Hawaiian Bird Conservation Action Plan

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PACIFIC RIM CONSERVATION
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TABLE OF CONTENTS

Cover photos: clockwise from top left: ‘Akiapōlā’au, Laysan Albatrosses, Palila, Laysan Duck, Brown Boobies, ‘I’iwi, O’ahu ‘Elepaio, and Bristle-thighed Curlew. All photos © Eric VanderWerf except ‘I’iwi © Jack Jeffrey.

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INTRODUCTION

The Hawaiian Islands are home to a unique assemblage of bird species, including at least 113 endemic species or subspecies found nowhere else, some of the largest tropical seabird colonies in the world, and an assortment of migratory and resident waterfowl and shorebirds. The Hawaiian honeycreepers (Drepanidinae), with their remarkable array of bill sizes and shapes that evolved from a single species of ancestral finch (Fringillidae), are one of the most spectacular examples of evolution and adaptive radiation (Pratt 2005). The Northwestern Hawaiian Islands support some of the most intact marine habitats on earth and provide nesting sites for 14 million seabirds of 21 species. Yet the Hawaiian Islands and the birds they support are literally and figuratively off the radar of many North American ornithologists, conservation biologists, law makers, and the general public.

Sadly, 71 bird species are known to have gone extinct in Hawaii, and many remaining birds are imperiled. At least 48 bird extinctions followed the arrival of Polynesian people in Hawai'i starting about 800 years ago, and at least 23 more species have been lost since the arrival of Europeans in 1778 (Olson and James 1982, Scott et al. 2001, Wallace and Leonard 2011, Wilmshurst et al. 2011). Of the 42 surviving endemic bird species and subspecies, 33 are listed under the U.S. Endangered Species Act (ESA). Hawaii is often ignominiously called the extinction capital of the United States, if not the world (Wallace and Leonard 2011). Worse, some extant Hawaiian birds are considered basket cases because of the gloomy extinction history in Hawai'i or because their threats appear so daunting. In reality, the threats faced by many Hawaiian birds are manageable, though long-term commitment to their conservation is needed to ensure their survival (Reed et al. 2012).

Multiple factors have contributed to the decline and extinction of Hawaiian birds, and these same factors continue to threaten the remaining species. Habitat loss and degradation has been perhaps the most pervasive threat and has affected all species on all islands. Complete loss of habitat is no longer a serious problem because most areas in the Hawaiian Islands that are important to birds are now legally protected to at least some degree (VanderWerf 2008), but some "protected" areas receive little or no management and birds in these areas continue to be at risk from habitat degradation by invasive alien plants and non-native ungulates, non-native diseases, and non-native predators. Habitat protection may be largely sufficient to ensure the continued survival of birds in continental areas, but in the Hawaiian Islands, New Zealand, and other oceanic islands, habitat protection alone is not sufficient (Clout 2001). There are a few encouraging examples of Hawaiian birds evolving natural responses to alien pathogens and predators (Woodworth et al. 2005, Foster et al. 2007, VanderWerf 2012), but many islands birds require active management of alien predators, invasive alien plants, and diseases even within protected habitats.

The effects of global climate change are expected to be particularly severe for many Hawaiian birds, almost all of which were categorized as having high vulnerability to climate change (http://www.stateofthebirds.org/2010/results-for-species/Hawaii_Scores.pdf). These effects can be grouped into four broad categories: 1) inundation of low-lying islands resulting from sea level rise, storm surge, and high wave events associated with increased frequency and intensity of storms (Vermeer and Rahmstorf 2009, Krause et al. 2012). Several endemic species and many seabirds occur on atolls that have an average elevation of just a few meters. 2) Inundation and incursion of salt water into coastal fresh water and brackish wetlands used for foraging and nesting by five waterbirds endemic to the main Hawaiian Islands. These waterbirds generally prefer fresh water and are precariously concentrated in small wetlands along the narrow coastal shelf (USFWS 2009). 3) Avian diseases that are transmitted by non-native mosquitoes, particularly avian malaria (*Plasmodium relictum*) and avian pox-virus (*Poxvirus avium*), have decimated the Hawaiian avifauna, and today most endemic Hawaiian passerines are restricted to forests above 1,500 meters in elevation, where cooler temperatures inhibit the survival and reproduction of mosquitoes and malaria parasites (van Riper et al. 1986, Atkinson and LaPointe 2009a). Rising temperatures are anticipated to exacerbate the threat of disease by facilitating the spread of mosquitoes into higher elevations (Benning et al. 2002, Harvell et al. 2002, Atkinson and LaPointe 2009b). Rising temperatures and declining precipitation also could facilitate outbreaks of avian botulism in wetland habitats (Work et al. 2010). 4) Rising temperatures, decreasing precipitation, and changing atmospheric circulation patterns, particularly elevation of the inversion layer, could result in long-term shifts in distribution of forest habitats vital to many Hawaiian forest birds and hinder reforestation efforts (Loope and Giambelluca 1998).

Conservation biologists have worked hard in Hawai'i to manage these threats and recover the imperiled avifauna (Scott et al. 2001, Pratt et al. 2009), however, it can be argued that a lack of support for conservation measures has limited conservation successes (Restani and Marzluff 2002, Male and Bean 2005, Leonard 2008). Despite the uniqueness and urgent conservation needs of many Hawaiian birds, they have received little attention or funding compared to their continental counterparts. There are 33 Hawaiian bird taxa listed under the ESA, more than one-third of all birds listed in the U.S. (Appendix 1). Yet from 1996-2004, Hawaiian bird taxa listed under the ESA received on average 15 times less funding than North American species listed under the ESA and only 4% of total recovery expenditures (Leonard 2008). None of the top-20 funded bird species were Hawaiian, and the Red-cockaded Woodpecker (*Picoides borealis*) received five times more funding than all Hawaiian birds combined (Leonard 2008). This funding discrepancy was not related to the urgency and need for recovery efforts. Compared to mainland taxa, a higher percentage of listed Hawaiian birds were full species rather than sub-species, a higher percentage were endangered rather than threatened, and the mean recovery priority ranks assigned by the USFWS were similar in Hawaiian and North American birds. If species such as the California Condor (*Gymnogyps californianus*) and Whooping Crane (*Grus americana*) had received as little funding as Hawaiian birds, they probably would be extinct today. The Cerulean Warbler (*Dendroica cerulea*) has received far more attention than Hawaiian birds, even though it is not listed under the ESA and is more numerous than all but two Hawaiian forest birds (Appendix 1), with a population of about 570,000 birds (USFWS 2006). These facts are not meant to be critical of, or detract from, conservation efforts for other bird species, but rather to illustrate the relative lack of attention and funding Hawaii's birds have received.

The disparity between North American and Hawaiian birds also has extended to legal protection. Until recently, most endemic Hawaiian birds were not protected under the Migratory Bird Treaty Act (MBTA). This situation was largely rectified in 2010 when the list of species included under the MBTA was revised (USFWS 2010). In that revision, 23 species of Hawaiian honeycreepers (Drepanidinae), the Millerbird (*Acrocephalus familiaris*), and 28 other species found only on other U.S. Pacific Islands were added to the MBTA list because they belong to families covered by the international conventions underlying the MBTA. Several other birds were added because they are now considered to be full species within such families, including the Hawaiian Petrel (*Pterodroma sandwichensis*), Hawaiian Coot (*Fulica alai*), Pacific Golden-Plover (*Pluvialis fulva*), Kama'o (*Myadestes myadestinus*), and 'Oloma'o (*Myadestes lanaiensis*). The three 'elepaio species (*Chasiempis* spp.) now have the dubious distinction of being the only bird species native to the U.S. that are not protected under the MBTA. The ‘elepaios were not included in the recent revision because they are members of a family, the Monarchidae, which does not occur elsewhere in the United States and is not mentioned in the underlying international conventions to the MBTA. The O’ahu ‘Elepaio (*C. ibidis*) is listed under the Endangered Species Act and thus is provided Federal protection, but the Hawai’i ‘Elepaio (*C. sandwichensis*) and Kaua’i ‘Elepaio (*C. sclateri*) still are not protected by Federal law.

Hawaiian birds are not included in many programs and documents that have been used to raise awareness and generate funding for bird conservation in North America, and they are short-changed by methods used to allocate funding in several Federal grant programs (Leonard 2008, 2009). Hawaiian birds have not been included in the Partners in Flight program, and in their most recent document, Saving Our Shared Birds: The Partners in Flight Tri-National Vision for Bird Conservation (Berlanga et al. 2010), Hawaiian species again were left out because they are not a part of the North American avifauna. Hawaiian birds are similarly excluded from the North American Bird Conservation Initiative (NABCI), and there is no counterpart to this program in the U.S. for Hawaiian birds. The Pacific Coast Joint Venture has funded several important wetland bird conservation projects in Hawai’i, but unlike some other joint ventures, it has not funded forest bird work in Hawai’i to date. Hawaiian birds are not eligible for funding under the Neotropical Migratory Bird Conservation Act, and there is no counterpart to this program for migratory birds in the Pacific region. Although fewer migrants pass through the Hawaiian Islands than other areas of the United States and Canada, the Pacific region contains critical flyways for some species (Gill et al. 2008) and is an important wintering area for several species of migratory waterfowl and shorebirds (Brown et al. 2001, Udvardy and Engilis 2001). Hawaiian birds are not included in any recent North American bird field guides and are not included in the American Birding Association’s area of primary interest (Leonard 2009, Schunke 2011), both of which are missed opportunities for raising awareness, interest, and perhaps ultimately, funding.

Many tools that are used to monitor bird populations in North America are lacking in Hawaii, and the current status of many bird species in Hawaii is poorly known. Hawai’i has no MAPS stations (monitoring avian productivity and survival; http://www.birdpop.org/maps.htm) or Breeding Bird Survey routes (http://www.pwrc.usgs.gov/bbs/). The status and distribution of Hawaiian forest birds was thoroughly investigated in the late 1970s and early 1980s (Scott et al. 1986), but monitoring efforts have been less consistent and thorough since (Camp et al. 2009, Gorresen et al. 2009), mostly due to a lack of funding and staff. Monitoring of forest birds currently is done on a rotating basis, using variable circular plots spaced at 150-200 m intervals along transects. Each island is surveyed once every five years, except that O’ahu has been surveyed only once (in 1991) and portions of Hawai’i Island are surveyed separately because it is larger than the other islands. The resulting data has been important in assessing species’ status and measuring efficacy of conservation actions (e.g., Camp et al. 2010). However, detecting population trends in Hawaiian forest bird species and estimating population sizes has been hampered by variation among years in the extent of surveys and the infrequency with which surveys are conducted (Camp et al. 2009).

The primary method used to monitor wetland birds in Hawaii is the biannual state-wide waterbird count, coordinated by the Hawai’i Division of Forestry and Wildlife, during which birds are counted at most wetlands on each island on a single day in summer and winter. However, data from these counts have not been fully analyzed since 1987 (Engilis and Pratt 1993). Portions of the data set have been used to examine population trends of some species on certain islands (Reed and Oring 1993, Reed et al. 2011), and data from some years has been used to estimate abundance (U.S. Fish and Wildlife Service 2011), but a comprehensive analysis of the complete data set is needed to help assess the status of wetland birds in Hawai'i.

The relative neglect of Hawaiian birds is related to several factors (Leonard 2009), perhaps the most pervasive of which is Hawaii's remote location on the geographic fringe of the U.S. The threats faced by many Hawaiian birds are somewhat different than those faced by many North American birds, and this is part of the reason Hawai'i has not been included in some "nation-wide" bird conservation efforts, such as Partners in Flight and the North American Bird Conservation Initiative. Conservation issues in Hawaii are more similar to those on other Pacific islands, but Hawaiian birds also have received little attention or funding from international programs like BirdLife International and the Secretariat of the Pacific Regional Environmental Programme (SPREP; http://www.sprep.org/) because Hawai'i is part of the U.S. and thus often viewed as well-funded. National Audubon Society, the Birdlife International partner in the U.S., funded the identification of Important Bird Areas (IBAs) in Hawaii (VanderWerf 2008), but otherwise has not been engaged in Hawaii.

Recent efforts have helped to better address the conservation needs of Hawaiian birds and begin bridging the funding gap, but much remains to be done (Leonard 2009, Wallace and Leonard 2011). One example is the State of the Birds (http://www.stateofthebirds.org/), an initiative sponsored by multiple agencies and organizations to provide an assessment and overview of the status of bird species in the U.S., their threats, and conservation needs. Hawaiian birds have been featured prominently in each of the annual reports issued by the State of the Birds from 2009-2011, and these efforts helped trigger additional Federal funding for Hawaiian birds. The American Bird Conservancy began developing a Hawai'i Program in 2006 (http://www.abcbirds.org/abcprograms/oceansandislands/hawaii/index.html), has worked to increase attention and funding for Hawaiian birds, and has actively participated in several important projects. The National Fish and Wildlife Foundation adopted conservation of Hawaiian forest birds in 2009 as one of their keystone initiatives, which has provided critical funding for several projects aimed at conservation of Hawaii's most endangered birds.

It has been estimated that recovering Hawaii's endangered birds and the habitats upon which they depend will cost upwards of one billion dollars over the next 10 years (USFWS 2006, Wallace and Leonard 2011). While this may seem like an exorbitant amount, it is not unprecedented; similar restoration efforts for the Everglades (http://www.evergladesplan.org/), Chesapeake Bay (http://www.chesapeakebay.net/track/restoration), and Great Lakes (http://greatlakesrestoration.us/) have estimated costs of $3.9 billion over 30 years, $1 billion over 10 years, and $5 billion over 10 years, respectively. Surely the Hawaiian Islands and their unique avifauna deserve a similar level of recognition and commitment.

PURPOSE

The purpose of this Hawaiian Bird Conservation Action Plan is to continue to fill the "Hawaiian bird gap" by drawing attention to the plight of Hawaiian birds, increasing awareness of their conservation needs, and ultimately, increasing the amount of funding available for their conservation. The species profiles that form the core of this plan are intended to provide concise and up to date summaries which can be used by decision-makers, funding agencies, managers, and land owners to quickly access information. Each profile provides a brief summary of a particular species (or group of species), its status, the threats it faces, and conservation actions that are needed and can be implemented in the next five years. Because the species profiles can serve as stand-alone documents, they can be revised easily and updated on an individual basis as conservation actions are completed and new actions are identified.

Some of the species included in these profiles are listed under the U.S. Endangered Species Act and recovery plans have been written for these species (USFWS 1983, 1984, 2004, 2006, 2008, 2009, 2011). The species profiles presented here are not intended to replace those recovery plans, which are more comprehensive and long-term, but rather to complement them. Compared to the recovery plans, the species profiles are more concise, include only a subset of the most urgently needed conservation actions, and develop these actions in more detail. Some species also have been addressed in national or regional conservation plans aimed at groups of species, such as seabirds and shorebirds (Brown et al. 2001, USFWS 2005). The Hawai'i Comprehensive Wildlife Conservation Strategy written by the Hawai'i Division of Forestry and Wildlife (Mitchell et al. 2005) is similar in some ways but provides fewer details on conservation actions and does not provide cost estimates.

