites with on-going restoration of desired vegetation. The refuge staff 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 use native material, where appropriate and feasible. The refuge staff use certified weed-free or weed-seed-free hay or straw where certified materials are reasonably available.
- The refuge staff provide information, training, and appropriate pest identification materials to permit holders and recreational visitors. The refuge staff educate them about pest identification, biology, impacts, and effective prevention measures.
- The refuge staff inspect borrowed material for invasive plants prior to use and transport onto and/or within refuge lands.
- The refuge staff consider invasive plants in planning for road maintenance activities.
- The refuge staff restrict off-road travel to designated routes.

The following are methods to prevent the introduction and/or spread of pests into refuge waters:

- The refuge staff inspect boats (including air boats), trailers, and other boating equipment and where possible, remove any visible plants, animals, or mud before leaving any waters or boat launching facilities.
- Where possible, the refuge staff drain water from motors, live wells, bilges, and transom wells while on land before leaving the site.
- If possible, the refuge staff wash and dry boats, downriggers, anchors, nets, floors of boats, propellers, axles, trailers, and other boating equipment to kill pests not visible at the boat launch.

These prevention methods to minimize/eliminate the introduction and/or spread of pests were taken verbatim or slightly modified from Appendix E of the U.S. Forest Service's (USFS's) *Preventing and Managing Invasive Plants Final Environmental Impact Statement* (2005).

D.3.2 MECHANICAL/PHYSICAL METHODS

These methods 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, shearing, 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 may be relocated to off-refuge sites with prior approval from the state.

Each of these tools are 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 must be destroyed or it may 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 are 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 improve the efficacy of the herbicide compared to herbicide only treatment.

D.3.3 Cultural Methods

These methods involve manipulating habitat to increase pest mortality by reducing its suitability to the pest. Cultural methods could include water-level manipulation, mulching, 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.

D.3.4 Biological Control Agents

Classical biological control involves 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 is no longer practical.

Biological control has advantages as well as disadvantages. Benefits 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 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 may work well in other areas. Biological control agents 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 decreases correspondingly. This is a natural cycle. Some pest populations (e.g., invasive plants) tend to persist for several years after a biological control agent becomes established due to seed reserves in the soil, inefficiencies in the agent's 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 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 species in Hawai'i, including banana poka (*Passiflora mollisima*) and Eurythrina gall wasps (*Quadrastichus erythrinae*). However, historically, each new introduction of a biological control agent in the United States has only about a 30 percent success rate (Coombs et al. 2004).

Introduced species without desirable close relatives in the United States are generally 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, Frank, and Dray Jr. 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 U.S. Environmental Protection Agency (EPA) under FIFRA, most biological control agents are regulated by the U.S. Department of Agriculture (USDA)-Animal Plant Health Inspection Service(APHIS), Plant Protection and Quarantine (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:

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 569 FW1. In addition, the refuge staff would follow the International Code of Best Practice for Classical Biological Control of Weeds (http://wiki.bugwood.org/Code_of_Best_Practices) 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 species, nontarget species, and the environment.

Biological control agents formulated as pesticide products and registered by the EPA (e.g., *Bti*) are also subject to pesticide use proposal (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.

For any new biological control agents, the relevant 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. See Section D.7.2 for more about incorporating previous analyses from other federal agencies.

D.3.5 PESTICIDES

The selective use of pesticides is 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 use 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) will 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) are prepared and approved in accordance with 569 FW 1. The PUP records provide a detailed, time-, site-, and target-specific description of the proposed use of pesticides on the Refuge. See Section D.6.5.2 for more on record-keeping related to PUPs.

Application equipment is 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) is used to treat target pests. Other target-specific equipment to apply pesticides 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.

Repeated use of one pesticide may allow resistant organisms to survive and reproduce, so multiple pesticides with variable modes of action are 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 could potentially harm natural resources or people, then a different product is 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 is acceptable for use on refuge lands in the context of an IPM approach.

D.3.6 Habitat Restoration/Maintenance

Restoration and/or proper maintenance of refuge habitats associated with achieving wildlife and habitat objectives is 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 Sheley 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 several 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 are important considerations.

D.4 Priorities for Treatments

For many refuges, the magnitude (number, distribution, and sizes of infestations) of 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 is essential to prioritize treatment of infestations. Highest priority treatments are focused on early detection and rapid response to eliminate infestations of new pests, if possible. This is 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 biological integrity, diversity, and environmental health.

The next priority is 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 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 are always of high priority for management, other pest species known to cause substantial ecological impact are also considered. For example, short-spined kiawe may not be listed by the State of Hawai‘i as noxious, but it can greatly alter fire regimes in the coastal dryland shrub habitat resulting in large monotypic stands that displace native bunch grasses, forbs, and shrubs. Pest control in support of the dWMWCP would likely require a multi-year commitment from Refuge staff. 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 are essential to the long-term success of pest management.

D.5 BEST MANAGEMENT PRACTICES (BMPS)

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 U.S. Department of the Interior (DOI) Pesticide Use Policy (517 DM 1) and the Service IPM Policy and Responsibilities (569 FW 1), the use of applicable BMPs (where feasible) also ensures 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 are 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.

D.5.1 PESTICIDE HANDLING AND MIXING

- As a precaution against spilling, spray tanks will not be left unattended during filling.
- All pesticide containers will be triple rinsed and the rinsate used as water in the sprayer tank and applied to treatment areas.
- All pesticide spray equipment will be properly cleaned. Where possible, rinsate will be used as part of the makeup water in the sprayer tank and applied to treatment areas.
- The refuge staff will dispose of triple-rinsed pesticide containers per label directions.
- All unused pesticides will be properly discarded at a local “safe send” collection.
- Pesticides and pesticide containers will 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 will 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 will be addressed immediately using procedures identified in the refuge spill response plan.

D.5.2 Applying Pesticides

- Pesticide treatments will only be conducted by or under the supervision of Service personnel and non-Service applicators with the appropriate state or BLM certification to safely and effectively conduct these activities on refuge lands and waters.
- The refuge staff will 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 will 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 will review the labels, safety data sheets (SDSs), and PUPs for each pesticide, determining the target pest, appropriate mix rate(s), personal protective equipment (PPE), and other requirements listed on the pesticide label.
- A 1-foot no-spray buffer from the water's edge will be used, where applicable and where 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 will use and adjust spray equipment to apply the coarsest droplet size spectrum with optimal coverage of the target species while reducing drift.
- Applicators will use the largest droplet size that results in uniform coverage.
- Applicators will use drift reduction technologies such as low-drift nozzles, where possible.
- Where possible, spraying will occur during low (average<seven mph and preferably three to five mph) and consistent direction wind conditions with moderate temperatures (typically <85°F).
- Where possible, applicators will 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 will be calibrated regularly to ensure that the proper rate of pesticide is applied to the target area or species.
- Spray applications will 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) will typically be conducted during early morning hours.
- Spray applications will not be conducted on days with >30% forecast for rain within six hours, except for pesticides that are rapidly rain fast (e.g., glyphosate in 1 hour) to minimize/eliminate potential runoff.
- Where possible, applicators will use drift retardant adjuvants during spray applications, especially adjacent to sensitive areas.
- Where possible, applicators will 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 will be stopped until repairs can be made to the sprayer.