HOW TO USE THIS ACTION PLAN

Each of the species profiles follows roughly the same format and has the section headings listed below. Each profile also includes one or more photographs of the species and sometimes a photograph of their habitat. Immediately following the photographs is a box that summarizes the status of each species, including their Federal, State of Hawai'i, and IUCN status. In the case of Hawaiian birds that currently are considered subspecies of other taxa (Newell's Shearwater, Hawaiian Gallinule, and Hawaiian Stilt), the IUCN status is not listed because subspecies are not considered separately by the IUCN. The box also includes three measures of conservation concern: 1) A conservation score and rank using species assessment criteria developed by Partners in Flight (Panjabi et al. 2012). Since Partners in Flight does not include Hawaiian birds, I scored them myself; 2) the status in the 2007 Watchlist of birds that are in immediate need of conservation help developed by the National Audubon Society and the American Bird Conservancy (http://birds.audubon.org/species-by-program/watchlist/hawaiian-species); and 3) the climate vulnerability score as calculated for the State of the Birds 2010 report on climate change (http://www.stateofthebirds.org/2010/results-for-species/Hawaii_Scores.pdf).

Synopsis. Each profile begins with a synopsis that briefly summarizes the most important information. This section can serve as an Executive Summary for readers with limited time.

Population Size and Trend. This section provides the best available information on the abundance of the species and whether its numbers are increasing, decreasing, or stable. For many species the estimates are rough, but the error associated with estimates has been included whenever possible.

Range. The range, or distribution, of each species is described. For species with broad ranges the description may be fairly general, but for species with very small ranges the description is more detailed and includes specific locations. Most profiles include a map showing the range of the species, broad land ownership categories, and important locations and features mentioned in the text.

Essential Biology. This section is deliberately brief and is not intended to provide a comprehensive description of each species' life history, which can be found in various other sources, such as The Birds of North America, and recovery plans in the case of species listed under the ESA. Rather, this section summarizes aspects of the species' biology that are directly relevant to its conservation and the actions discussed in the profile.

Primary Threats: The major threats are listed with subheadings, but are not necessarily listed in order of severity. Some threats are inter-related, such as habitat degradation, invasive alien plants, and alien ungulates; in some cases these factors are combined, while in others they are treated separately to highlight their importance.

Conservation Actions to Date: This section describes actions that have been taken to conserve the species, including regulatory protection, land acquisition, habitat protection and management, predator control, research, monitoring, etc. The actions are roughly grouped by type and are not presented chronologically or in order of importance. In some cases the actions are ongoing and also are mentioned in the section on conservation actions needed.

Planning/Research Needs: This section lists conservation-oriented research topics that will help inform management decisions. For many species, planning documents such as regulatory compliance documents, translocation plans, predator control plans, or public outreach materials also are needed to improve and coordinate conservation efforts.

5-Year Conservation Goals: These are short-term goals that, if accomplished, would indicate progress is being made toward recovery. Some are general in nature, such as obtaining greater public support for conservation efforts, while others are more specific and focused, such as creation of additional populations by translocation.

Conservation Actions Needed in the Next Five Years. The 5-year time frame is somewhat arbitrary but is a reasonable period over which to plan actions and gauge progress. Some actions, such as control of invasive alien plants and predators, will be needed in perpetuity and will not be complete after five years. Other actions may be largely completed within 5 years but there may be a time-lag until the benefits to the species are realized. The starting year for this 5-year period is 2013, but the desired schedule may be delayed, though in most cases this would not decrease the need for the actions.

Summary and Estimated Costs of Conservation Actions. The costs provided are estimates and should not be viewed as the actual cost of completing the prescribed action. If there is interest in funding and implementing a particular action, the managing agency or other entity and any potential partners should be contacted for more details about the project and budget.

Potential Partners: This is a list of agencies and organizations that have been involved in conservation efforts for the species previously, agencies that are mandated to manage natural resources, landowners, and other stakeholders. Potential partners are not necessarily limited to those listed; private foundations may be interested in funding projects, and university researchers and their students may be interested in helping to conduct research projects.

Ancillary Species: This list includes other native bird species that would benefit from conservation actions aimed at the focal species. In general these are more common and widespread bird species that are not the focus of a profile. The list does not include non-native bird species. In general, numerous species of native plants and invertebrates also would benefit from the same actions, many of which are rare or endangered, but these are not listed here.

LIST OF SPECIES PROFILES
- Albatrosses (Laysan, Black-footed, Short-tailed)
- Endangered Seabirds (Hawaiian Petrel, Newell’s Shearwater, Band-rumped Storm-petrel)
- Nene
- Koloa or Hawaiian Duck
- Laysan Duck
- Hawaiian Waterbirds (Hawaiian Coot, Hawaiian Gallinule, Hawaiian Stilt)
- Raptors (Hawaiian Hawk or ‘Io, Hawaiian Short-eared Owl or Pueo)
- Puaiohi or Small Kaua’i Thrush
- O’ahu ‘Elepaio
- ‘Alalā or Hawaiian Crow
- Northwestern Hawaiian Island Passerines (Millerbird, Nihoa Finch, Laysan Finch)
- Palila
- Kaua’i Honeycreepers (‘Anianiau, ‘Akikiki or Kaua’i Creeper, ‘Akeke’e or Kaua’i ‘Ākepa)
- Maui Honeycreepers (Maui Parrotbill, ‘Akohekohe or Crested Honeycreeper, Maui Creeper)
- Hawai’i Honeycreepers (‘Akiapōlā’au, Hawai’i Creeper, Hawai’i ‘Ākepa)
- ‘I’iwi
- Hawaiian Hoary Bat

It is difficult to choose among the many conservation actions that are urgently needed, and each profile includes several important conservation actions, but below is a list of the top-10 highest priority conservation actions for Hawaiian birds:

Rank	Action	Species Profile(s)
1	Restore ‘Alalā to the wild by releasing captive birds into managed habitat.	‘Alalā
2	Complete ungulate fencing around critical habitat for the Palila and eradicate all ungulates inside the fence.	Palila
3	Fence and remove feral ungulates from three management units encompassing 1,215 ha (3,000 acres) in the Alaka’i Wilderness Preserve on Kaua’i.	Kaua’i forest birds
4	Prevent establishment of mongoose on Kaua’i using all available methods.	Nēnē, Endangered seabirds, Hawaiian waterbirds, Kaua’i forest birds
5	Establish a second population of Maui Parrotbills by translocation into managed habitat on leeward Haleakalā	Maui honeycreepers
6	Complete lead paint remediation on Midway to prevent poisoning of albatross chicks.	Albatrosses
7	Establish additional populations of the Hawaiian Petrel and Newell’s Shearwater in protected and managed areas.	Endangered seabirds
8	Continue restoration and management of high-elevation	Hawai’i

	forests on Hawai'i Island.	honeycreepers
9	Establish a breeding population of Hawaiian Gallinules on Maui and/or Molokai by translocation.	Hawaiian waterbirds
10	Conduct public outreach about the threat to native birds posed by non-native predators, particularly rats and feral cats, and the need for large-scale predator control.	All

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Focal Species: Laysan Albatross or Mōlī (*Phoebastria immutabilis*)
Black-footed Albatross or Ka'upu (*Phoebastria nigripes*)
Short-tailed Albatross (*Phoebastria albatrus*)

Synopsis: These three North Pacific albatrosses are demographically similar, share vast oceanic ranges, and face similar threats. Laysan and Black-footed Albatrosses nest primarily in the Northwestern Hawaiian Islands, while the Short-tailed Albatross nests mainly on islands near Japan but forages extensively in U.S. waters. The Short-tailed Albatross was once thought to be extinct but its population has been growing steadily since it was rediscovered in 1951 and now numbers over 3,000 birds. The Laysan is the most numerous albatross species in the world with a population over 1.5 million, but its trend has been hard to determine because of fluctuations in number of breeding pairs. The Black-footed Albatross is one-tenth as numerous as the Laysan and its trend also has been difficult to determine. Fisheries bycatch caused unsustainable mortality of adults in all three species but has been greatly reduced in the past 10-20 years. Climate change and sea level rise are perhaps the greatest long-term threat to Laysan and Black-footed Albatrosses because their largest colonies are on low-lying atolls. Protecting and creating colonies on higher islands and managing non-native predators and human conflicts may become keys to their survival.

Laysan, Black-footed, and Short-tailed Albatrosses (left to right), Midway. Photos Eric VanderWerf

Status	Laysan Albatross	Black-footed Albatross	Short-tailed Albatross
Federal	Species of Concern	Species of Concern	Endangered
State of Hawaii	Protected	Threatened	Endangered
IUCN	Near Threatened	Endangered	Vulnerable
Conservation score, rank	**15/20, Vulnerable**	**17/20, At-risk**	**17/20, At-risk**
Watch List 2007 Score	**Red**	**Red**	**Red**
Climate Change Vulnerability	**High**	**High**	**High**

Population Sizes and Trends:

Laysan Albatross – Annual breeding population estimated to be about 590,000 pairs, >99% of which nest in the Northwestern Hawaiian Islands (NWHI; USFWS 2005, Arata et al. 2009). Small numbers also nest in the main Hawaiian Islands (~500 pairs), on islands near Japan (~20 pairs), and off western Mexico (~400 pairs) (VanderWerf et al. 2007, Arata et al. 2009, Flint 2009, Young et al. 2009, Henry 2011). An estimated 15-20% of adults skip breeding each year and birds do not begin breeding until 7-8 years of age, so the total population is higher (VanderWerf and Young 2011). The population trend is thought to be stable overall, but is difficult to determine due to variability in breeding frequency and consequent fluctuations in number of breeders (Arata et al. 2009). Several recently established colonies in the main Hawaiian Islands (Young et al. 2009) and Mexico (Henry 2011) are growing.

Black-footed Albatross – Annual breeding population estimated to be about 60,000 pairs, >95% of which nest in the NWHI (USFWS 2005, Arata et al. 2009). Small numbers also nest in the main Hawaiian Islands (~30 pairs), on several islands near Japan (~2,500 pairs) and off western Mexico (1-2 pairs) (USFWS 2005, Arata et al. 2009). An estimated 15-20% of adults skip breeding each year and young birds do not begin breeding until 7-8 years of age, so the total population is higher (Whittow 1993b). The population trend is thought to be stable overall, but is difficult to determine due to variability in breeding frequency and consequent fluctuations in number of breeders (Arata et al. 2009).

Short-tailed Albatross – Once thought to be extinct, its population has been growing steadily since it was rediscovered in 1951 and now numbers over 3,000 birds. Almost all of the population nests on islands near Japan, including 512 pairs on Torishima in the Izu Islands and about 50 pairs on Minami-kojima in the Senkaku Islands. One pair fledged a chick on Midway in 2011 and 2012. Infertile eggs were laid on Midway starting in 1993 and on Kure in 2010 and 2011.

Island (west to east)	LAAL breeding pairs (year estimated)	BFAL breeding pairs (year estimated)
Kure[a]	20,255 (2011)	3,486 (2011)
Midway[b]	388,017 (2011)	25,510 (2011)
Pearl & Hermes[b]	6,912 (2003)	6,116 (2003)
Lisianksi[b]	26,500 (1982)	2,126 (2006)
Laysan[b]	141,743 (2009)	19,088 (2009)
Gardner Pinnacles[b]	10-15	0
French Frigate Shoals[b]	2,988 (2009)	4,309 (2009)
Necker[b]	500 (1995)	112 (1995)
Nihoa[b]	0 (2007)	1 (2007)
Kaula[b]	55 (1993)	0? (1998)
Lehua[c]	89 (2011)	32 (2011)
Ni'ihau[b]	190 (2002)	?
Kaua'i[b]	271 (2008)	0
O'ahu[d]	91 (2011)	0
Total	587,393	60,773

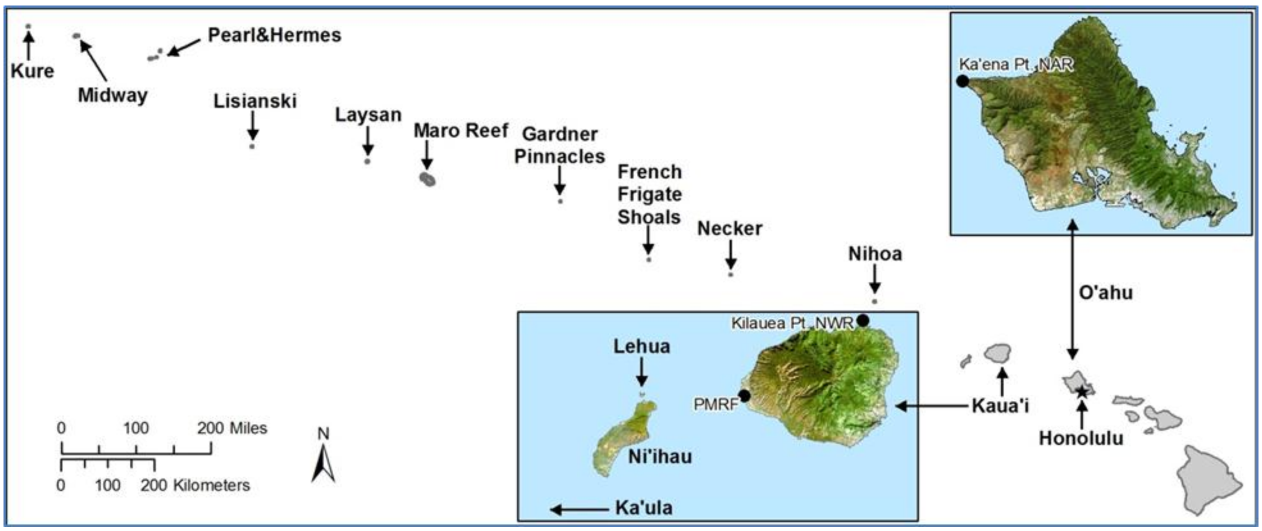
[a]Vanderlip 2011; [b]Flint 2009; [c]VanderWerf et al. 2007, A. Raine pers. comm. 2011; [d]Young et al. 2009, unpubl. data.

Ranges:

Laysan Albatross – The largest breeding colonies are in the NWHI, with smaller colonies in the main Hawaiian Islands, the Ogasawara Islands or Bonin Islands southeast of Japan, and several islands off western Mexico (USFWS 2005). On Kauai, the largest concentrations are at Kilauea Point National Wildlife Refuge and the Pacific Missile Range Facility (PMRF). On Oahu, the largest colony is at Kaena Point Natural Area Reserve, with another at nearby Kuaokala Game Management Area, and a few pairs at Marine Corps Base Hawaii in Kaneohe. At sea, Laysan Albatrosses disperse widely over the northern Pacific Ocean, generally further west and north than Black-footed Albatrosses (Fischer et al. 2009, Young et al. 2009, Kappes et al. 2010, Block et al. 2011).

Black-footed Albatross – The largest breeding colonies are in the NWHI, with smaller colonies in the main Hawaiian Islands and several islands off Japan and western Mexico (USFWS 2005). At sea, Black-footed Albatrosses disperse widely over the northern Pacific Ocean, generally further south and east than Laysan Albatrosses (Hyrenbach et al. 2002, Fischer et al. 2009, Kappes et al. 2010), regularly occurring in large numbers off western North America (Hyrenbach et al. 2006, Block et al. 2011).

Short-tailed Albatross – Most birds breed on islands near Japan, with the largest colony on Torishima in the Izu Islands, and a smaller colony on Minami-kojima in the Senkaku Islands. An effort to create another breeding colony was conducted from 2008-2012 by translocating 70 chicks from Torishima to Mukojima in the Ogasawara or Bonin Islands. In the U.S., one pair fledged a chick on Midway in 2011 and 2012, and infertile eggs were laid on Kure in 2010 and 2011. At sea, Short-tailed Albatrosses range widely across the Northern Pacific Ocean. In U.S. waters, most birds are concentrated along the edge of the continental shelf in the northern Gulf of Alaska, Bering Sea, and Aleutian Islands, but some reach the continental shelf off western North America (USFWS 2005, Suryan et al. 2006, 2007).



Essential Biology:

Albatrosses are large seabirds that are adapted to nest on predator-free islands and forage over enormous areas of open ocean. They are classic examples of "K-selected" species, being characterized by long lifespan, low annual fecundity, delayed recruitment, and intermittent breeding. Annual adult survival of Laysan Albatross averages 93-96% (Fisher 1975, VanderWerf and Young 2011). Annual adult survival of Black-footed Albatrosses ranges ranges from 92-96%, varying with amount of fisheries by-catch (Véran et al. 2007, LeBreton and Véran 2012). The oldest known Laysan Albatross, located on Midway and nick-named Wisdom, is at least 61 years old and is among the longest-lived birds ever documented. Because of their low annual fecundity, albatross populations are slow to recover from adult mortality caused by threats such as fisheries by-catch.

Albatrosses are colonial, with aggregations of birds nesting in a few locations. Each pair lays a single egg in November-December that hatches in January-February. They will not re-nest if the first attempt fails. Short-tails nest about one month earlier and Black-foots about two weeks earlier than Laysans (Whittow 1993a, 1993b, USFWS 2005). Fledglings depart nesting islands in June-July. Young albatross usually return to their natal colony to breed, but do not begin breeding until 5-8 years of age (Fisher 1975, VanderWerf and Young 2009). The annual recruitment probability for Black-footed Albatross was 2% in 5-year olds, 29% for 6-year olds, and 59% for birds seven and older (Lebreton and Véran 2012). In these albatross species, 15-20% of adults skip breeding each year, causing fluctuations in the apparent size of the breeding population. Frequency of skipped breeding is higher in birds that raised a chick the year before and also appears to be related to oceanic conditions and food availability (VanderWerf and Young 2009).

All three species forage over enormous areas of the northern Pacific Ocean and feed primarily on squid, fish, and fish eggs. They catch live prey and scavenge by seizing food at or just below the water surface. Albatross often follow fishing vessels to scavenge bait and offal, when they can be caught on hooks or entangled in lines and injured or drowned (Fischer et al. 2009, Lebreton and Véran 2012). Albatross generally obtain all their food from the ocean, but chicks may pick at and ingest objects near their nests; this behavior has caused problems on Midway where chicks ingest lead paint from aging buildings.

Primary Threats:

These species suffer from many of the same threats, but the nature and severity of these threats differ among species and among colonies depending on their location. Colonies in the NWHI are currently safe from disturbance and predators but are vulnerable to inundation from sea level rise and storm surge. Other threats occur at sea away from breeding colonies, such as adult mortality from fisheries by-catch. Some threats have been at least partly mitigated, but others have not been adequately addressed.

- Human Disturbance and Conflict. In the early 1900s, albatross populations on many islands were reduced or completely wiped out by feather hunters. Military activities during World War II also took a heavy toll. During the 1950s and 1960s, thousands of albatrosses were killed at Midway to reduce risk of collisions with aircraft. Today, human disturbance is a threat primarily on Oahu and Kauai. At the U. S. Navy Pacific Missile Range Facility on Kauai, Laysan Albatrosses are a collision hazard to aircraft and their eggs are removed each year. In a small colony at Kuaokala on Oahu, all chicks disappeared under suspicious circumstances in 2009, probably as a result of human disturbance.
- Fisheries By-catch. Accidental by-catch in commercial fisheries managed by Regional Fisheries Management Organizations is among the most serious threats to albatrosses. By-catch occurs in all commercial fisheries throughout the North Pacific, but low observer coverage rates in most fisheries can make calculating reliable estimates difficult. Although numbers of each species killed may be similar in some cases, by-catch may represent a greater threat to Black-footed Albatrosses because they tend to follow fishing vessels more often and their population size is smaller than that of Laysan Albatrosses. The baseline annual adult survival of Black-footed Albatross averaged 96%, but was only 90-92% from 1997-2002, a period of higher by-catch (Véran et al. 2007, Lebreton and Véran 2012). Lebreton and Véran (2012) also showed that by-catch of Black-footed Albatross probably is underestimated by at least 50%. From 1950 to 1977, by-catch of Laysan Albatross was estimated to be less than 6,000 per year, but during the period of driftnet fishing, 1978 to 1992, by-catch increased to an estimated 27,800 per year (Arata et al. 2009). For Black-footed Albatrosses, by-catch estimates showed a bimodal distribution with a peak of 15,290 birds in 1961 and a second peak of 16,215 birds in 1988 due to the combined effect of high-seas driftnet and long-line fisheries (Arata et al. 2009). Between 1990 and 1994, Cousins and Cooper (2000) estimated that >23,000 Black-footed Albatross were killed on long-line hooks set by the north Pacific swordfish fishery and that 1,800 were killed annually between 1994 and 1998 by the domestic Hawaii long-line fishery.

- Marine Pollution. Ingestion of plastic debris by adult albatrosses at sea, who then feed it to their chicks, causes mortality of chicks. Adults are less susceptible because they are more capable of regurgitating plastic debris. Plastic may harm or kill chicks by obstructing or damaging the digestive tract, reducing the volume of the gut available for food, facilitating absorption of petroleum-soluble contaminants, and creating a false feeling of satiation so chicks literally starve while feeling full. Albatross chicks regurgitate a bolus of indigestible material before they fledge, and these can provide a means of measuring the amount of plastic ingested. Weaker chicks or those with too large a plastic load may be unable to regurgitate the bolus, resulting in death.
- Environmental Contaminants. On Midway, Laysan Albatross chicks nesting near aging buildings may ingest paint chips or soil that contain lead, causing neurological disorders, “droop wing syndrome,” and often death (Work and Smith 1996). Up to 7% of albatross chicks may die each year from lead poisoning (Finkelstein et al. 2010). Organochlorine and mercury contamination have been detected in Laysan and Black-footed Albatrosses in varying levels on Midway and in birds sampled at sea (Auman et al. 1997, Guruge et al. 2001, Finkelstein et al. 2006, Caccamise et al. 2012). Oil spills are also a threat.
- Alien Predators. Albatross are naïve to predators and are vulnerable to predation even by small mammals. Predators are not present in the NWHI, but in the main Hawaiian Islands predation has been documented on Laysan Albatross eggs, chicks, and adults by a variety of introduced mammals, including feral dogs (*Canis familiaris*), feral cats (*Felis cattus*), small Indian mongooses (*Herpestes auropunctatus*), feral pigs (*Sus scrofa*), and possibly black rats (*Rattus rattus*) and Pacific rats (*Rattus exulans*). Predation limits the distribution and reproduction of albatrosses in the main islands.
- Invasive Alien Plants. The invasive alien golden crown-beard plant (*Verbesina encelioides*) threatens Laysan and, to a lesser degree, Black-footed Albatrosses on some islands, particularly Midway and Kure. This annual plant can grow into dense, tall stands that limit albatross nesting density, entangle chicks, prevent them from reaching open fledging areas, and reduce air flow and cause them to overheat. Klavitter et al. (2009) found that *Verbesina* reduced hatching and fledging success of Laysan Albatrosses, resulting in a reduction in reproductive success of over 50%. *Verbesina* is less of a threat to Black-footed Albatrosses because they often nest on sandier substrate near the shore where this plant is less invasive.
- Climate Change. Most colonies of Black-footed and Laysan Albatrosses are on low-lying atolls that are extremely vulnerable to sea level rise, storm surge, and high wave events associated with climate change. Black footed Albatrosses are particularly vulnerable because they often nest in open sandy areas closer to the shoreline. In 2011, high wave events and the Japan tsunami wiped out 56% of Black-footed Albatross nests and 41% of Laysan Albatross nests in the NWHI. Remarkably, the Short-tailed Albatross chick on Midway was twice swept from its nest, but survived.



Albatross colonies on low atolls like Midway (left) are vulnerable to climate change and sea level rise; those on high islands like Lehua (center) and Oahu (right) may become more important. Photos Eric VanderWerf.

Conservation Actions to Date: The Short-tailed Albatross was listed as endangered under the U.S. Endangered Species Act (ESA) in 2000 (USFWS 2008). The USFWS was petitioned in October 2007 to list the Black-footed Albatross under the ESA, but the USFWS determined in October 2011 that listing was not warranted.

- Habitat Protection and Management. All of the albatross colonies in the NWHI are protected. Midway Atoll was designated a National Wildlife Refuge in 1988 while it was administered by the U.S. Navy. In 1996, Midway Naval Air Station was closed and administration was transferred to the USFWS. Kure Atoll was commissioned a LORAN Station in 1961 and was administered by the U.S. Coast Guard until 1992, when it was transferred to the State of Hawai`i to be managed by the Hawai`i Department of Land and Natural Resources as a State Seabird Sanctuary. All of the other NWHI are managed by the USFWS as National Wildlife Refuges. In 2006, approximately 139,793 square miles of emergent and submerged lands and waters of the NWHI, including the National Wildlife Refuges and State Seabird Sanctuary, were included in the Papahānaumokuākea Marine National Monument.
- Predator Control.
  - Pacific rats were eradicated from Kure in 1994 and from Midway in 1997. In the NWHI, only house mice (*Mus musculus*) now remain on Midway.
  - A predator-proof fence enclosing the Laysan Albatross colony at Kaena Point Natural Area Reserve on Oahu was built in 2011 and all predators were removed.
  - Other colonies on Kauai and at Kuaokala on Oahu have been protected from dogs and feral pigs by construction of small fences, but they are still vulnerable to other predators.

Predator fence, Kaena Pt., Oahu. Photo Lindsay Young.

- Invasive Species Control and Biosecurity.
  - Efforts are underway to control the invasive golden crown-beard plant on Midway and Kure, but the work is labor intensive and additional effort and resources are needed.
  - Strict biosecurity programs, including restrictions on movement of food and equipment among islands and quarantine procedures, are in place to help prevent spread of invasive plants and animals among islands and prevent the introduction of additional pest species.

- Environmental Contaminants. Midway Atoll National Wildlife Refuge is in year 2 of a 6-year, $21 million project to remediate lead paint from all structures and soil. Remediation of lead on Midway had been attempted previously, but those efforts were not completely effective. Previous methods included fencing to keep albatross away from buildings and ground cloth to prevent albatross from ingesting paint chips or contaminated soil. Current methods also include demolition of some buildings, remediation and excavation and removal of contaminated soil.
- Fishery Management. Regulations designed to reduce the incidental take of albatrosses and other seabirds in commercial fishing operations have been promulgated for several U.S. fisheries that operate out of Hawai`i and Alaska (Arata et al. 2009). In Hawaii, incidentally hooked or entangled albatrosses have been reduced by 92 to 99% annually compared to pre-regulation estimates (NMFS 2010). Seabird bycatch rates in the Alaska longline fisheries were reduced by 78% and albatross mortality has been reduced by 88% (Fitzgerald et al. 2008). Canada has required the use of seabird avoidance measures since 2002 in the long-line fisheries off British Columbia. Currently, the west coast groundfish fishery is the only U.S. managed fishery in the north Pacific that does not require mandatory seabird bycatch mitigation. Collaborative efforts with the fishing industry are currently underway to develop practical mitigation options to minimize by-catch in this fleet. Other nations, including Japan, China, and Taiwan, that operate pelagic long-line fisheries in the North Pacific typically do not require the use of mitigation measures to reduce the by-catch of seabirds and do not have trained and dedicated observers to monitor the magnitude and composition of the seabird by-catch. In 2003, mortality of Black-footed Albatrosses was estimated from available data to be at least 26,000 in Japanese and Taiwanese fleets (Birdlife International 2010). These fleets currently pose the greatest known fisheries threat.
- **Agreement on the Conservation of Albatrosses and Petrels (ACAP).** ACAP (http://www.acap.aq/) is a multilateral agreement which seeks to conserve albatrosses and petrels by coordinating international activity to mitigate known threats to their populations. ACAP came into force in February 2004. ACAP has produced a detailed assessment for each species, including the three North Pacific albatrosses, as well as fact sheets on fisheries by-catch and mitigation. The U.S. is not yet a party to ACAP but participates as an observer.

Planning/Research Needs:

- Explore methods of reducing impacts of climate change on albatross colonies in the NWHI.
- Estimate annual mortality from U.S. and foreign fisheries by-catch and use demographic models to determine effect of this mortality on albatross populations (e.g., Lebreton and Véran 2012, Zydelis et al. 2012).
- Continue research and development of techniques and gear that will minimize fishing by-catch mortality and explore alternatives to mitigate mortality by fishing industry.
- Continue monitoring of albatross colonies on Midway, Laysan, Tern Island, Kure, Oahu, Kauai, and Lehua to collect demographic data and inform management decisions and measure efficacy of conservation actions.
- Perform another plastics study similar to Auman (1997) to understand current plastic loads in albatross chicks at Midway.
- Monitor rate of soil erosion and inundation at colonies in the NWHI and estimate numbers of albatrosses that may be forced to emigrate.

- Continue to investigate the at-sea distribution of albatrosses and the environmental factors that influence them. Climate models predict significant changes in oceanic conditions, which could affect the quality and quantity of foraging habitat.

5-Year Conservation Goals:

- Establish new albatross colonies on high islands that are less vulnerable to climate change.
- Continue to reduce mortality of adult albatross from fisheries by-catch.
- Increase albatross productivity by continuing to protect and restore nesting habitat in the NWHI through biosecurity and removal of invasive alien plants.
- Protect albatross colonies in the main islands from predators and resolve or mitigate human conflicts.

Conservation Actions Needed in Next 5 Years:

- <u>Human Disturbance and Conflict</u>.
    - Continue protection of national wildlife refuges in the NWHI and Kilauea Point on Kauai, and of state seabird sanctuaries on Kure and Lehua.
    - Continue Laysan Albatross egg swap project on Kauai, in which some of the eggs removed from the U.S. Navy Pacific Missile Range Facility as part of a Bird-Aircraft Strike Hazard reduction program are placed with foster parents whose eggs are not viable at Kilauea Point NWR and nearby private properties.
- <u>Fisheries By-catch</u>.
    - Continue, promote, and enhance observer programs in all long-line fishing fleets.
    - Compare the spatial and temporal overlap between fisheries and albatrosses throughout the North Pacific to prioritize conservation and management efforts.
    - Develop fishery-specific best-practice mitigation measures in long-line fisheries throughout the species ranges.
- <u>Marine Pollution</u>. Support public education programs aimed at increasing awareness of marine pollution, especially plastic, and its effects on seabirds, other organisms, and the oceans.
- <u>Environmental Contaminants</u>. Continue lead remediation on Midway by removing lead paint from buildings, and removing, treating, and/or stabilizing contaminated soil.
- <u>Introduced Predators</u>.
    - Eradicate alien Pacific rats from Lehua Islet to eliminate predation on eggs and chicks and allow growth of existing Black-footed and Laysan Albatross colonies.
    - Continue to maintain the predator-proof fence at Kaena Point and ungulate fence at Kuaokala, Oahu.
    - Control or eradicate predators at additional sites in the main Hawaiian Islands to allow establishment of new colonies.
- <u>Introduced Plants</u>.
    - Continue Hawaii DLNR winter camp on Kure Atoll to facilitate control of *Verbesina encelioides* and restoration of native habitat.
    - Continue USFWS efforts to control *Verbesina encelioides* and other non-native plants on Midway, Laysan, and other islands.
- <u>Colony Protection and Creation</u>.
    - Continue to maintain the predator-proof fence at Kaena Point, Oahu to provide a safe haven for albatross that immigrate from inundated colonies in the NWHI.