- For pesticide uses associated with cropland and facilities management, buffers, as appropriate, will 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 will only apply adjacent to sensitive areas when the wind is blowing the opposite direction.
- Applicators will utilize scouting for early detection of pests to eliminate unnecessary pesticide applications.
- The refuge staff will consider timing of application so native plants are protected (e.g., senescence) while effectively treating invasive plants.
- Rinsate from cleaning spray equipment after application will be recaptured and reused or applied to an appropriate pest plant infestation.
- Application equipment (e.g., sprayer, all-terrain vehicle, tractor) will be thoroughly cleaned and PPE will be removed/disposed of on-site by applicators after treatments to eliminate the potential spread of pests to uninfested areas.
- Cleaning boots (or use rubber boots to aid in sanitation) and brush off clothing in a place where monitoring is feasible to control for new seed transportation.

D.6 Safety

D.6.1 Personal Protective Equipment

All applicators will 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 a National Institute for Occupational Safety and Health (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 Occupational Safety and Health Administration (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.

D.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 are notified about treatment areas. Posting occurs 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 are also posted on its perimeter and at other likely locations of entry. The refuge staff also notify appropriate private property owners of an intended application, including any private individuals who have requested notification. Special efforts are made to contact nearby individuals who are beekeepers or who have expressed chemical sensitivities.

D.6.3 Medical Surveillance

Medical surveillance may be required for Service personnel and approved volunteers who mix, apply, and/or monitor the use of pesticides (see 242 FW 7 [Pesticide Users] and 242 FW 4 [Medical Surveillance]). In accordance with 242 FW 7.12A, Service personnel are 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 FW 7.7A, "**Frequent Pesticide Use** means when a person applying pesticide handles, mixes, or applies pesticides, with a Health Hazard rating of three or higher, for eight 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 D.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) are responsible for their own medical monitoring needs and costs.

Standard examinations (at refuge expense) of appropriate refuge staff are provided by the nearest certified occupational health and safety physician as determined by Federal Occupational Health.

D.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 are trained and state or federally (BLM) licensed to apply pesticides to refuge lands or waters. In accordance with 242 FW 7.18A 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. New staff unfamiliar with proper procedures for storing, mixing, handling, applying, and disposing of herbicides and containers will receive orientation and training before handling or using any products. Documentation of training is kept in the files at the refuge office.

D.6.5 Record Keeping

D.6.5.1 Labels and Material Safety Data Sheets

Pesticide labels and SDSs are maintained at the refuge shop and laminated copies in the mixing area. These documents also will 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 will 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 to pesticide labels and SDSs.

D.6.5.2 Pesticide Use Proposals

A PUP is prepared for each proposed pesticide use associated with annual pest management on refuge lands and waters. A PUP includes 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.

Upon meeting identified criteria, including an approved IPM plan, where necessary and consistent with Service guidelines (see Director's memo [December 12, 2007]), refuge staff may receive up to five-year approvals for proposed pesticide uses that have been reviewed and approved by the field and Headquarters offices. For a refuge, an IPM plan (requirements described herein) can be completed independently or in association with a Comprehensive Conservation Plan (CCP), a habitat management plan (HMP), or as in this case, a dWMWCP 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.

D.6.5.3 Pesticide Usage

In accordance with 569 FW 1, the refuge Project Leader is required to maintain records of all pesticides annually applied on lands or waters under refuge jurisdiction. This encompasses pesticides applied by other federal agencies, state and county governments, non-government applicators including cooperators, and pest management service providers with Service permission. For clarification, pesticide means all insecticides, insect and plant growth regulators, desiccants, 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 (pounds [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 will 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 Geographic Information System [RLGIS]) to facilitate data analyses and subsequent reporting. In accordance with adaptive management, data analysis and interpretation 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.

D.7 EVALUATING PESTICIDE USE PROPOSALS

Pesticides will only be used on refuge lands for habitat management as well as croplands/facilities maintenance after approval of a PUP. In general, proposed pesticide uses on refuge lands will 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 will be evaluated with quantitative ecological risk assessments (ERAs) and other screening measures. Potential effects to environmental quality will be based upon pesticide characteristics of environmental fate (water solubility, soil mobility, soil persistence, and volatilization) and other quantitative screening tools. ERAs, as well as characteristics of environmental fate and potential to degrade environmental quality for pesticides, would be documented in Chemical Profiles (see Section D.7.5). These profiles will include threshold values for quantitative measures of ERAs 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 D.4) for habitat management and cropland/facilities maintenance on refuge lands that will potentially have minor, temporary, or localized effects on refuge biological and environmental quality (threshold values not exceeded) will be approved.

D.7.1 OVERVIEW OF ECOLOGICAL RISK ASSESSMENT

An ERA process will 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 provides 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 ERAs 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 D.7.2.3.

The toxicological data used in ERAs are typically results of standardized laboratory studies provided by pesticide registrants to the EPA to meet regulatory requirements under 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 can 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 at the end of Section D.7.5.

TABLE D-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.

D.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 will be evaluated using EPA's Ecological Risk Assessment Process (EPA 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 ERAs. 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 D-1).

$$RQ = EEC/Toxicological\ Endpoint$$

The level of risk associated with direct effects of pesticide use is characterized by comparing calculated RQs to the appropriate Level of Concern (LOC) established by EPA (1998) [Table D-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 indicates 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 are used as toxicological endpoints for RQ calculations. In contrast, chronic risks 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 NOAEC or NOEC for reproduction are used as toxicological endpoints for RQ calculations. Where available, the NOAEC is 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 (ESA; 16 USC 1531–1544, 87 Stat. 884, as amended-Public Law 93-205). For listed species, potential adverse effects are assessed at the individual level because loss of individuals from a population could detrimentally impact a species. In contrast, risks to nonlisted species consider effects at the population level. A RQ<LOC indicates the proposed pesticide use “may affect, not likely to adversely affect” individuals (listed species) and it would not pose an unacceptable risk for adverse effects to populations (non-listed species) for each taxonomic group (Table D-2). In contrast, a RQ>LOC indicates a “may affect, likely to adversely affect” for listed species and it would pose unacceptable ecological risk for adverse effects to nonlisted species.

TABLE D-2. PRESUMPTION OF UNACCEPTABLE RISK FOR BIRDS, FISH, AND MAMMALS (EPA 1998)

Risk Presumption		*Level of Concern Listed Species*	*Level of Concern 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

D.7.2.1 ENVIRONMENTAL EXPOSURE

Following release into the environment through application, pesticides experience several different routes of environmental fate. Pesticides which are 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, DeWitt, and Ellerhoff 1999; Butler, Martinkovic, and Nesheim 1998; Ramsay, Craig, and McConnell 1995; EXTOXNET 1993). Pesticides which are 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).

D.7.2.2 TERRESTRIAL EXPOSURE

The EEC for exposure to terrestrial wildlife would be quantified using an EPA screening-level approach (EPA 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.

Terrestrial – Spray Application

For spray applications, exposure will be determined using the Kanaga nomogram method (EPA 2005a, 2004; Pfleeger et al. 1996) through the EPA’s Terrestrial Residue Exposure model (T-REX) version 1.2.3 (EPA 2005b). 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 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 parts per million [ppm] per lb active ingredient [a.i.]/acre) for worst-case risk assessments. Short grass is not representative of forage for carnivorous species (e.g., raptors), but it characterizes the maximum potential exposure through the diet of avian and mammalian prey items. Consequently, this approach provides 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, Collins, and Baril 1996). For example, body weights of bobwhite quail and mallard are included in T-REX by default, but body weights of other organisms (Table D-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 is 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 is used as a default. Alternatively, zero is 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 is used as an EEC for calculation of RQs. This approach yields a conservative estimate of ecological risk.

TABLE D-3. AVERAGE BODY WEIGHT OF SELECTED TERRESTRIAL WILDLIFE SPECIES FREQUENTLY USED IN RESEARCH TO ESTABLISH TOXICOLOGICAL ENDPOINTS (DUNNING 1984)

Species	*Body Weight (kilograms)*
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 (1,000 g)	1.000
Mallard	1.082
Ring-necked pheasant	1.135

Terrestrial – Granular Application

Granular pesticide formulations and pesticide-treated seed 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 will be calculated by dividing the maximum milligrams of a.i. exposed (e.g., EEC) on the surface of an area equal to one square foot by the appropriate LD_{50} value multiplied by the surrogate's body weight (Table D-3). An adjustment to surface area calculations is made for broadcast, banded, and in-furrow applications. An adjustment also is made for applications with and without incorporation of the granules. Without incorporation, it is assumed that 100 percent 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 is assumed only 15 percent of the applied granules remain available to wildlife. It is assumed that only one percent of the granules are available on the soil surface following in-furrow applications.

EECs for pesticides applied in granular form and as seed treatments are determined considering potential ingestion rates of avian or mammalian species (e.g., 10–30% body weight/day). This provides 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 is also considered by calculating the loading per unit area (LD_{50}/ft^2) for comparison to EPA LOCs (EPA 1998). The T-REX version 1.2.3 (EPA 2005b) 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

$$mg\ a.i./ft^2 = [(lbs\ product/1{,}000\ ft\ row)(\%\ a.i.)(1{,}000\ ft\ row)(453{,}580\ mg/lb)(1\%\ exposed)$$

$$EEC = [(mg\ a.i./ft^2)(\%\ of\ pesticide\ biologically\ available)]$$

- Incorporated banded treatments assume that 15% of granules, bait, and seeds are unincorporated.

$$mg\ a.i./ft^2 = [(lbs\ product/1{,}000\ row\ ft)(\%\ a.i.)(453{,}580\ mg/lb)(1\text{-}\%\ incorporated)] / (1{,}000\ ft)(band\ width\ (ft))$$

$$EEC = [(mg\ a.i./ft^2)(\%\ of\ pesticide\ biologically\ available)]$$

- 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 will be used to calculate a RQ based on the EEC calculated by one of the above equations. The EEC is divided by the surrogate LD_{50} toxicological endpoint multiplied by the body weight (Table D-3) of the surrogate.

$$RQ = EEC / [LD_{50}\ (mg/kg) * body\ weight\ (kg)]$$

As with other risk assessments, a RQ>LOC is a presumption of unacceptable ecological risk. A RQ<LOC is a presumption of acceptable risk with only minor, temporary, or localized effects to species.

D.7.2.3 Aquatic Exposure

Exposures to aquatic habitats (e.g., wetlands, meadows, ephemeral pools, water delivery ditches) will be evaluated separately for ground-based pesticide treatments of habitats managed for fish and wildlife compared with cropland/facilities maintenance. The primary exposure pathway for aquatic organisms from any ground-based treatments likely is particle drift during the pesticide application. However, different exposure scenarios are 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) and facilities maintenance (e.g., roadsides, parking lots, trails) compared with other managed habitats on the Refuge. In addition, pesticide applications may be done within <25 feet of the high water mark of aquatic habitats for habitat management treatments; whereas, no-spray buffers (≥25 feet) are used for croplands/facilities maintenance treatments.

D.7.2.4 Habitat Treatments

For the worst-case exposure scenario to non-target aquatic habitats, EECs (Table D-4) will be derived from Urban and Cook (1986) that assumes an intentional overspray to an entire, non-target water body (1-foot depth) from a treatment <25 feet from the high water mark using the max application rate (acid basis [see above]). However, use of BMPs for applying pesticides (see Section D.4.2) will likely minimize/eliminate potential drift to non-target aquatic habitats during actual treatments. If there is unacceptable (acute or chronic) risk to fish and wildlife with the simulated 100 percent 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 D-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)*[1]	*Lbs/acre*	*EEC (ppb)*
0.10	36.7	2.00	735.7

Lbs/acre	*EEC (ppb)*[1]	*Lbs/acre*	*EEC (ppb)*
0.20	73.5	2.25	827.6
0.25	91.9	2.50	919.4
0.30	110.2	3.00	1103.5
0.40	147.0	4.00	1471.4
0.50	183.7	5.00	1839
0.75	275.6	6.00	2207
1.00	367.5	7.00	2575
1.25	459.7	8.00	2943
1.50	551.6	9.00	3311
1.75	643.5	10.00	3678

[1]parts per billion (ppb)

D.7.2.5 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 EPA 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., version [v]2.01 through v2.10). The Spray Drift Task Force AgDRIFT® model version 2.01 (AgDRIFT 2001; Spray Drift Task Force 2003) 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.

D.7.2.6 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 is relevant to evaluation of effects from pesticide uses on refuge lands, would be reviewed. Possible source agencies for such NEPA documents would include the BLM, USFS, National Park Service, USDA-APHIS, and the military services.