- Establish a breeding colony of Laysan Albatrosses at James Campbell NWR, Oahu, and control predators, by translocating chicks hatched from excess eggs removed from PMRF, Kauai as part of a BASH reduction program.
- Establish a breeding colony of Black-footed Albatrosses within the predator-proof fence at Kaena Point, Oahu, through social attraction or, if necessary, translocation of chicks from the NWHI.
- Continue Short-tailed Albatross social attraction project at Midway Atoll NWR.

Summary and Estimated Costs of Conservation Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
U.S. Navy PMRF egg swap program	2012-2016	$15,000	$75,000
Remove lead paint from buildings and soil on Midway	2012-2017	NA	$21,000,000
Eradicate alien Pacific rats from Lehua Islet	2013	$400,000	$400,000
Maintain predator-proof fence at Kaena Point, Oahu	2012-2016	$20,000	$100,000
Eradicate alien *Verbesina* and restore native habitat on Sand Island, Midway Atoll	2012-2022	NA	$6,000,000
Eradicate alien *Verbesina* and restore native habitat on Eastern Island, Midway Atoll	2012-2016	$200,000	$1,000,000
Establish Laysan Albatross colony at James Campbell NWR, Oahu using excess eggs from PMRF, Kauai	2014-2016	$150,000	$450,000
Establish Black-footed Albatross colony at Kaena Point, Oahu by social attraction (or by translocation if necessary)	2012-2016 (2014-2016)	$3,000 ($150,000)	$15,000 ($450,000)
Continue demographic monitoring of Laysan Albatross on Oahu	2012-2016	$15,000	$75,000
Continue demographic monitoring of Laysan and Black-footed Albatrosses on Midway	2012-2016	$70,000	$350,000

Potential Partners: U.S. Fish and Wildlife Service-Refuges, Hawaii Division of Forestry and Wildlife (Kure, Lehua, Kauai, and Oahu), Hawaii Natural Area Reserves System (Oahu), U.S. Navy (PMRF on Kauai), U.S. Coast Guard (Lehua), Pacific Rim Conservation.

Ancillary Species: Numerous other seabirds, migratory shorebirds, and several endemic land birds occur on many of the same islands that support albatross colonies, including: Bonin Petrel (*Pterodroma hypoleuca*), Hawaiian Petrel (*Pterodroma sandwichensis*), Bulwer's Petrel (*Bulweria bulwerii*), Wedge-tailed Shearwater (*Puffinus pacificus*), Christmas Shearwater (*Puffinus nativitatis*), Newell's Shearwater (*Puffinus auricularis newelli*), Band-rumped Storm-petrel (*Oceanodroma castro*), Tristram's Storm-petrel (*Oceanodroma tristrami*), White-tailed Tropicbird (*Phaethon lepturus*), Red-tailed Tropicbird (*Phaethon rubricada*), Masked Booby (*Sula dactylatra*), Brown Booby (*Sula leucogaster*), Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Laysan Duck (*Anas laysanensis*), Gray-backed Tern (*Sterna lunata*), Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Black Noddy (*Anous minutus*), Blue Noddy (*Procelsterna cerulea*), White Tern (*Gygis alba*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Tringa incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), Ruddy Turnstone (*Arenaria *interpres*), Millerbird (*Acrocephalus familiaris*), Nihoa Finch (*Telespiza ultima*), and Laysan Finch (*Telespiza cantans*).

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Focal Species: Hawaiian Goose or Nēnē (*Branta sandvicensis*)

Synopsis: The Hawaiian Goose, commonly known as the Nēnē, is the State bird of Hawai'i and is one of the best examples of species recovery by captive breeding. Nēnē were extirpated from all islands except Hawai'i by the 1950s, and their numbers fell to fewer than 50 birds. A captive breeding program began in 1949, and over 2,800 Nēnē have been released on four islands. Nēnē numbers have grown rapidly on Kaua'i, where mongooses are not established and high quality lowland habitat is more prevalent; populations on other islands have been periodically supplemented with captive-bred birds. Conservation actions focus on control of non-native predators and restoration of high quality habitat.

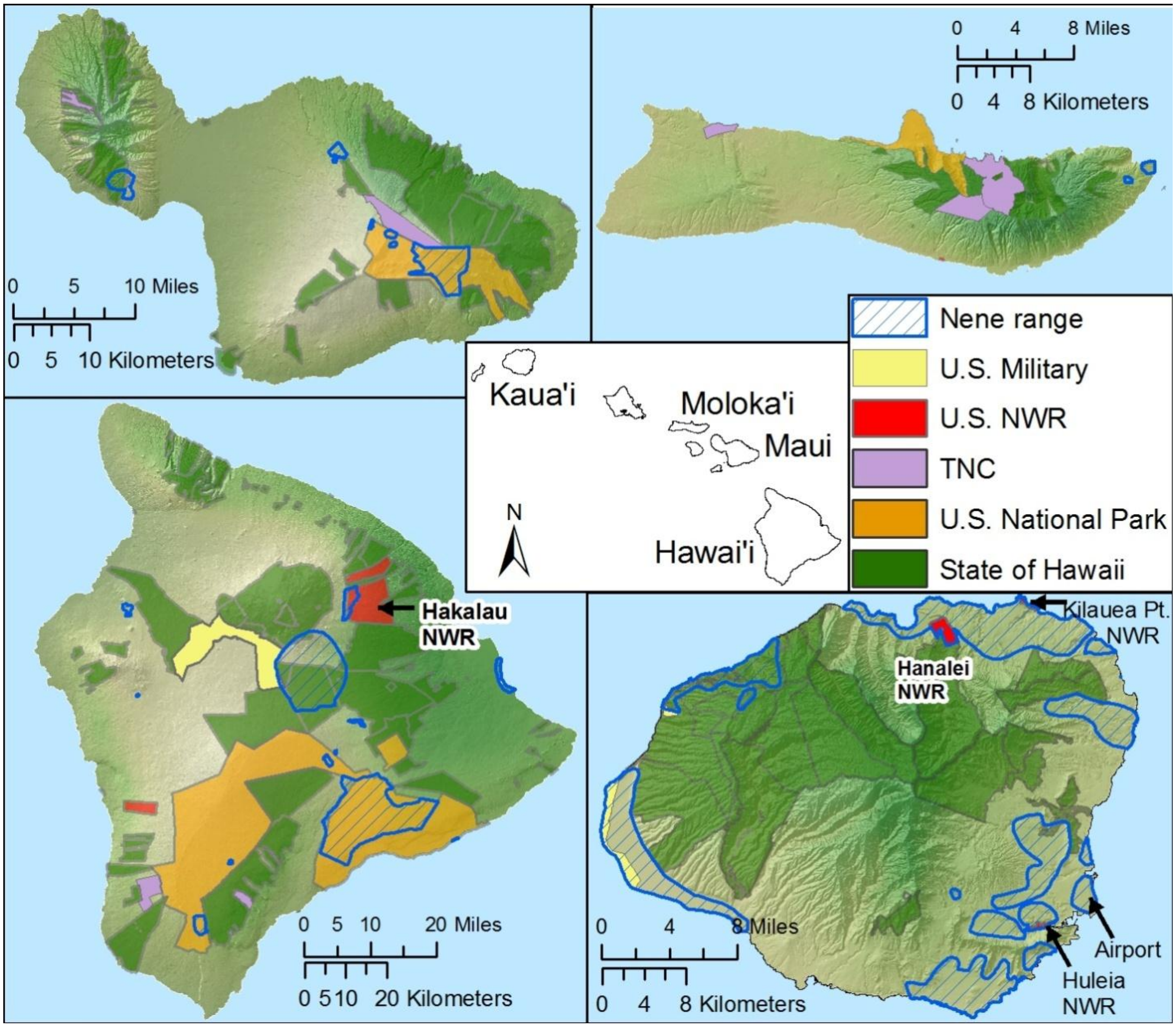
Geographic region: Hawaiian Islands
Taxonomic Group: Waterbirds
Federal Status: Endangered
State status: Endangered
IUCN status: Vulnerable
Conservation score: 17/20, At-risk
Watch List 2007 Score: RED
Climate Change Score: LOW



Nēnē at Volcanoes National Park (left) and Hanalei NWR Kaua'i. Photos E. VanderWerf.

Population Size and Trend: In 2011, the Nēnē population was estimated to be 2,465-2,555 birds, including 416 on Maui, 83 on Moloka'i, 1,424-1,514 on Kaua'i, and 542 on Hawai'i (Nēnē Recovery Action Group, unpubl. data). The total population has increased since 2005, when the number of birds was estimated to be 1,754. This increase was caused largely by growth of the Kaua'i population, which grew from 829 birds in 2005 (USFWS 2011). Populations on other islands have been stable or increased slightly, despite periodic releases of captive-bred birds. The Nēnē population was reduced to an estimated 30 wild and 11 captive birds in the late 1940s (Smith 1952, Kear and Berger 1980). In 2011-2012, 292 Nēnē were removed from areas near the Līhu'e Airport on Kaua'i to reduce the risk of bird-aircraft strikes, of which 239 were moved to Hawai'i and 30 were moved to Maui, where they eventually will be released (Hawai'i Division of Forestry and Wildlife [DOFAW] 2012).

Range: Nēnē currently occur on Hawai'i, Maui, Kaua'i, and Moloka'i, between sea level and 2,700 meters (9,000 feet) elevation. Nēnē formerly occurred on all the main Hawaiian Islands, but they were extirpated from all islands except Hawai'i by the 1950s. Current populations on other islands were re-established through release of captive-bred birds (USFWS 2004). At least five species of geese are known from the fossil record in Hawai'i; today, only the Nēnē survives (Banko et al. 1999).



Essential Biology: Nēnē are brown with pale edges to many feathers, have a black face and crown, cream-colored cheeks, and a buff neck with black streaks. Females are smaller than males. Compared to other geese, Nēnē are more terrestrial and have longer legs and less webbing between their toes (Banko et al. 1999). Vocalizations are varied and include soft mewing or mooing, loud cackling alarm calls, and high-pitched trumpeting for long-distance communication (Kear and Berger 1980).

Nēnē use a variety of habitats during different parts of the year and breeding cycle, including low and high elevation dry and mesic forest and woodland, shrubland, sparsely vegetated lava flows, grasslands, golf courses, and pastures (Banko et al. 1999, USFWS 2004). Their current distribution to some degree reflects where captive birds have been released. Historically, flocks moved between high-elevation feeding habitats to lowland nesting and molting areas (Munro 1944, Baldwin 1945), and similar movement patterns have been observed again in re-established populations (Hess et al. 2012). Water is not necessary for successful breeding, although it is readily used for bathing and drinking and appears to attract Nēnē in some areas. Nēnē graze and browse on the leaves, seeds, flowers, and fruits of at least 50 native and non-native grasses, sedges, composites, and shrubs; several species of non-native grass are important to their contemporary diet (Baldwin 1947, Black et al. 1994). Diet composition varies with location and habitat, and the species may require a diverse suite of food plants (USFWS 2004). Nēnē disperse seeds and therefore play an important ecological role, especially in influencing the species composition of early successional plant communities (Banko et al. 1999).

Historically, Nēnē primarily nested in leeward lowlands after winter rains stimulated a flush of growth of grasses and other food plants (Henshaw 1902, Perkins 1903, Munro 1944, Baldwin 1947). Today, however, most Nēnē nest in mid- and high-elevation habitats on Hawai'i and Maui. On Kaua'i, natural high-elevation nesting habitat probably has never been available and most Nēnē nest and live year-round in areas of managed grass (e.g., golf courses) below 300 m elevation. Pairs may mate for life and engage in simple courtship displays. Nēnē have an extended breeding season and eggs can be found in all months except May-July, although the majority of birds nest between October and March (Kear and Berger 1980, Banko 1988). Nēnē nests consist of a shallow scrape lined with plant materials and down (Banko 1988). Pairs often return to previous years' nests sites, typically under trees or shrubs, though vegetation varies greatly by area. Females lay between two and five eggs that hatch after 30 days. Young are precocial and feed themselves after hatching but remain with their parents until the following breeding season.

Primary Threats:

- **<u>Habitat Loss and Degradation</u>**. Degradation of lowland habitats used by Nēnē began with Polynesian colonization and agricultural practices hundreds of years ago (Cuddihy and Stone 1990). Lowland habitats have been further degraded since European arrival during the past 200 years, through agriculture, ungulate grazing and browsing, and the spread of alien plants that provide low quality foraging and nesting habitat. High elevation nesting areas are less modified than lowlands, but may be lower quality habitat for Nēnē foraging and nesting, and gosling mortality can be high in these areas (USFWS 2004). Palatable grasses and other plants in some pastures, golf courses, lawns, and roadsides allow Nēnē to forage and nest where they otherwise could not, but these areas expose Nēnē to other hazards (see below).
- **<u>Non-native Predators</u>**. Predation by non-native mammals is the most serious threat to the Nēnē, which nests on the ground. Predators known to take Nēnē eggs, goslings, or adults include dogs (*Canis familiaris*), feral pigs (*Sus scrofa*), feral cats (*Felis catus*), small Indian mongooses (*Herpestes auropunctatus*), and black, Norway, and Pacific rats (*R. rattus*, *norvegicus*, and *exulans*, respectively) (Hoshide et al. 1990, Baker and Baker 1996). Mongooses are responsible for the most Nēnē nest failures on Hawai'i and Maui, and feral cats may be the most serious predator on adults (Hoshide et al. 1990, Banko 1992, Black and Banko 1994, Baker and Baker 1996, Hu and Misajon unpubl. data). Kaua'i was thought to be mongoose-free, but two mongooses were captured on Kaua'i in 2012, although it is unknown if a breeding population has been established. The non-native Barn Owl (*Tyto alba*) may take goslings occasionally.
- **<u>Collisions</u>**. The species' low flight path when landing and taking off make Nēnē vulnerable to collisions with vehicles and man-made structures. Birds foraging along mowed roadsides are at risk from being hit by cars; between 1989 and 1999, at least 55 Nēnē were killed by cars in Hawai'i Volcanoes and Haleakalā National Parks (Banko et al. 1999). In many instances, nesting and brooding sites are separated by roads, making pairs leading small goslings vulnerable to vehicles. Birds using golf courses are vulnerable to

being struck by golf balls. Wind turbines have killed at least nine Nēnē on Maui from 2007-2011.