In accordance with the requirements set forth in 43 CFR 46.135, the Service will specifically incorporate by reference (40 CFR 1502.21) any relevant ERAs prepared by the USFS (https://www.fs.fed.us/foresthealth/protecting-forest/integrated-pest-management/pesticide-management/pesticide-risk-assessments.shtml) and BLM (https://www.blm.gov/programs/natural-resources/weeds-and-invasives/risk-assessments and https://www.blm.gov/programs/natural-resources/weeds-and-invasives/vegetative-peis). 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* (USFS 2005) and *Vegetation Treatments Using Herbicides on Bureau of Land Management Lands in 17 Western States Programmatic EIS* (PEIS) (BLM 2007). In accordance with 43 CFR 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, ERAs for the following herbicide and adjuvant uses prepared by the USFS will be incorporated by reference:

- 2,4-D
- Chlorsulfuron
- Clopyralid
- Dicamba
- Glyphosate
- Imazapic
- Imazapyr
- Metsulfuron methyl
- Picloram
- Sethoxydim
- Sulfometuron methyl
- Triclopyr
- Nonylphenol polyethylate (NPE) based surfactants

As a basis for completing "Chemical Profiles" for approving or disapproving refuge PUPs, ERAs for the following herbicide uses as well as evaluation of risks associated with pesticide degradates and adjuvants prepared by the BLM will 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*)

D.7.2.7 ASSUMPTIONS FOR ERAS

There are several assumptions involved with the ecological risk assessment process for terrestrial and aquatic organisms associated with utilization of the EPA's (2004) process. These assumptions may be risk neutral or may lead to an over- or underestimation 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 are not be evaluated by ERAs. 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 (EPA 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 are 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 are 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 are 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 is 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, these data are 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 is 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 produces a maximum estimate of exposure for risk characterization. This assumption could likely lead to an overestimation of exposure for species that do not permanently and exclusively occupy the treated area (EPA 2004).
- Exposure through incidental ingestion of pesticide contaminated soil is not considered in the EPA risk assessment protocols. Research suggests <15% of the diet can consist of incidentally ingested soil depending upon species and feeding strategy (Beyer, Connor, and Gerould 1994). An assessment of pesticide concentrations in soil compared to food item categories in the Kanaga nomogram indicates incidental soil ingestion would 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 of a contaminated food source (Fletcher, Nellessen, and Pfleeger 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 EPA 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 EPA (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 one percent 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 American Society of Agricultural Engineers (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 pertains to those pesticides with a high vapor pressure. The EPA 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 EPA 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 EPA 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 the 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 EPA is actively developing protocols to quantify drinking water exposures from puddles and dew. If and when protocols are formally established by the EPA 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 EPA relies on Fletcher et al. (1994) for setting the assumed pesticide residues in wildlife dietary items. The EPA (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 et al.'s (1994) research suggests that the pesticide active ingredient residue assumptions used by the EPA represent a 95th percentile estimate. However, research conducted by Pfleeger et al. (1996) indicates EPA residue assumptions for short grass was not exceeded. Baehr and Habig (2000) compared EPA residue assumptions with distributions of measured pesticide residues for the EPA'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 effects 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 is 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) are not be considered for ecological risk assessment. The water body is assumed to capture all pesticide active ingredients entering as runoff, drift, and adsorbed to eroded soil particles. It is also 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 lead to a near maximum possible water-borne concentration. However, this assumption would not account for the 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 is no averaging time for exposure. An instantaneous peak concentration is 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 is likely 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 EPA 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 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 effects 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 will be included, either quantitatively or qualitatively, in this risk assessment process.
- EPA 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, EPA 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.

D.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 EPA (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 EPA 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 SDSs 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 is 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 is only 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 USFS (2005) found that mixtures of pesticides used in land (forest) management likely do 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 (Agency for Toxic Substances and Disease Registry 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 EPA's IRIS, the Hazardous Substance Data Bank, the Registry of Toxic Effects of Chemical Substances [RTECS]).
- EPA'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).
- SDSs 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 EPA-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 will 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 will 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 could 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 EPA 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.

D.7.4 Determining Effects to Soil and Water Quality

The approval process for pesticide uses considers 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, Jenkins, and Vogue 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 runoff or wind; and/or
- Dissolve in water that can be subjected to runoff 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 include the following: persistence, sorption coefficient (K_{oc}), groundwater ubiquity score (GUS), and solubility.

Persistence, which is expressed as half-life (t½), represents the length of time required for 50 percent 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, Jenkins, and Vogue 1996). Half-life data are usually available for aquatic and terrestrial environments.

Another measure of pesticide persistence is dissipation time (DT_{50}). It represents the time required for 50 percent 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 are 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 are 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 have greater potential to move from the application site (off-site movement).

The degree of pesticide adsorption to soil particles and organic matter (Kerle, Jenkins, and Vogue 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 K_{oc} 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]. Pesticides with solubility <0.1 ppm are virtually insoluble in water, 100–1000 ppm are moderately soluble, and >10,000 ppm highly soluble (USGS 2000). As pesticide solubility increases, there would be greater potential for off-site movement.

The 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.

$$GUS = \log_{10}(t_{1/2}) \times [4 - \log_{10}(K_{oc})]$$

The potential pesticide movement rating is based upon its GUS value. Pesticides with a GUS <0.1 are considered to have an extremely low potential to move toward groundwater. Values of 1.0–2.0 are low, 2.0–3.0 are moderate, 3.0–4.0 are high, and >4.0 are considered to 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 ppm. Solubility is useful as a comparative measure because pesticides with higher values are more likely to move by runoff or leaching. GUS, water solubility, $t^{1/2}$, and K_{oc} values are available for selected pesticides from the Oklahoma State University 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 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 pore size lowers likelihood and rate water moves through the soil profile. Clay also serves to adsorb (bind) pesticides to soil particles. Soils with high clay content absorb more pesticide than soils with relatively low clay content. In contrast, sandy soils with coarser texture and lower water holding capacity 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 allow for less restricted flow of water through the soil profile resulting in greater infiltration.
- Organic matter is the single most important factor affecting pesticide adsorption in soils. Many pesticides are adsorbed to organic matter which reduces their rate of downward movement through the soil profile. Also, soils high in organic matter tend to hold more water, which may make less water available for leaching.
- Soil moisture affects how fast water moves through the soil. If soils are already wet or saturated before rainfall or irrigation, excess moisture runoff rather than infiltrate into the soil profile. Soil moisture also influences microbial and chemical activity in soil, which affects pesticide degradation.
- Soil pH influences 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 are sandy soils with low organic matter. In contrast, the least vulnerable soils are 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) will 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 runoff and leaching considers 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 is 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 has 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 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 decreases 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 affects the potential for surface runoff and the intensity of runoff. Steeper slopes have greater potential for runoff following a rainfall event. In contrast, soils that are relatively flat have little potential for runoff, except during intense rainfall events. In addition, soils in lower areas are more susceptible to leaching as a result of receiving excessive water from surrounding higher elevations.
- Depth to groundwater is 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 have less distance to travel to reach groundwater. Shallower water tables that persist for longer periods are 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 persists. In some situations, a hard pan exists above the water table that would prevent pesticide contamination from leaching.

D.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 is 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 $I<10$ have a low potential to volatilize; whereas, pesticides with $I>1,000$ have a high potential to volatilize (Oregon State University 1996). Vapor pressure values for pesticides are usually available in the pesticide product SDS or the USDA Agricultural Research Service (ARS) pesticide database.

D.7.6 Preparing a Chemical Profile

The following instructions are used by Service personnel to complete Chemical Profiles for pesticides. Specifically, profiles are prepared for pesticide active ingredients (e.g., glyphosate, imazapic) that are contained in one or more trade name products that are registered and labeled with EPA. All information fields under each category (e.g., Toxicological Endpoints, Environmental Fate) are completed for a Chemical Profile. If no information is available for a specific field, then “No data are available in references” is recorded in the profile. Available scientific information is used to complete Chemical Profiles. Each entry of scientific information is shown with applicable references.

Completed Chemical Profiles provide a structured decision-making process utilizing quantitative assessment/screening tools with threshold values (where appropriate) that are used to evaluate potential biological and other environmental effects to refuge resources. For ERAs 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 D.5), the proposed pesticide’s use in a PUP has 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 includes a lower application rate than the maximum labeled rate in order to protect refuge resources. As necessary, Chemical Profiles are 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) are 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 will be approved for pesticides with Chemical Profiles where there would be no exceedances of threshold values. However, BMPs are identified for some screening tools to minimize/eliminate potential effects (exceedance of the threshold value) as a basis for approving PUPs.

Date: Service personnel record the date when the Chemical Profile is completed or updated. Chemical Profiles (e.g., currently approved pesticide use patterns) are periodically reviewed and updated, as necessary. The most recent review date is recorded on a profile to document when it was last updated.

Trade Name(s): Service personnel 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 record a trade name for each pesticide product with the same active ingredient.

Common chemical name(s): Service personnel record the common name(s) listed on the pesticide label or safety data sheet (SDS) 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 SDS, Section 2: Composition/Information on Ingredients. A Chemical Profile is completed for each active ingredient.

Pesticide Type: Service personnel record the type of pesticide for an active ingredient as one of the following: herbicide, desiccant, fungicide, fumigant, growth regulator, insecticide, piscicide, or rodenticide.

EPA Registration Number(s): This number (EPA Reg. No.) appears on the title page of the label and SDS, Section 1: Chemical Product and Company Description. It is not the EPA Establishment Number that is usually located near it. Service personnel record the EPA Reg. No. for each trade name product with an active ingredient based upon PUPs.

Pesticide Class: Service personnel 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 SDS. The SDS table listing components usually contains this number immediately prior to or following the % composition.

Other Ingredients: From the most recent SDS for the proposed pesticide product(s), Service personnel 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), TSCA, OSHA, State Right-to-Know, or other listed authorities. These are usually found in SDS 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 record this information in the Chemical Profile by trade name. SDS(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).

D.7.7 Toxicological Endpoints

Toxicological endpoint data is collected for acute and chronic tests with mammals, birds, and fish. Data is recorded for species available in the scientific literature. If no data are found for a particular taxonomic group, then "No data are available in references" is recorded as the data entry. Throughout the Chemical Profile, references (including toxicological endpoint data) are cited using parentheses (#) following the recorded data.

Mammalian LD_{50}: For test species in the scientific literature, Service personnel 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 are used as a toxicological endpoint for dose-based RQ calculations to assess acute risk to mammals (see Table D-1 in Section D.7.1).

Mammalian LC_{50}: For test species in the scientific literature, Service personnel 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 are used as a toxicological endpoint for diet-based RQ calculations to assess acute risk (see Table D-1 in Section D.7.1).

Mammalian Reproduction: For test species listed in the scientific literature, Service personnel 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 are used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table D-1 in Section D.7.1).

Avian LD_{50}: For test species available in the scientific literature, Service personnel 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 are used as a toxicological endpoint for dose-based RQ calculations to assess acute risk (see Table D-1 in Section D.7.1).

Avian LC_{50}: For test species available in the scientific literature, Service personnel 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 are used as a toxicological endpoint for dietary-based RQ calculations to assess acute risk (see Table D-1 in Section D.7.1).

Avian Reproduction: For test species available in the scientific literature, Service personnel 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 are used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table D-1 in Section D.7.1).

Fish LC_{50}: For test freshwater or marine species listed in the scientific literature, Service personnel 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 are used as a toxicological endpoint for RQ calculations to assess acute risk (see Table D-1 in Section D.7.1).

Fish Early Life Stage (ELS)/Life Cycle: For test freshwater or marine species available in the scientific literature, Service personnel 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) are used as a toxicological endpoint for RQ calculations to assess chronic risk (see Table D-1 in Section D.7.1).

Other: For test invertebrate as well as non-vascular and vascular plant species available in the scientific literature, Service personnel 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.

D.7.8 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 EPA 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 effects 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.

D.7.9 ENVIRONMENTAL FATE

D.7.9.1 WATER SOLUBILITY

Service personnel 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 are categorized as one of the following: insoluble <0.1 ppm, moderately soluble = 100 to 1000 ppm, highly soluble >10,000 ppm (USGS 2000). As pesticide S_w increases, there is a greater potential to degrade water quality through runoff and leaching.

S_w is used to evaluate potential for bioaccumulation in aquatic species [see **Octanol-Water Partition Coefficient (K_{ow})** below].

D.7.9.2 SOIL MOBILITY

Service personnel 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 are used in evaluating the potential to degrade groundwater by leaching (see **Potential to Move to Groundwater** below).

D.7.9.3 SOIL PERSISTENCE

Service personnel record values for soil half-life (t½), 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 t½ value, soil persistence is categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days (Kerle, Jenkins, and Vogue 1996).

Threshold for Approving PUPs:

If soil t½ ≤100 days, then a PUP will be approved without additional BMPs to protect water quality.

*If soil t½ >100 days, then a PUP will only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following could be included in the **Specific Best Management Practices (BMPs)** section to minimize potential surface runoff 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 t½ values are used in evaluating the potential to degrade groundwater by leaching (see **Potential to Move to Groundwater** below).

D.7.9.4 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 t½ describes the rate for degradation only. As for t½, units of dissipation time are usually expressed in days. Field dissipation time is the preferred data for use to estimate pesticide concentrations in the environment because it is based upon field studies compared to soil t½, which is derived in a laboratory. However, soil t½ is the most common persistence data available in the published literature. If field dissipation data are not available, soil half-life data is used in a Chemical Profile. The average or representative half-life value of most important degradation mechanism is selected for quantitative analysis for both terrestrial and aquatic environments.

Based upon the DT_{50} value, environmental persistence in the soil also is 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 will be approved without additional BMPs to protect water quality.