- **Human Conflicts**. Nēnē are attracted to feeding opportunities provided by mowed grass and human handouts and can become tame and unafraid of human activity, making them vulnerable to accidents. Human presence can also disrupt nests and brooding family groups. Crop damage by foraging Nēnē has become an issue in some areas. A large population of Nēnē has become established on the Kaua'i Lagoons golf course adjacent to the Līhu'e Airport, where they pose an aircraft strike hazard. Following a Governor's Proclamation in 2011, Nēnē are being captured near the airport and moved to other areas on Kaua'i and to Maui and Hawai'i. 292 Nēnē were removed in 2011-2012, additional birds will be relocated in the future (DOFAW 2012). Legal hunting by humans contributed to declines historically, and some poaching may occur occasionally today (Banko and Elder 1990, Banko et al. 1999).
- **Genetic Inbreeding**. Low levels of genetic diversity have been found in wild and captive Nēnē populations, and there is some evidence that fertility and gosling survival have declined in captivity as inbreeding has increased (Rave et al. 1994, Rave 1995, Rave et al. 1999). A condition known as "hairy-down" caused by a recessive gene has been observed in captive and wild Nēnē goslings (USFWS 2004), such birds do not survive in the wild (K. Misajon pers. comm.).

Conservation Actions to Date: Nēnē were reduced to an estimated 30 wild and 11 captive birds in the late 1940s, but the species was brought back from the brink of extinction by a successful captive propagation and release program (Smith 1952, USFWS 2004). Between 1960 and 2008, over 2,800 captive-bred Nēnē have been released on Hawai'i, Moloka'i, Maui, and Kaua'i. Early captive breeding programs were conducted by Herbert Shipman, the Territory and State of Hawai'i, and the Severn Wildlife Trust in Slimbridge, England. The National Park Service operated captive-breeding pens in the 1970s to 1990s. More recently, captive breeding programs have been conducted by the Peregrine Fund and the Zoological Society of San Diego at facilities at Olinda, Maui, and Keauhou, Hawai'i with funding from the State of Hawai'i and the U.S. Fish and Wildlife Service. Safe harbor agreements have facilitated re-establishment of Nēnē on Moloka'i at Pu'u O Hoku Ranch and several private lands on Maui.

The Nēnē was listed as endangered on 11 March 1967. An annual count is used to monitor Nēnē numbers, but methods and effort have been somewhat inconsistent (USFWS 2004). Research conducted through the 1990s demonstrated that many wild pairs did not attempt to nest, and those that did suffered high nest predation and high gosling mortality, indicating that nutrition and predation were important limiting factors (Banko 1992, Woog and Black 2001). Demographic analyses have shown that high mortality of wild young prior to fledging and among recently released captive goslings were limiting factors (Black et al. 1997, Hu 1998). Nēnē conservation efforts at Hawai'i Volcanoes National Park and Haleakalā National Park have emphasized controlling predators around nesting and rearing areas, habitat enhancement by mowing and outplanting, reducing human disturbance, and judicious supplemental feeding, and occasional augmentation with releases of captive-bred birds. Nēnē were reared in pens offering some predator protection at Hakalau Forest NWR, which now supports a sizable breeding population. At Hawai'i Volcanoes NP, various fence designs have been used successfully to exclude mongooses, cats, dogs, and pigs. Predator control programs are conducted in most areas where Nēnē nest, including Hanalei, Kilauea Point, and Hakalau Forest National Wildlife

Refuges, Haleakala and Hawai'i Volcanoes National Parks, and Pu'u O Hoku Ranch on Moloka'i. Recent satellite-tracking research on Hawai'i has revealed important information about Nēnē movements and seasonal use of different regions and habitats on Hawai'i, which will aid in habitat protection and coherent management of the Nēnē population throughout the island (Hess et al. 2012).

Planning/Research Needs:

- Complete reporting for previous work and continue investigating diet, nutrition, and forage quality, including the value of native versus non-native vegetation, focusing on the needs of goslings and breeding females.
- Refine predator control and exclusion methods.
- Evaluate translocation and release methods, including subsequent dispersal patterns, survival, and reproduction.
- Continue studies on movement patterns and habitat use by Nēnē.
- Investigate genetic population management to assess existing genetic variation, potential for inbreeding and inbreeding depression.
- Standardize monitoring protocols and develop a platform to more easily share data.

5-Year Conservation Goals:

- Ensure that mongooses do not become established on Kaua'i.
- Increase predator control effort and effectiveness, including use of predator-proof fences.
- Identify and protect habitats used by Nēnē for foraging, breeding, and flocking.
- Minimize human-Nēnē conflicts through increased public education.
- Develop a statewide, long-range management plan for all islands.

Conservation Actions:

- Habitat Restoration and Protection. Enhance habitat in existing protected areas for Nēnē and protect additional areas feasible based on the USFWS Nēnē Recovery Plan.
- Establish Additional Populations. Captive-breeding of Nēnē played a crucial role in saving the species from extinction, and such programs may continue to play an important role in Nēnē conservation. Nēnē removed from areas near the Līhu'e Airport on Kaua'i could be used as another source of birds for establishing new populations, but those birds may have established behaviors and habitat choices that would not be desirable in other areas and their use should be carefully considered.
  - Move family groups to Hūlei'a National Wildlife Refuge, Kaua'i from the airport.
  - Establish Nēnē at Haleakalā Ranch, Maui.
- Predator Control.
  - Increase efforts to detect and remove mongooses from Kaua'i using live traps, kill traps, and poison bait stations, where appropriate.
  - Continue predator control programs at all sites.
  - Evaluate feasibility of predator-proof fences at Hanalei NWR, Hakalau Forest NWR, and additional sites. Before fence construction, each site will require a scoping and feasibility study to determine the optimum size and placement of a fence and the estimated cost, a cost-benefit analysis comparing other forms of management, and regulatory compliance.
- Minimize Collisions.

  - Where Nēnē have been hit by cars, reduce attractive habitat along roads and increase signage.
  - Continue monitoring collisions with wind turbines and mitigating their effects.
  - In high-risk areas on golf courses, educate and work with staff and golfers to minimize risk and if necessary haze Nēnē.
- Minimize Negative Human Interactions.
  - Continue to address the aircraft strike hazard at Līhu'e Airport on Kaua'i by removing birds and modifying attractive habitats where appropriate.
  - Collaboration between U.S. Department of Agriculture, Natural Resources Conservation Service, Hawai'i Department of Agriculture, and farmers to develop Nēnē barriers and deterrents and, if necessary, safe hazing techniques and a crop damage reimbursement program.
- Outreach. Educate the public about Nēnē, their needs, and their threats.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Years	Annual Cost	Total Cost
Habitat management, all sites	1-5	$500,000	$2,500,000
Establish Nēnē population at Hūlei'a NWR, Kaua'i	1	$125,000	$125,000
Establish Nēnē population at Haleakalā Ranch, Maui	1	$100,000	$100,000
Increase efforts to capture mongoose on Kaua'i	1-5	$150,000	$750,000
Predator control, all sites	1-5	$600,000	$3,000,000
Evaluate feasibility of a predator-proof fence at Hakalau Forest NWR	1	$10,000	$10,000
Minimize collisions	1-5	$100,000	$500,000
Continue research on movements and habitat use	1-2	$150,000	$300,000
Minimize human conflicts	1-5	$200,000	$1,000,000

Potential Partners: U.S. Fish and Wildlife Service, Hawai'i Division of Forestry and Wildlife, National Park Service, Zoological Society of San Diego, Kaua'i Watershed Alliance, East Maui Watershed Partnership (WP), West Maui Mountains WP, Leeward Haleakalā Watershed Restoration Partnership, East Moloka'i WP, Kohala WP, Three Mountain Alliance, Mauna Kea Watershed Alliance, University of Hawai'i, U.S. Geological Survey Pacific Island Ecosystems Research Center, U.S. Department of Agriculture Wildlife Services and Natural Resources Conservation Service.

Ancillary Species: Because Nēnē use different habitats on different islands and at different seasons, management for Nēnē would benefit a variety of other native birds. In high elevation areas of Haleakalā NP on Maui, management for Nēnē, particularly predator control, also directly benefits the Hawaiian Petrel or 'Ua'u (*Pterodroma sandwichensis*), Pacific Golden Plover (*Pluvialis fulva*), and the Hawaiian Short-eared Owl or Pueo (*Asio flammeus sandwichensis*). Management of wetlands at Hanalei NWR would benefit several endangered waterbirds, including the Hawaiian Coot (*Fulica alai*), Hawaiian Gallinule or 'Alae 'Ula (*Gallinula galeata sandvicensis*), and Hawaiian Stilt or Ae'o (*Himantopus mexicanus knudseni*). In coastal areas on Kaua'i such as Kilauea Point NWR, management for Nēnē would benefit several seabirds, including the Laysan Albatross (*Phoebastria immutabilis*), Wedge-tailed

Shearwater (*Puffinus pacificus*), threatened Newell's Shearwater (*Puffinus auricularis newelli*), Red-tailed Tropicbird (*Phaethon rubricauda*), and White-tailed Tropicbird (*Phaethon lepturus*).

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Focal Species: Hawaiian Duck or Koloa Maoli (*Anas wyvilliana*)

Synopsis: The Koloa is part of the Mallard species complex, and hybridization with feral Mallards and genetic introgression is the greatest threat to this endemic species. Difficulty in distinguishing Koloa from hybrids has hindered estimation of their population size and trend. Koloa use a variety of wetland types, but habitat loss and degradation has decreased their range and abundance. They nest on the ground in dense vegetation near wetlands, where they are vulnerable to non-native mammalian predators. The most important conservation actions for Koloa are removal of feral Mallards and hybrids, habitat protection and management, and predator control to increase reproduction.

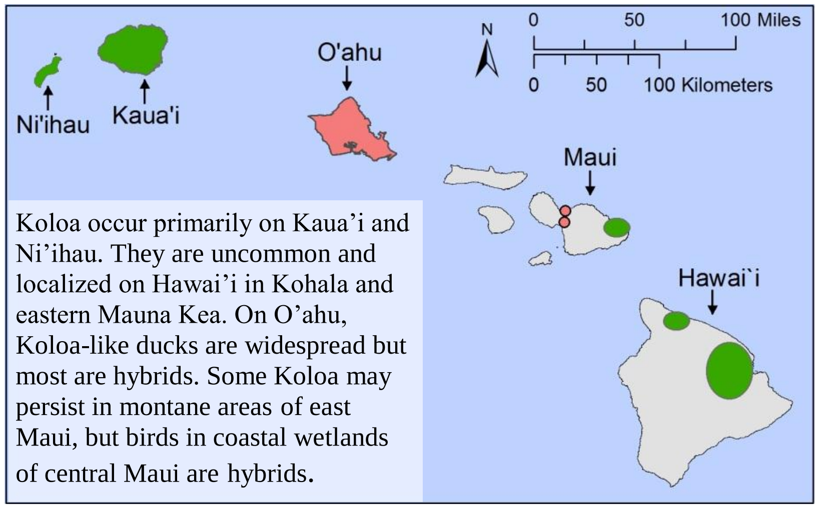
Koloa pair (male on left), Hanalei, Kaua'i. Photo E. VanderWerf

Hanalei National Wildlife Refuge, Kaua'i, showing natural and agricultural wetlands used by Koloa. Photo E. VanderWerf

Geographic region: Hawaiian Islands
Group: Water birds
Federal Status: Endangered
State status: Endangered
IUCN status: Endangered
Conservation score, rank: 17/20, At-risk
Watch List 2007 Score: Red
Climate Change Vulnerability: Moderate

Population Size and Trend: The Koloa population has been estimated at 2,200 birds, including 2,000 on Kaua'i and 200 on Hawai'i (Engilis and Pratt 1993), but the actual population size is poorly known and may be lower. Biannual state-wide waterbird counts yielded an average of only 360 birds from 2000-2007 (USFWS 2011), because they do not cover montane streams on Kaua'i that are thought to support much of the population. Koloa-like ducks also occur on O'ahu and Maui, but genetic research has shown that most or all of them are hybrids between Koloa and feral Mallards (*Anas platyrhynchos*; Fowler et al. 2009). The population size is thought to have increased since the 1950s on Kaua'i, but more recent trends are unknown because of incomplete survey coverage and difficulty in distinguishing Koloa from hybrids.

Range: Historically, the Koloa occurred on all the larger Hawaiian Islands except Lāna'i and Kaho'olawe, but they were extirpated from all islands except Kaua'i by the 1960s. Populations that occur on other islands today are the result of captive breeding and reintroduction (Engilis et al. 2002). The Koloa currently is found primarily on Kaua'i, Ni'ihau, and Hawai'i. Koloa also



Koloa occur primarily on Kaua'i and Ni'ihau. They are uncommon and localized on Hawai'i in Kohala and eastern Mauna Kea. On O'ahu, Koloa-like ducks are widespread but most are hybrids. Some Koloa may persist in montane areas of east Maui, but birds in coastal wetlands of central Maui are hybrids.

may occur on Maui and O'ahu but most birds on those islands are hybrids, and difficulty in distinguishing Koloa from Koloa-Mallard hybrids has hindered determination of their range. Koloa occur in a variety of wetland habitats from sea level to 2,100 meters (6,900 feet) elevation. On Kaua'i, the largest concentration is at Hanalei National Wildlife Refuge, including the upper reaches of Hanalei Stream, but they are widespread and also are found at Hūleiʻa National Wildlife Refuge, montane streams on the Alaka'i Plateau, river valleys, reservoirs, taro fields, and a variety of managed wetlands. On Ni'ihau, surveys in the 1990s indicated the playa lakes in the southern part of the island, particularly Halali'i Lake, and Apana Reservoir were the most important locations, but recent radio telemetry and satellite tracking research has shown that Koloa also use wetlands in the northern and western parts of the island (C. Malachowski unpubl. data). On Oʻahu, Koloa-like ducks are widespread in wetlands scattered around the island, including Kawainui, Hāmākua, and He'eia marshes, James Campbell National Wildlife Refuge, Kāneʻohe Marine Corps Base, and in wetlands at Punaho'olapa, Halei'wa, Pearl Harbor, and Lualualei Valley, but most or all of them are hybrids. On Maui, Koloa may persist in montane streams on the northeastern slope of Haleakalā, and Koloa-like ducks are sometimes found at Keālia Pond NWR and Kanahā Pond Wildlife Sanctuary. On the island of Hawaiʻi, Koloa occur in the Kohala Mountains, in Pololū, Waimanu, and Waipi'o valleys, and in stock ponds and montane streams on Mauna Kea.

Essential Biology: The Koloa is a small brownish duck (604 g in males and 460 g in females) in which both sexes are similar in appearance to a female Mallard (USFWS 2011). Males are darker brown and have a greenish bill, while females are lighter brown, especially on the head, and have an orangish bill (Engilis et al. 2002).