If soil DT_{50} >100 days, then a PUP will only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following could be included in the ***Specific Best Management Practices (BMPs)*** *section to minimize potential surface runoff 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 t½) are used in evaluating the potential to degrade groundwater by leaching (see Potential to Move to Groundwater below), if available.

D.7.9.5 AQUATIC PERSISTENCE

Service personnel record values for aquatic t½, which represents the length of time required for 50% of the deposited pesticide to degrade (completely or partially) in water. Based upon the t½ value, aquatic persistence is categorized as one of the following: non-persistent <30 days, moderately persistent = 30 to 100 days, and persistent >100 days (Kerle, Jenkins, and Vogue 1996).

Threshold for Approving PUPs:

If aquatic t½ ≤100 days, then a PUP will be approved without additional BMPs to protect water quality.

If aquatic t½ >100 days, then a PUP will only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following could be included in the ***Specific Best Management Practices (BMPs)*** *section to minimize potential surface runoff 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.

D.7.9.6 AQUATIC DISSIPATION

Dissipation time (DT_{50}) represents the time required for 50% of the deposited pesticide to degrade or move (dissipate); whereas, aquatic t½ describes the rate for degradation only. As for t½, units of dissipation time are usually expressed in days. Based upon the DT_{50} value, environmental persistence in aquatic habitats also is 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 will be approved without additional BMPs to protect water quality.

If aquatic DT_{50} >100 days, then a PUP will only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following could be included in the ***Specific Best Management Practices (BMPs)*** *section to minimize potential surface runoff 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.

D.7.9.7 POTENTIAL TO MOVE TO GROUNDWATER

$GUS = \log_{10}(\text{soil t ½}) \times [4 - \log_{10}(K_{oc})]$. If a DT_{50} value is available, it is used rather than a t ½ value to calculate a GUS score. Based upon the GUS value, the potential to move toward groundwater is 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 will be approved without additional BMPs to protect water quality.

If GUS >4.0, then a PUP will only be approved with additional BMPs specifically to protect water quality. One or more BMPs such as the following could be included in the ***Specific Best Management Practices (BMPs)*** *section to minimize potential surface runoff 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.

D.7.9.8 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 is recorded by Service personnel in exponential form ($I \times 10^{-7}$), where I represents a vapor pressure index. In general, pesticides with $I<10$ have low potential to volatilize; whereas, pesticides with $I > 1{,}000$ have a high potential to volatilize (Oregon State University 1996). Vapor pressure values for pesticides are usually available in the pesticide product SDS or the USDA ARS pesticide database (see References).

Threshold for Approving PUPs:

If $I \leq 1{,}000$, then a PUP will be approved without additional BMPs to minimize drift and protect air quality.

If $I > 1{,}000$, then a PUP will only be approved with additional BMPs specifically to minimize drift and protect air quality. One or more BMPs such as the following could 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°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.

D.7.9.9 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} is used to assess potential for a pesticide to bioaccumulate in tissues of aquatic species (e.g., fish). If $K_{ow} > 1{,}000$ or $S_w < 1$ mg/L and soil $t_{½} > 30$ days, then there is a high potential for a pesticide to bioaccumulate in aquatic species such as fish (USGS 2000).

Threshold for Approving PUPs:

If there is not a high potential for a pesticide to bioaccumulate in aquatic species, then the PUP will be approved.

If there is a high potential to bioaccumulate in aquatic species (K_{ow}>1,000 or S_w<1 mg/L and soil t½>30 days), then the PUP will not be approved, except under unusual circumstances where approval would only be granted by the Washington Office.

D.7.9.10 Bioaccumulation/Bioconcentration

The physiological process where pesticide concentrations in tissue increase in biota because they are taken and stored at a faster rate than they are metabolized or excreted. The potential for bioaccumulation is evaluated through bioaccumulation factors (BAFs) or bioconcentration factors (BCFs). Based upon BAF or BCF values, the potential to bioaccumulate is recorded as one of the following: low – 0 to 300, moderate – 300 to 1,000, or high >1,000 (Calabrese and Baldwin 1993).

Threshold for Approving PUPs:

If BAF or BCF≤1,000, then a PUP will be approved without additional BMPs.

If BAF or BCF>1,000, then a PUP will not be 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 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 is 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.

D.7.9.11 Estimated Environmental Concentration

An estimated environmental concentration (ECC) represents potential exposure to fish and wildlife (birds and mammals) from using a pesticide. EECs is derived by Service personnel using an EPA screening-level approach (EPA 2004). For each max application rate [see description under **Max Application Rates (acid equivalent)**], Service personnel record 2 EEC values in a Chemical Profile; these 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.

D.7.9.12 Presumption of Unacceptable Risk/Risk Quotients

Service personnel calculate and record acute and chronic 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 represent the worst-case assessment for ecological risk. See Section D.7.2 for discussion regarding the calculations of RQs.

For aquatic assessments associated with habitat management treatments, RQ calculations are based upon selected acute and chronic toxicological endpoints for fish and the EEC are derived from Urban and Cook (1986) assuming 100% overspray to an entire one-foot deep water body using the max application rate (ae basis [see above]).

For aquatic assessments associated with cropland/facilities maintenance treatments, RQ calculations are done by Service personnel based upon selected acute and chronic toxicological endpoints for fish and an EEC are 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 D.7.2 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 are done by Service personnel based upon dietary exposure, where the "short grass" food item category represent the worst-case scenario. For terrestrial spray applications associated with habitat management and cropland/facilities maintenance treatments, exposure (EECs and RQs) are determined using the Kanaga nomogram method through the EPA's T-REX version 1.2.3. T-REX input variables 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 D.7.2 for the procedure that is used to calculate RQs.

All calculated RQs in both tables are compared with Levels of Concern (LOCs) established by EPA (see Table D-2 in Section D.7.2). If a calculated RQ exceeds an established LOC value (in brackets inside the table), then there is a potential for an acute or chronic effect (unacceptable risk) to federally listed species and nonlisted species. See Section D.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 will be approved without additional BMPs.

If RQs>LOCs, then a PUP will 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 could 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.

D.7.9.13 Specific Best Management Practices (BMPs)

Service personnel 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 are based upon scientific information documented in previous data fields of a Chemical Profile. Where necessary and feasible, these specific practices are included in PUPs as a basis for approval.