Koloa occur in a variety of wetland types, including natural wetlands such as freshwater marshes, coastal ponds, streams, montane pools, and flooded fields, and wetlands created or maintained by humans, including taro fields and other agricultural wetlands, aquaculture ponds, irrigation ditches, reservoirs, and sewage treatment ponds (Engilis et al. 2002, Uyehara et al. 2008). Koloa may use different habitats for nesting, feeding, and resting, and may move seasonally among areas (Engilis and Pratt 1993, Gee 2007). Recent radio telemetry and satellite tracking research has shown that some Koloa move seasonally between islands, especially Kaua'i and Ni'ihau, and between lowland wetlands near the coast and montane streams (C. Malachowski unpubl. data). Montane areas are thought to be important nesting and possibly molting sites. Koloa are opportunistic feeders and consume a variety of aquatic invertebrates, small fish, green algae, and leaves and seeds of aquatic plants (Swedberg 1967, Engilis et al. 2002). They most often feed in water less than 24 centimeters (9 inches) deep (Engilis et al. 2002).

Hawaiian Ducks may nest year-round, but the majority of nesting occurs from March-June (Giffin 1983). Nests are built on the ground in dense vegetation, where they are vulnerable to non-native predators and fluctuating water levels (Engilis et al. 2002). Nests may be built away from water, and parents may lead ducklings to wetlands after hatching. Clutch size ranges from 2-10 eggs, with a mean of 8.3 (Swedberg 1967). Incubation lasts approximately 30 days, with most chicks hatching in April-June.

Primary Threats: The most serious threat to the Hawaiian Duck is hybridization with non-native feral Mallards and genetic introgression into the Hawaiian Duck population. Hybrids are most prevalent on O'ahu, where all Koloa-like ducks may actually be hybrids, but hybridization and genetic introgression has occurred on all islands, including Kaua'i, which supports the core of the population. Hawaiian Ducks also share a number of threats with the endangered Hawaiian Coot, Hawaiian Gallinule, and Hawaiian Stilt and are included in the same recovery plan with those species (USFWS 2011).

- Hybridization. Mallards were raised for food in the Hawaiian Islands historically and have escaped and established feral populations on all islands that support Koloa. Hybridization between Koloa and feral Mallards compromised Koloa reintroductions conducted from the 1950s to the 1990s, especially on O'ahu (USFWS 2011). Hybridization with feral Mallards and domestic Mallard varieties continues to be a problem today (Uyehara et al. 2007, Fowler et al. 2009). Feral Mallards have been removed in a few areas, but hybrids are difficult to distinguish from Koloa and their management has been problematic (Fowler et al. 2009). Until the hybridization threat is dealt with, other management actions aimed at Koloa on O'ahu and Maui will also benefit hybrids and possibly exacerbate the problem.
- Habitat loss and degradation. Filling, dredging, and draining of wetlands in Hawai'i has greatly reduced the amount of habitat available for Hawai'i's waterbirds and thus limited their distribution and abundance. In the last 110 years, approximately 31 percent of coastal plain wetlands have been lost (USFWS 2011). A shift from wetland agriculture to other crops also has reduced the amount of wetland habitat. Feral pigs (*Sus scrofa*) and goats (*Capra hircus*) can degrade nesting habitat along montane streams.
- Introduced predators. Koloa and other Hawaiian waterbirds are threatened by a variety of non-native predators. Feral dogs (*Canis familiaris*), feral cats (*Felis silvestris*), and small Indian mongooses (*Herpestes auropunctatus*) prey on adults and young. Predation by rats (*Rattus* spp.), Cattle Egrets (*Bulbulcus ibis*), Barn Owls (*Tyto alba*), and non-native fish has been documented on eggs or chicks (USFWS 2011). These predators are pervasive in wetland habitats throughout Hawai'i. Mongooses have been captured recently on Kaua'i but may not be established yet; preventing them from becoming established is of the highest priority. Native predators include the Black-crowned Night Heron (*Nycticorax nycticorax*) and Short-eared Owl or Pueo (*Asio flammeus*), which prey on chicks.
- Altered hydrology. Modifications of wetland habitats for flood control, agriculture, or to make them suitable as municipal water sources may compromise their value as habitat for Hawaiian Ducks.
- Non-native invasive plants. Several species of invasive alien plants can reduce value of wetland habitat for Hawaiian Ducks and other waterbirds, including water hyacinth (*Eichornia crassipes*), mangrove (*Rhizophora mangle*), Indian fleabane (*Pluchea indica*), and California grass (*Urochloa mutica*).
- Avian diseases. Avian botulism is a paralytic disease caused by ingestion of a toxin produced by the bacteria *Clostridium botulinum*. Botulism outbreaks occur regularly in

Hawaiian wetlands, and often are triggered by anaerobic conditions in warm water with decomposing vegetation and invertebrates. Birds can be treated if detected early, but outbreaks sometimes cause substantial mortality (Work et al. 2010).

- Environmental contaminants. Fuel and oil spills are the most important contaminant threat to all Hawaiian waterbirds.
- Human disturbance and hunting. The Hawaiian Duck was a popular game bird until hunting was prohibited in 1939, and hunting contributed to population declines.
- Climate change. Hawaiian Ducks and other waterbirds are vulnerable to climate change, particularly rising sea level, because they occur primarily in low-lying coastal wetlands. Rising water levels and storm surge could flood nests and inundate nesting areas. Incursions of salt water into freshwater wetlands appear to diminish habitat suitability.

Conservation Actions to Date: The Hawaiian Territorial Fish and Game Commission closed the Hawaiian Duck hunting season in 1925, but because of its similarity to female Mallards this may have provided little actual protection (USFWS 2011). A complete ban on all waterfowl hunting was imposed in 1939 and is still in effect today. The Hawaiian Duck was declared an endangered species by the Federal government in 1967, and it is also considered endangered by the State of Hawai’i.

The State Division of Forestry and Wildlife (then called the Division of Fish and Game) initiated Koloa restoration efforts in 1956 when they brought birds from Kaua`i into captivity at Pōhakuloa, Hawai`i to create a captive breeding population for use in reestablishing the species on other islands. The first release of 26 captive-bred Koloa occurred in 1958 at Kahua Ranch, Hawai`i (Engilis et al. 2002). Releases of captive-bred birds continued on Hawai`i from 1968 to 1979, with 361 birds released at Kahua Ranch and 58 released in the Hilo Forest Reserve. On O’ahu, 350 Koloa were released from 1968 through 1982 (Engilis and Pratt 1993). Feral Mallards were not removed from reintroduction sites on O’ahu prior to the releases, however, resulting in extensive hybridization and genetic introgression into the Koloa population. Koloa also were released on Maui in 1989 and 1990, resulting in the establishment of a small population, although hybridization with feral mallards has proven problematic there as well.

State and Federal biologists published an assessment of wetland habitats for endangered waterbirds (USFWS and HDLNR 1970), and that was followed by a summary of the status of Hawai`i’s wetlands followed by Shallenberger (1977), both of which helped lead to establishment of numerous wetland refuges and reserves for the protection of waterbirds including the Koloa. Habitat restoration is currently underway at several sites, notably Kawainui Marsh on Oahu and the Mānā Plain on Kaua’i. Predator control is conducted at Hanalei National Wildlife Refuge to protect Koloa and other endangered waterbirds.

Various conservation-oriented research has been conducted to examine population trends (Engilis and Pratt 1993, Reed et al. 2011), habitat use (Gee 2007, Uyehara et al. 2008), hybridization and methods of distinguishing Koloa from Mallards and hybrids (Rhymer 2001, Fowler et al. 2009). Researchers from Oregon State University began a comprehensive Koloa research program in 2011 that includes habitat use, movements, survival, foraging ecology, and reproductive ecology. This research already has provided important information and funding is needed for its continuation through 2013.

Planning/Research Needs:

- Complete research to determine methods of distinguishing Koloa from feral Mallards and hybrids. This research has been ongoing and has shown that feral Mallards and Koloa can be distinguished reliably by field marks, but that some hybrids, especially second-generation back-crosses with Koloa, are difficult to identify visually and can only revealed by genetic screening. Final recommendations are needed on the best field marks to allow removal of birds from the wild and how to best deal with hybrid back-crosses.

- Continue research on habitat use, seasonal movement patterns, and importance of different wetland types (C. Malachowski, Oregon State University).
- Continue research on demography to determine home range size, sex ratio, age structure, sex-specific survival rates, breeding ecology (C. Malachowski, Oregon State University).
- Investigate foraging ecology of Koloa in different wetland types.
- Investigate the value to Koloa of different wetland types, including carrying capacity of natural wetlands and taro fields and other managed agricultural wetlands.
- Develop survey methods to more fully estimate the population size on Kaua'i, and obtain permission from private landowners to resume surveys on Ni'ihau, possibly using aerial methods.

5-Year Conservation Goals:

- Manage hybridization on all islands by removing feral Mallards and hybrids to the maximum extent practicable.
- Obtain public acceptance of feral duck control.
- Continue protection and restoration of important wetland habitats.
- Develop alternative predator control methods and explore the use of predator fences.

Conservation Actions:

- <u>Hybridization</u>
  - o Remove feral Mallards and Koloa-Mallard hybrids to the maximum extent practicable on all islands, using the best available identification methods.
  - o Conduct a public outreach campaign on the threat posed by hybridization and the need to control feral Mallards and hybrids in order to protect Koloa.
- <u>Habitat restoration and management.</u>
  - o Continue management of important wetland areas, including Hanalei and Hūleiʻa National Wildlife Refuges.
  - o Restore former wetland habitat on the Mānā Plain on Kaua'i (DOFAW).
- <u>Predator control</u>.
  - o Investigate feasibility of predator fences at various wetlands on Kaua'i, including Hanalei and Hūleiʻa National Wildlife Refuges.
  - o Continue predator control at Hanalei and Hūleiʻa National Wildlife Refuges.
  - o Prevent establishment of mongooses on Kauaʻi and Lānaʻi using all available methods. Improve biosecurity at airports and seaports.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Complete research to determine methods of distinguishing Koloa from Mallards and hybrids	1-2	$50,000	$100,000
Continue research on habitat use and demography	1-2	$75,000	$150,000
Public outreach on the threat of hybridization and the need to control feral Mallards and hybrids	1-3	$50,000	$150,000
Remove feral Mallards and hybrids on all islands,	2-5	$150,000	$750,000

following public outreach			
Investigate feasibility of predator fences at various wetlands	1-2	$10,000	$20,000
Habitat management at Mānā Plain, Kaua'i	1-5	$300,000	1,500,000
Prevent establishment of mongooses on Kaua'i	1-5	$150,000	$750,000
Predator control at Hanalei and Hūlei'a NWRs	1-5	$50,000	$250,000

Potential Partners: U.S. Fish and Wildlife Service-Refuges, Hawai'i Division of Forestry and Wildlife, Ducks Unlimited, Pacific Coast Joint Venture, Natural Resource Conservation Service, Oregon State University.

Ancillary Species: Three other endemic Hawaiian waterbirds occur in the same areas as Koloa, the Hawaiian Coot (*Fulica alai*), Hawaiian Gallinule or 'Alae 'Ula (*Gallinula galeata sandvicensis*), and Hawaiian Stilt or Ae'o (*Himantopus mexicanus knudseni*), all of which are listed as endangered. Numerous species of migratory waterfowl and migratory shorebirds use the same habitats that are important to the endemic Hawaiian waterbirds. Some of the more common migrants are Northern Pintail (*Anas acuta*), Northern Shoveler (*Anas clypeata*), American Wigeon (*Anas americana*), Lesser Scaup (*Aythya affinis*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Tringa incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), Ruddy Turnstone (*Arenaria interpres*), and Sanderling (*Calidris alba*).

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Focal Species: Laysan Duck (*Anas laysanensis*)

Synopsis: The Laysan Duck is a small, primarily nocturnal and terrestrial duck that is restricted to the small islands of Laysan and Midway. It formerly was more widespread on the larger Hawaiian Islands. The Midway population was created by translocations from Laysan in 2004 and 2005. Rising sea level, increasing storm surge, and lower precipitation associated with global climate change are expected to have serious impacts on the low-lying islands where this species occurs. Occasional outbreaks of avian botulism can cause high mortality. The primary conservation actions are preventing predators and other alien species from becoming established on these remote islands, managing habitat to provide adequate foraging and nesting sites, and establishing populations on additional islands by translocation.

Male Laysan Duck, Midway. Photo Eric VanderWerf

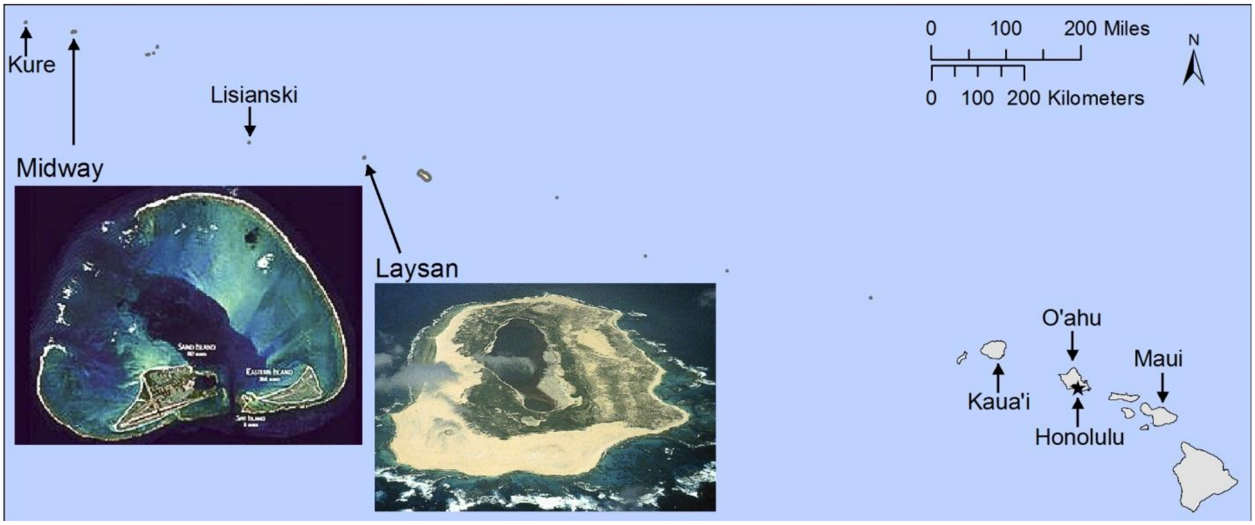
Created wetland, Midway. Photo Eric VanderWerf

Laysan Ducks feeding on brine flies around the hypersaline lake on Laysan. Photo Cameron Rutt

Geographic region: Northwestern Hawaiian Islands
Group: Water birds
Federal Status: Endangered
State status: Endangered
IUCN status: Critically Endangered
Conservation score, rank: 17/20, At-risk
Watch List 2007 Score: Red
Climate Change Vulnerability: High

Population Size and Trend: On Laysan, the most recent (2010) population estimate was 434±72 birds (Reynolds et al. 2011), but estimates have fluctuated from 322-688 over the last several decades (USFWS 2004). The population trend on Laysan is thought to be stable, but it has been difficult to determine due to the fluctuations. On Midway, 42 birds were translocated in two cohorts from Laysan in 2004 and 2005. The population on Midway increased rapidly to 473 (95% CI 439–508) in 2010 (Reynolds et al. 2012), though it has declined to around 300 after botulism outbreaks and the 2011 Japan tsunami (USFWS unpubl. data). Laysan Ducks have been kept in captivity since 1957, but most captive birds are not considered useful for reintroduction purposes because of concerns about the spread of disease and genetic introgression from hybridization with other waterfowl species in captivity (Reynolds and Kozar 2000).

Range: The Laysan Duck currently is found only on Laysan Island and Midway Atoll, which are located in the Northwestern Hawaiian Islands (NWHI). The ducks use most of each island, but both islands are very small; Laysan is 414 hectares (1,023 acres) in size, and Midway encompasses 596 hectares (1,473 acres; Krause et al. 2012). Even with the establishment of a second population on Midway, the Laysan Duck is thought to have the smallest range of any waterfowl species in the world, less than 10 km^2. Laysan Ducks were still extant on Lisianski, also in the NWHI, as late as 1844 (Olson and Ziegler 1995). Fossil and subfossil evidence indicates that Laysan Ducks were widespread in the Hawaiian Islands prior to the arrival of rats (*Rattus* spp.) and occurred on Hawai‘i, Moloka‘i, O‘ahu, Maui, and Kaua‘i (USFWS 2004).



Essential Biology: The Laysan Duck is a small (420-500 g) brownish duck wing orange legs and a white patch around the eye. The bill is greenish in males and orange in females. The amount of white on the head increases with age (Moulton and Marshall 1996). Laysan Ducks are unusual among waterfowl in being largely nocturnal and terrestrial. They forage primarily at night and rarely fly, preferring to walk. They exhibit several adaptations to a largely terrestrial lifestyle, including longer legs, shorter wings, fewer primary feathers, and reduced flight muscles (Moulton and Marshall 1996). Because they nest on the ground and tend to freeze rather than flush, Laysan Ducks are vulnerable to predation by mammals and today occur only on predator-free islands.

The habitat requirements of the Laysan Duck include dense vegetated cover for nesting, a year-round prey base, and a source of fresh water (USFWS 2004). They use all available habitats on Laysan and Midway, including upland vegetation, ephemeral wetlands, freshwater seeps, mudflats, the hypersaline lake, and coastal areas. Laysan Ducks feed on terrestrial and wetland invertebrates, algae, and seeds (USFWS 2004). Historical and paleoecological evidence suggests this species was a habitat generalist and occurred in a wide range of habitats. On high elevation islands, Laysan Ducks once were found in both coastal wetland and upland forests.

The clutch size is small for a duck, averaging 3.8 eggs (Moulton and Marshall 1996). The chicks are precocial and can walk and swim almost immediately after hatching, but they follow the female to learn how and where to feed. Ducklings have more restrictive habitat requirements than adults because of their higher nutritional needs for growth and initial inability to process salt water. Duckling activities therefore are concentrated around sources of fresh water with nearby cover and high prey densities. The female provides almost all parental care, but breeding pairs exhibit long-term pair bonds (Reynolds et al. 2009). Laysan Ducks molt all of their flight feathers simultaneously, usually in July-August, causing them to become flightless for several weeks until the new feathers have grown in, during which time they are even more vulnerable to predation. Annual adult survival is high; survival of released birds on Midway was 0.65±0.08 (Reynolds et al. 2012), but juvenile survival is low (10-30%; USFWS 2002).

Primary Threats:

- <u>Small population size and range</u>. Small populations with limited ranges are especially vulnerable to a variety of natural processes. Fluctuations in demographic parameters such as survival and reproduction can cause population declines and even extinction. The Laysan Duck's limited range exacerbates the risk of extinction due to catastrophes such as droughts, tsunamis, severe storms, and disease epizootics. Loss of genetic variation is more likely in small populations, potentially limiting adaptation to changing conditions, although there is no evidence of inbreeding depression in Laysan Ducks so far.
- <u>Habitat loss and degradation</u>. On Laysan, filling of the hypersaline lake by invasive wetland plants and declining precipitation during drought are concerns given the importance of the lake as foraging habitat. On Midway, some of the freshwater wetlands created for ducks were inundated with salt water and physically damaged by the Japan tsunami in March 2011. Most of these wetlands have recovered to near pre-tsunami levels after being pumped and salinity is steadily dropping. These wetlands continue to be vulnerable to saltwater incursions from high wave events and rising sea level, requiring periodic maintenance including removal of alien mosquito fish (*Gambusia affinis*) and preventing algae and plants from filling the wetlands.
- <u>Non-native predators</u>. Laysan Ducks disappeared from the main Hawaiian Islands 800–900 years ago after rats were introduced. Laysan and Midway, where the Laysan Duck is currently found, are free of non-native mammalian predators but accidental introduction of predators to Midway and Laysan is a potential threat. However, the long-term recovery strategy for the species calls for re-establishment of populations on the larger, high-elevation Hawaiian Islands, all of which are inhabited by a variety of non-native predators. Establishment of such populations will require protecting them from predators including feral dogs (*Canis familiaris*), feral cats (*Felis silvestris*), small Indian mongooses (*Herpestes auropunctatus*), rats (*Rattus* spp.), Cattle Egrets (*Bulbulcus ibis*), Barn Owls (*Tyto alba*), and bullfrogs (*Rana catesbeiana*). These predators are pervasive throughout the islands, but mongooses are not established on Kauai, Kahoolawe, or Niihau.
- <u>Non-native invasive plants</u>. Several species of invasive alien plants can alter habitat structure and decrease its value for Laysan Ducks. On Laysan, the non-native grass *Cenchrus echinatus* is highly invasive and can crowd out the native bunch grass *Eragrostis variabilis*, which is the preferred nesting substrate for Laysan Ducks. Eradication of this invasive grass was expensive and required 10 years of year-round effort. *Pluchea indica* is a wetland invasive shrub that degrades foraging habitat on Laysan and accelerates wetland filling.
- <u>Avian diseases</u>. Avian botulism has occurred in Laysan Ducks on Midway and a severe outbreak in August 2008 caused the death of 181 ducks (Work et al. 2010). Botulism is a paralytic disease caused by ingestion of a toxin produced by the bacterium *Clostridium botulinum*, which thrives under anaerobic conditions in warm water with decomposing vegetation and animal carcasses. Birds can be treated and vaccinated if detected early. Removing carcasses of dead birds helps to reduce the severity of the outbreak. Wetland

exclusion and water control structures have been proposed as additional methods of reducing the impact of outbreaks and possibly controlling the environmental conditions that can foster botulism. Mortality has been documented on Laysan due to drought, emaciation, and infestation by the nematode *Echinurea uncinata* (Work et al. 2004).

- Global climate change. Climate change and associated sea-level rise caused by thermal expansion of ocean water and melting of ice sheets is a serious long-term threat to all birds on atolls in the Northwestern Hawaiian Islands, including the Laysan Duck. Recent projections estimate a rise in sea level of 1-2 meters by the end of the 21st century (Vermeer and Rahmstorf 2009). The mean elevation of Laysan is 3.8 meters (12 feet) and the mean elevation of Sand Island on Midway is only 2.5 meters (8 feet). Rising sea level and storm surge are predicted to result in substantial losses of foraging and nesting habitat for the Laysan Duck caused by inundation, physical damage, and incursions of salt water into freshwater wetlands (Berkowitz et al. 2012, Krause et al. 2012). Other predicted results of climate change in the Hawaiian Islands include rising temperatures and declining precipitation, both of which could facilitate botulism outbreaks and *Echinuria uncinata* nematode infestation (Work et al. 2004, 2010).

Conservation Actions to Date: The Laysan Duck was federally listed as endangered in 1967 (USFWS 2004). Conservation actions have focused on maintaining the population on Laysan and creating a new population on Midway. Management actions conducted by the USFWS on Laysan have included removal of invasive alien plants such as *Cenchrus echinatus* and *Pluchea indica*, restoration of native plant species, and biosecurity to prevent introduction of additional alien plants and animals. The Laysan Duck population on Midway was created by translocation of 42 birds in two cohorts from Laysan in 2004 and 2005 (Reynolds and Klavitter 2006, Reynolds et al. 2008). Management conducted by the USFWS for Laysan Ducks on Midway has included enhancement and creation of freshwater wetlands, responding to outbreaks of avian botulism, and monitoring movements, habitat use, and demography.

A substantial amount of research has been conducted on the Laysan Duck in preparation for translocations and to monitor populations, primarily by the U.S. Geological Survey Biological Resources Division Pacific Islands Ecosystem Research Center, including habitat use, home range size, survival and causes of mortality, nesting phenology and behavior, demography and population dynamics, diseases, and vulnerability to climate change (see references).

Planning/Research Needs:

- Complete translocation plans for sites deemed suitable, particularly Lisianski, Kure, and Kaho'olawe (see USFWS 2004 for more details on site suitability assessments).
- Assess options for re-establishing a breeding population of Laysan Ducks on Kaua'i, O'ahu, or Maui, including methods of excluding or controlling predators, such as predator-proof fences. The cost-effectiveness of various options may differ among sites and should be investigated on a site by site basis. Potential sites include but are not limited to Hanalei and Huleia National Wildlife Refuges on Kauai, James Campbell National Wildlife Refuge on Oahu, and Kealia Pond National Wildlife Refuge and Kanaha Pond State Wildlife Sanctuary on Maui.
- Conduct research to further investigate demographic parameters that drive population fluctuations and cause differences in clutch size and fecundity on Laysan and Midway, including food and water resources, hatchability, and brood survival.

- Determine if the avian botulism outbreaks could be reduced at Midway Atoll by eliminating mosquito fish from the managed wetlands.

5-Year Conservation Goals:

- Continue management of Laysan Ducks and their habitat on Laysan and Midway.
- Establish breeding populations of Laysan Ducks on both Lisianski Island and Kure Atoll. After Midway, these two islands have been identified as the most suitable sites for establishing populations of Laysan Ducks. Each island would require wetland habitat preparation before it could support Laysan Ducks, and each presents different challenges. Lisianski is Laysan's nearest neighbor and is known to have previously supported Laysan Ducks, but mammal introductions in the mid-1800s resulted in loss of vegetation cover and shifting sands that filled the island's wetland. Test pits dug by hand in 2006 had difficulty reaching fresh groundwater and use of heavy equipment would be difficult on this remote island. On Kure, two small freshwater seeps were dug by hand in 2006 and 2007, but additional habitat would be needed, including creation of at least one more wetland or the installation of several 500-gallon artificial wetlands ("Guzzlers"). Control of golden crown-beard (*Verbesina encelioides*), an invasive alien plant that is used by Laysan Ducks for nesting but is detrimental to nesting seabirds, would need to be controlled before ducks are brought to the island.
- Re-establish a breeding population of Laysan Ducks on one of the southeastern Hawaiian Islands.

Conservation Actions:

- Establish breeding populations of Laysan Ducks on both Lisianski and Kure.
- Habitat management.
    - Continue to manage wetlands on Midway, including removal of mosquito fish.
    - Eradicate mice (*Mus musculus*) from Sand Island, Midway to increase natural recruitment of native bunch grass to ensure availability of quality nesting habitat.
    - Continue habitat management on Laysan, including removal of alien plants such as *Pluchea indica*, and restoration of native plants.
- <u>Avian diseases</u>.
    - Respond to any outbreaks of avian botulism that occur by removing dead bird carcasses.
    - Investigate methods of controlling water level and environmental conditions that can lead to botulism outbreaks on Midway.
- <u>Global climate change</u>. Develop feasibility plans for re-establishing a breeding population of Laysan Ducks on Kauai, Oahu, Kahoolawe, or Maui, which are high islands that would provide more of a refuge from rising sea level and storm events.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Continue habitat management on Laysan, including biosecurity, removal of detrimental alien plants, and restoration of native plants	1-5	$100,000	$500,000
Maintain wetlands on Midway	1-5	$50,000	$250,000

Respond to botulism outbreaks on Midway	1-5	$30,000	$150,000
Habitat management on Lisianski and Kure to prepare wetland sites for translocation of ducks	1-3	$100,000	$300,000
Translocate ducks to Lisianski	4-5	$250,000	$500,000
Translocate ducks to Kure	4-5	$200,000	$400,000
Investigate feasibility of establishing Laysan Ducks on Kaua'i, O'ahu, Kaho'olawe, and Maui, including methods of predator control or exclusion	1-2	$30,000	$60,000

Potential Partners: U.S. Fish and Wildlife Service, U.S. Geological Survey Biological Resources Division Pacific Islands Ecosystem Research Center, Papahanaumokuakea Marine National Monument, Hawaii Division of Forestry and Wildlife, Hawaii Wetland Joint Venture, Ducks Unlimited, Bird Conservation International, American Bird Conservancy.

Ancillary Species: Habitat management on Laysan also would benefit the endangered Laysan Finch (*Telespiza cantans*) and the endangered Millerbird (*Acrocephalus familiaris*), which was re-introduced to the island in 2011. Management on Laysan and Midway would benefit numerous species of seabirds, migratory waterfowl, and shorebirds, including the Bonin Petrel (*Pterodroma hypoleuca*), Hawaiian Petrel (*Pterodroma sandwichensis*), Bulwer's Petrel (*Bulweria bulwerii*), Wedge-tailed Shearwater (*Puffinus pacificus*), Christmas Shearwater (*Puffinus nativitatis*), Tristram's Storm-petrel (*Oceanodroma tristrami*), White-tailed Tropicbird (*Phaethon lepturus*), Red-tailed Tropicbird (*Phaethon rubricada*), Masked Booby (*Sula dactylatra*), Brown Booby (*Sula leucogaster*), Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Gray-backed Tern (*Sterna lunata*), Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Black Noddy (*Anous minutus*), White Tern (*Gygis alba*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Tringa incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), and Ruddy Turnstone (*Arenaria interpres*). On Kaua'i, O'ahu, and Maui, four other species of endangered waterbird would benefit from management directed at the Laysan Duck, particularly predator control or exclusion, including the Hawaiian Duck or Koloa (*Anas wyvilliana*), Hawaiian Coot or 'Alae ke'oke'o (*Fulica alai*), the Hawaiian Gallinule or 'Alae 'Ula (*Gallinula galeata sandvicensis*), and the Hawaiian Stilt or Ae'o (*Himantopus mexicanus knudseni*).

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Focal Species: Hawaiian Water birds:

- Hawaiian Coot or ʻAlae keʻokeʻo (*Fulica alai*)
- Hawaiian Gallinule or ʻAlae ʻUla (*Gallinula galeata sandvicensis*)
- Hawaiian Stilt or Aeʻo (*Himantopus mexicanus knudseni*)

Synopsis: These three waterbirds use a variety of wetlands, but habitat loss and degradation have reduced their range and abundance. The Hawaiian Coot is considered a full species, while the gallinule and stilt are subspecies of North American taxa. The coot and stilt are widespread and relatively numerous, but the more secretive gallinule is found on only two islands and is thought to have a smaller population. Habitat protection and management are keys to recovery of these species. They nest on the ground or in low wetland vegetation, where they are vulnerable to non-native predators, so predator control also is important to increase reproduction.