If there are no specific BMPs that are appropriate, then Service personnel can 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 D.4 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 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, U.S. 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. Food and Agriculture specifications and evaluations for plant protection products. Pesticide Management Unit, Plant Protection Services, Food and Agriculture Organization, United Nations. (http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmps/manual/en/)
5. Human health and ecological risk assessments. Pesticide Management and Coordination, Forest Health Protection, U.S. Department of Agriculture, U.S. Forest Service.
6. Pesticide Fact Sheets. Published by Information Ventures, Inc. for Bureau of Land Management, Department of Interior; Bonneville Power Administration, U.S. Department of Energy; and Forest Service, U.S. Department of Agriculture.
7. Pesticide Fact Sheets. National Pesticide Information Center. (http://npic.orst.edu/npicfact.htm)
8. Pesticide Fate Database. U.S. Environmental Protection Agency, Washington, D.C. (http://www.epa.gov/opp00001/science/efed_databasesdescription.htm).
9. 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.
10. Registered Pesticide Products (Oregon database). Oregon Department of Agriculture. (http://oda.state.or.us/dbs/pest_productsL2K/search.lasso)

11. Regulatory notes. Pest Management Regulatory Agency, Health Canada, Ontario, Canada. (http://www.hc-sc.gc.ca/pmra-arla/)

12. Reptile and Amphibian Toxicology Literature. Canadian Wildlife Service, Environment Canada, Ontario, Canada. (http://publications.gc.ca/site/eng/96287/publication.html)

13. Specific Chemical Fact Sheet – New Active Ingredients, Biopesticide Fact Sheet and Registration Fact Sheet. U.S. Environmental Protection Agency, Washington, DC. (http://www.epa.gov/oppbppd1/biopesticides/)

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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 $LC_{5}0$:	
Fish early life stage (ELS)/Life Cycle:	
Other:	

Ecological Incident Reports

Environmental Fate

Water solubility (S_w):	
Soil Mobility (K_{oc}):	
Soil Persistence (t½):	
Soil Dissipation (DT_{50}):	
Aquatic Persistence (t½):	
Aquatic Dissipation (DT_{50}):	
Potential to Move to Groundwater (GUS score):	
Volatilization (mm Hg):	
Octanol-Water Partition Coefficient (K_{ow}):	
Bioaccumulation/Bioconcentration:	**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 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 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, 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.

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APPENDIX E. IMPLEMENTATION

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E.1 OVERVIEW

Implementation of the WMWCP will require increased funding, which will be sought from a variety of sources including congressional allocations and public and private partnerships and grants. There are no guarantees that additional federal funds will be made available to implement any of these projects. Activities and projects identified will be implemented as funds become available.

The WMWCP identifies several projects to be implemented over the next 15 years. Some of these projects are included in the Refuge Management Information Systems (RONS–Refuge Operational Needs System or SAMMS–Service Asset Maintenance Management System) which are used to request funding from Congress. Upon completion of the WMWCP, new projects that are needed to meet Hanalei National Wildlife Refuge (NWR or Refuge) goals and objectives and legal mandates will be entered into RONS documents or SAMMS databases. Currently, a backlog of maintenance needs exists on the Refuge. Prioritized staffing needs identified in RONS will be necessary to implement the WMWCP 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 would be sought for these projects through a variety of sources.

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 responses to management practices. Actual monitoring and evaluation procedures will be detailed in an Inventory and Monitoring Plan.

E.2 COSTS TO IMPLEMENT WMWCP

The following sections detail both one-time and recurring costs for various projects as described within the WMWCP. One-time costs (Table E-1) reflect the initial costs associated with a project, such as the purchase of equipment, contracting services, construction, or other activity. Recurring costs (Tables E-2 and E-3) reflect the future operational and maintenance costs associated with the project. The potential funding sources identify both base funding that is appropriated by Congress as part of the Refuge's budget (e.g., 126X series such as 1261, 1262, etc.) and grants/external funds received (e.g., Ecological Services [ES], Inventory and Monitoring [I&M], North American Wetlands Conservation Act [NAWCA]). Note that for both Tables E-1 and E-2, only costs the Refuge is directly responsible for have been identified. For partnering or cost-sharing strategies identified, due to the unknown associated costs and timing, these figures have not been identified in the tables below.

E.2.1 ONE-TIME COSTS

One-time costs have a start-up cost associated with them, such as purchasing equipment necessary for wildlife and habitat monitoring or designing and testing a monitoring protocol. Some cost estimates are for projects that can be completed in three 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 would be sought through increases in Refuge base funding, special project funds, and grants. One-time costs in Table E-1 are also associated with projects such as habitat restoration, research, and infrastructure developments. In many cases, new research projects, because of their relatively high initial establishment cost, are considered one-time projects and include costs of contracting services or hiring a temporary staff position for the short-term project. Some project costs are estimated from past projects and RONS or SAMMS proposals. Others are not yet in any project database but their costs have been estimated, particularly if the scope of the project is unknown at this time due to lack of baseline data.

TABLE E-1. ONE-TIME COSTS (5-YEAR INTERVAL TIMELINE)

WMWCP Objective and Strategy	*Estimated Cost*	*Potential Fund Source*[1]
Obj. 1.2: Construct rotational managed wetland (moist-soil) units (1–10 acre in size)	$100,000	Deferred maintenance (DM), 1113 (ES), NAWCA
Obj. 1.2: Install water delivery system and water control structures to manage water levels (≥1 riser per unit)	$30,000	DM, 1113 (ES), NAWCA
Obj. 1.2: Contour pond bottoms to create variable topography (includes units w/fine textured soils)	$20,000	DM, 1113 (ES), NAWCA
Obj. 1.2: Create sloughs to promote drainage	$20,000	DM, 1113 (ES), NAWCA
Obj. 1.3: Rehabilitate dike around DU ponds (2023)	$1,000,000	DM
Obj. 1.3: Rehabilitate main irrigation intake (2019–2020)	$10,000,000	DM, disaster relief funds
Obj. 2.1: Equipment purchase costs to support reduction of pest hau (*Hibiscus tiliaceus*) by 2–5 acre/year in priority areas (e.g., blocking drainage, potential cause of accelerated erosion)	TBD	TBD
Obj. 2.2: Install water delivery system (~100 feet of six-inch pipeline and supply valves)	TBD	TBD
Obj. 2.2: Build and maintain 1–1.5 miles of new protective fencing (2029)	$60,000	DM, 1113 (ES)
Obj. 2.2: Establish ≥150-foot riparian/wildlife buffer zones	$10,000	DM, 1113 (ES), NAWCA
Obj. 1.2 and 2.2: Erection of fences and gates and infrastructure for in-pasture water supplies to support cooperative grazing (see Appendix B)	$6,500	TBD
To support strategies, additional equipment costs include vehicle for staff and fieldwork. Average cost is $35,000.	$105,000 (3 vehicles)	126x
To support strategies, one-time facilities costs include additional housing and office space.	$100,000	DM, 1262

[1]ISST- Invasive Species Strike Team; TBD – to be determined; DM in this table only is Deferred Maintenance

E.2.2 ANNUAL OPERATIONAL (RECURRING) COSTS

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 three years. Operational costs use base funding in Service fund code 1260.

Table E-2 displays projected annual operating costs to implement strategies under the WMWCP. The WMWCP will require increased funding for new or expanded habitat management and restoration activities and new monitoring needs. This table includes such things as salary and operational expenditures such as travel, training, supplies, utilities, and maintenance costs. Project costs listed in Table E-2 include administrative support for all programs and projects as well as permanent and 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.

TABLE E-2. OPERATIONAL (RECURRING) COSTS (ANNUAL, OVER THE ENTIRE 15-YEAR PLAN)

WMWCP Objective and Strategy	*Estimated Costs*	*Potential Fund Source*[1]
Habitat management (Goal 1): ▪ Mowing, disking, rototilling, and water level management to set back wetland plant succession and provide suitable habitat structure and function ▪ Use integrated pest management (IPM) strategies including mechanical/physical (e.g., mowing, brush-cutting, excavation, prescribed fire), cultural (e.g., water levels), chemical (herbicides), biological, and other suitable techniques to control pest/undesirable plants (Appendix D) ▪ Pulse water/flood to promote vegetation and invertebrates ▪ Flood after water pulse to break down vegetation that promotes invertebrate production growth ▪ Slow drawdown, as needed to control pest fish, concentrate invertebrates, and promote invertebrate/plant growth ▪ Maintain minimal water level fluctuations during laying and incubation ▪ Flood for pre-breeding (as a follow-up to full treatment) ▪ Maintain dikes and ditches (mowing and using IPM strategies to control pest/undesirable plants)	$100,000	126x, RO, ISST, ES, KPNHA, grants
Threat management (Goals 1 and 2): ▪ Live-trapping, shooting, and bait stations to exclude or remove vertebrate pests that prey on threatened or endangered waterbirds ▪ Avian botulism surveillance and response ▪ Live-trapping and shooting feral mallards and their hybrids ▪ Maintain fences to protect wetland management units from feral pigs and dogs	$90,000	126x, ES, KPNHA, grants, ISST
Obj. 2.1: Reduction of pest hau by 2–5 acre/year in priority areas (e.g., blocking drainage, potential cause of accelerated erosion)	$20,000	126x, ISST

WMWCP Objective and Strategy	*Estimated Costs*	*Potential Fund Source*[1]
Obj. 1.2 and 2.2: Explore use of seasonal livestock grazing (through CAA)	$15,000	126x (cooperator for seasonal livestock grazing)
Obj. 2.2: Mowing of grassy sedgelands to set back plant succession and provide suitable habitat structure and function	$10,000	126x
Obj. 2.1: Develop and implement water quality and flow monitoring program	TBD (design); $15,000 (implementation)	I&M, WRB, USGS, NRCS, 126x, Grants, TBD

[1]KPNHA – Kīlauea Point Natural History Association; NRCS- Natural Resources Conservation Service; RO – Regional Office; TBD – to be determined; USGS - US Geological Survey; WRB – Water Resources Branch;

E.2.3 STAFFING

To fulfill the National Wildlife Refuge System (NWRS or Refuge System) mission, Refuge purpose, and other legal mandates, a full and skilled workforce must be fostered that operates with integrity to achieve their greatest potential in an environment that promotes appreciation, team work, efficient business practices, and effective communication. In order to develop this workforce, the following staffing costs have been identified. Costs include salary and 18.43 percent cost of living adjustment (COLA), benefits at 35 percent, and management capability (MC) at 35 percent, applicable only to federal employees. Note that (*) positions are Kaua‘i National Wildlife Refuge Complex (KNWRC or Complex)-wide. As a result, unless otherwise stated, for Complex-wide positions, staffing cost identified is equally proportioned among the three refuges in the Complex.

TABLE E-3. STAFFING COSTS TO IMPLEMENT WMWCP (ANNUAL)

Staff[1]	*Cost*	*Potential Funding Source*
Project Leader (GS-13)* - Permanent (40% FTE)	$74,000	1261, 1263
Deputy Project Leader (GS-12)* - Permanent (40% FTE)	$62,230	1261
Wildlife Biologist (GS-11)* - Permanent (40% FTE)	$51,920	1261
Wildlife Refuge Specialist (GS-11), Site Manager	*$129,800*	*1261*
Wildlife Refuge Specialist – Permits (GS-7/9) (50% FTE)	*$44,674*	*1261, 8081*
Visitor Services Manager (GS-12)* - Permanent (20% FTE)	$31,115	1263
Environmental Education/ Interpretation Specialist (GS-5/7) (30% FTE)	$21,242	TBD
Biological Science Technician (Predator Control) (GS-07, Term)* (40% FTE)	$35,739	ISST
Biological Science Technician (GS-5/7/9, Term) (40% FTE)	*$28,322*	*1261*
2 Kupu biological interns*	$60,000	1261
Engineer Equipment Operator (Supervisory) (WG-10)* (40% FTE)	$50,983	1262
Maintenance – Mechanic/Facilities (WG-7/8) (30% FTE)	$31,242	1262
Engineer Equipment Operator (WG-7/8) (40% FTE)	*$41,657*	*1262*
Maintenance Worker (WG-06)	$96,154	1262
Maintenance Worker (WG-06) (50% FTE)	$48,077	1262
Law Enforcement Officer (GL-09)* (40% FTE)	$44,175	1264

[1]FTE – full time equivalent

Note that (*) positions are Complex-wide. Unless otherwise stated, staffing cost for Complex-wide positions are equally proportioned among the three refuges in the Complex. Italics denote a new position.

Annual personnel costs = 2019 step 5 salary for appropriate GS or GL level (including locality payment of 18.43%) x 35% for benefits. For WG, 2019 step 3 hourly rate x 35% for benefits. For ladder positions, the lowest grade is assumed.

Overhead costs (management capability) = salary + benefit costs x 0.35. Overhead expenses include building rent, utilities, equipment and supplies, and support personnel, and do not include salary-related benefits.

E.3 PARTNERING OPPORTUNITIES

Partnerships are an important component of the implementation of this WMWCP. None of the Kaua‘i refuges have ever been fully funded to accomplish adequate refuge management. Towards this end, we rely on partnering opportunities to assist with this shortfall, both in terms of funding and personnel. Partnering opportunities are reflected in the goals, objectives, and strategies identified in Chapter 4. Coordinated partnership efforts relevant to the WMWCP focus on species and habitat restoration and protection; and surveys, inventories, and research. Refuge staff will work to strengthen existing partnerships and will actively look for new partnerships to assist in achieving the goals, objectives, and strategies in this WMWCP.

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National Wildlife Refuge System Information
1 800/344 WILD

August 2020

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

Cover:
Hanalei National Wildlife Refuge. Photo: USFWS
'Alae 'ula (Hawaiian comon gallinule). Photo: Gary Kramer/USFWS
Nēnē (Hawaiian goose). Photo: Gary Kramer/USFWS
Koloa maoli (Hawaiian duck). Photo: Gary Kramer/USFWS