Hawaiian Coot, Gallinule, and Stilt (left to right). Photos Eric VanderWerf

Geographic region: Hawaiian Islands
Group: Water birds
Federal Status: Endangered (coot, gallinule, and stilt)
State status: Endangered (coot, gallinule, and stilt)
IUCN status: Vulnerable (coot only, gallinule and stilt NA)
PIF/ABC score, rank: 17/20, 18/20, 18/20, At-risk
Watch List 2007 Score: Red (coot, gallinule, and stilt)
Climate Change Score: Moderate (coot, gallinule, and stilt)

Status: The Hawaiian Coot, Hawaiian Gallinule, and Hawaiian Stilt are all listed as endangered under the U.S. Endangered Species Act (ESA) and by the state of Hawaii. The Hawaiian Coot is considered vulnerable by the IUCN. The Hawaiian Gallinule and Hawaiian Stilt are subspecies of the Common Gallinule and Black-necked Stilt of North America, respectively, and thus are not specifically considered by the IUCN. The Hawaiian Gallinule was formerly called the Hawaiian Moorhen, but in a recent taxonomic revision the North American and Eurasian forms were split and the North American form was renamed the Common Gallinule (Chesser et al. 2011), though under the ESA it is still listed as the Hawaiian Common Moorhen (*Gallinula chloropus sandvicensis*; USFWS 2011).

Population Sizes and Trends: The primary method used to monitor abundance of these species and other wetland birds is the biannual state-wide waterbird counted administered by the Hawaii Division of Forestry and Wildlife (DOFAW). The survey is conducted twice a year, in winter and summer, and covers most of the wetlands known to support waterbirds on each island (except Ni'ihau). Additional surveys are conducted monthly by USFWS staff at each national wildlife refuge.

Hawaiian Coot – The average number of Hawaiian Coots observed during the biannual state-wide waterbird count has averaged about 2,000 from 1997-2006, but numbers have fluctuated between 1,500 and 2,800 (USFWS 2011). The population trend has been increasing over the past 30 years (USFWS 2011, Reed et al. 2011), but numbers are still lower than historical estimates.

Hawaiian Gallinule – An average of 287 Hawaiian Gallinules were observed during the biannual state-wide waterbird count from 1998-2007 but numbers have fluctuated between about 100 and 450 (USFWS 2011). However, these numbers are not accurate and are best viewed as an index; the actual population size probably is higher, but it is difficult to estimate because of the species secretive habits and preference for densely vegetated wetlands. The population trend is thought to be increasing or stable (USFWS 2011, Reed et al. 2011).

Hawaiian Stilt – Based on the biannual Hawaiian waterbird counts from 1998-2007, the Hawaiian stilt population averaged 1,484 birds, but fluctuated between approximately 1,100 and 2,100 birds (USFWS 2011). The population trend has been increasing over the past 30 years (USFWS 2011, Reed et al. 2011), but numbers are still lower than historical estimates.

Range: All three species have patchy distributions because they are restricted to scarce wetland habitats. For distribution maps see USFWS (2011).

Hawaiian Coot - Hawaiian Coots currently are found on all the larger Hawaiian Islands except Kaho‘olawe, but breeding is restricted to relatively few sites (USFWS 2011). They occur primarily in coastal plain wetlands below 400 meters (1,320 feet) elevation. On Kaua'i, coots are found at many locations (USFWS 2011), but the largest concentrations are at Hanalei National Wildlife Refuge (NWR), the Kaua'i Lagoons golf course, Waitā Reservoir, and fragmented wetlands on the Mānā Plain. Coots may move seasonally between Kaua‘i and Ni‘ihau in response to water level changes in Ni‘ihau's ephemeral lakes, with over 900 birds counted on Ni`ihau in particularly wet years. On O‘ahu, most coots are found in coastal wetlands along the northern, eastern, and southern sides of the island, with large concentrations at the Ki`i Unit of James Campbell (NWR), the Kahuku aquaculture ponds, Kuilima wastewater treatment plant, Ka`elepulu Pond and Hāmākua Marsh State Waterbird Sanctuary in Kailua, Pearl Harbor NWR, and the Hawai`i Prince Golf Course. Smaller number are found on interior reservoirs such as Lake Wilson, Nu‘uanu Reservoir, and Salt lake. On Maui, the majority of coots occur at Keālia Pond NWR and Kanahā Pond State Wildlife Sanctuary, with smaller numbers at various sugar cane settling ponds. On Moloka‘i, most coots occur at the Kaunakakai and Maunaloa Wastewater Reclamation Facilites and at Ohiapilo Pond Bird Sanctuary. A small number of coots are found at the Lāna‘i City wastewater treatment plant. On the island of

Hawai‘i, coots are found primarily at ‘Aimakapā and ‘Ōpae‘ula ponds and the Kona wastewater treatment ponds on the Kona Coast, and Waiākea and Loko Waka ponds in Hilo.

Hawaiian Gallinule - Hawaiian Common Gallinules currently are found only on the islands of Kaua`i and O`ahu, with each island supporting roughly half the total population, but historically Hawaiian Gallinules occurred on all the main Hawaii Islands except Lāna‘i and Kaho‘olawe (USFWS 2011). They occur in densely vegetated wetlands, usually below 125 meters (410 feet) elevation. On Kaua‘i, the largest populations occur in the Hanalei and Wailua river valleys, and in irrigation canals on the Mānā Plains of southwestern Kaua‘i. On O‘ahu, the species is widely distributed with most birds found on the northern and eastern coasts between Hale‘iwa and Waimanalo; smaller numbers occur at Pearl Harbor and the leeward coast at Lualualei Valley.

Hawaiian Stilt - Hawaiian Stilts currently occur on all the main Hawaiian Islands except Kaho‘olawe. They occur primarily in wetlands below 200 meters (660 feet) elevation. On Kaua‘i, stilts are found in large river valleys including Hanalei, Wailua, and Lumaha‘i, on the Mānā Plains, and at reservoirs and former sugarcane settling ponds near Līhue and Waimea. Hawaiian Stilts move seasonally between Kaua‘i and Ni‘ihau in response to water level changes in Ni‘ihau’s ephemeral lakes. On O‘ahu, the largest numbers are found on the northern and eastern coasts, including James Campbell NWR, Turtle Bay Wastewater Treatment Plant, the Kahuku aquaculture ponds, Nu‘upia ponds at Marine Corps Base Hawai’i in Kāne‘ohe, Ka`elepulu Pond and Hāmākua Marsh State Waterbird Sanctuary in Kailua, the Waiawa and Honouliuli units of Pearl Harbor NWR, and Pouhala Marsh State Waterbird Sanctuary. On Maui, the majority of coots occur at Keālia Pond NWR and Kanahā Pond State Wildlife Sanctuary, with smaller numbers at various sugar cane settling ponds. On Moloka‘i, most stilts occur at the Kaunakakai Wastewater Reclamation Facility and at Ohiapilo Pond. On Lāna‘i, a population of stilts occurs at the Lāna‘i City wastewater treatment ponds. On the island of Hawai‘i, the largest numbers of stilts occur on the Kona coast at ‘Aimakapā Pond, the Kealakehe sewage treatment plant, at ‘Ōpae‘ula Pond and at the Cyanotech ponds at the Hawaii Energy Lab.

Essential Biology: All three species are found in a variety of wetland habitats, including freshwater marshes and ponds, coastal estuaries and ponds, artificial reservoirs, kalo or taro (*Colocasia esculenta*) lo’i or patches, irrigation ditches, sewage treatment ponds, and golf course ponds, but they differ somewhat in their habitat preferences. Hawaiian Coots often use more open wetlands with deeper water. Hawaiian Stilts favor shallower water for foraging and are more tolerant of higher salinity. Hawaiian Gallinules are more secretive and prefer wetlands and marshes with dense emergent and shoreline vegetation (Desrochers et al. 2008). Nests are built on the ground or in low wetland vegetation, where they are vulnerable to non-native predators and flooding from fluctuating water levels.

Hawaiian Coot – The Hawaiian Coot is a dark gray to black rail (Rallidae) with white undertail coverts. It is smaller than the American Coot (*F. americana*) and has a larger, more bulbous frontal shield above the bill. The bill and frontal shield are white in most Hawaiian Coots, with a small percentage having a brick red to brown shield and a maroon subterminal ring at the tip of the bill, similar to the American Coot. Coots have large feet with lobed toes, unlike the webbed feet of ducks. Calls include a variety of loud clucks.

Hawaiian Coots occur in a variety of wetland types, including natural marshes and ponds, artificial reservoirs, kalo or taro (*Colocasia esculenta*) lo'i or patches, irrigation ditches, sewage treatment ponds, and golf course ponds. They are most common in low elevation wetlands that have both open water and emergent vegetation (Brisbin et al. 2002, USFWS 2011). They prefer freshwater but are often found in brackish wetlands. Hawaiian Coots are generalist feeders, obtaining food from the water surface, by diving to the bottom, picking in mud, sand, and shallow water, and grazing on upland grassy sites near wetlands. Foods eaten include algae, leaves and seeds of a variety of aquatic plants, various invertebrates including snails, crustaceans, insects and their larvae, tadpoles, and small fish (USFWS 2011). They usually forage in water less than 30 cm (12 in) deep, but can dive below the surface up to about 120 cm (48 in).

The nesting season is primarily in late winter and spring but may vary depending on water levels, and nests have been found in all months (Shallenberger 1977, Byrd et al. 1985, Engilis and Pratt 1993). The nest is a platform built of aquatic vegetation and may be floating in open water, anchored to emergent vegetation, or in clumps of vegetation on the shoreline. Small islands may be preferred if available (USFWS 2011). Clutch size averages 5 eggs but ranges from 3-10. Eggs hatch after 25 days and the chicks are able to swim and forage as soon as their down has dried (Shallenberger 1977, Byrd et al. 1985, Brisbin et al. 2002). Hawaiian Coots may gather in large flocks outside the nesting season and may move large distances, even among islands, in search of food and preferred water levels (Engilis and Pratt 1993, Dibben-Young 2010, USFWS 2011). There is limited information on survival of adults or juveniles.

<u>Hawaiian Gallinule</u> – The Hawaiian Gallinule is a dark gray to black rail (Rallidae) with white undertail coverts, white stripes on the flanks, yellow legs with long, unlobed toes, and a bright red frontal shield and bill with a yellow tip. It differs slightly from the North American Common Gallinule in having a reddish blush on the front of the legs (USFWS 2011).

Hawaiian Gallinules prefer freshwater wetlands with water depth less than 1 meter (3.3 feet) and dense emergent and shoreline vegetation (USFWS 2011). Moorhens are secretive and shy, foraging in dense emergent or floating vegetation. Foods eaten include algae, grasses, plant seeds, aquatic insects and their larvae, and mollusks, but they are opportunistic and diet may vary among habitats (Shallenberger 1977).

Nesting occurs year round but is concentrated from March-August and may depend on water levels (Shallenberger 1977, Byrd and Zeillemaker 1981). Nests are built in areas of dense aquatic vegetation and are formed from emergent plants bent over into a platform. Clutch size averages 5 eggs and eggs hatch after 19-22 days. Chicks are precocial and can walk and swim within a few hours of hatching but are dependent on their parents for cover and finding food for several weeks. Pairs have been observed with broods of 2-7 chicks, with an average of 4.4 (Smith and Polhemus 2003), but there is no information on survival of chicks to maturity or adult survival. Hawaiian Gallinules are territorial and defend an area of wetland ranging in size from 0.09-0.24 ha (0.22-0.60 acres; Smith and Polhemus 2003). Hawaiian Gallinules cannot fly for about 25 days each year when they are molting, usually from June-September, increasing their vulnerability to predation (DesRochers et al. 2009). Gallinules are more sedentary than coots, but some dispersal occurs in spring among wetlands, and probably islands, in response to water levels and has been documented with banded birds (Engilis and Pratt 1993, Dibben-Young 2010).

Hawaiian Stilt – The Hawaiian Stilt is a tall (40 cm, 16 in), slender, black and white shorebird with very long pink legs and a thin black bill. Females are more brownish on the back than males, and immatures have more white on the face and sides of the neck. The bill, legs, and tail are slightly longer than in the North American Black-necked Stilt (Robinson et al. 1999), and it also has more black on the face and sides of the neck (the juvenile is more similar in appearance to the North American form).

Hawaiian Stilts are opportunistic feeders that take a variety of prey from shallow water and mudflats. Food items documented include insects, polychaete worms, crustaceans, tadpoles, and small fish (USFWS 2011). They prefer water less than 13 cm (5 in) for foraging, though they sometimes forage in grassy areas adjacent to wetlands. Such shallow wetlands are often ephemeral, forming after heavy rains and varying seasonally, and movements by stilts among wetlands and among islands are thought to be driven by searching for preferred feeding conditions (Engilis and Pratt 1993, Reed et al. 1994, 1998b).

Hawaiian Stilts nest on bare exposed ground, often mudflats, sometimes interspersed with low vegetation. The nest is a simple scrape, sometimes with small stones around the edge. Islands may be preferred for nesting if available (Shallenberger 1977, USFWS 2011). Hawaiian Stilts are territorial during the breeding season, with the distance between nests ranging from 16-over 80 m (53-262 feet; Coleman 1981, Robinson et al. 1999). The nesting season extends from February-August but varies among years, perhaps depending on water levels (USFWS 2011). The clutch size is 3-4 eggs, which hatch after about 24 days (Coleman 1981, Chang 1990). The chicks are precocial and leave the nest within 24 hours but remain with their parents for several months. Hatching and fledging success vary among sites and years, with most failures caused by predation and flooding (Chang 1990, USFWS 2011). Robinson et al. (1999) estimated that 2.18 eggs hatched per nest and 0.93 chicks fledged per successful nest. Reed et al. (1998a) estimated survival of first-year birds to be 0.53-0.60 and survival of second year birds to be 0.80.

Primary Threats:

The two most serious threats to all endemic Hawaiian waterbirds are loss and degradation of wetland habitat and predation by non-native animals. Several other factors have contributed to waterbird population declines and continue to be detrimental, some of which are more species-specific as noted below.

- Habitat loss and degradation. Filling, dredging, and draining of wetlands in Hawaii has greatly reduced the amount of habitat available for Hawaii's waterbirds and thus limited their distribution and abundance. In the last 110 years, approximately 31 percent of coastal plain wetlands have been lost (USFWS 2011). A shift from wetland agriculture to other crops also has reduced the amount of wetland habitats. Many of the wetlands that remain have been degraded by the factors below.
- Predators. Hawaiian waterbirds are threatened by a variety of non-native predators. Feral dogs (*Canis familiaris*), feral cats (*Felis silvestris*), and small Indian mongooses (*Herpestes auropunctatus*) prey on adults and young. Predation by rats (*Rattus* spp.), Cattle Egrets (*Bulbulcus ibis*), and Barn Owls (*Tyto alba*) has been documented on eggs or chicks. Bullfrogs (*Rana catesbeiana*) were documented to be important predators on Hawaiian Stilt chicks at James Campbel NWR (Eijzenga 2004). These predators are pervasive in wetland habitats throughout Hawai'i, but mongooses do not occur on Lāna'i. Mongooses have been captured recently on Kaua'i but may not be established yet; preventing them from becoming established is of the highest priority. Native predators

include the Black-crowned Night Heron (*Nycticorax nycticorax*) and Short-eared Owl or Pueo (*Asio flammeus*), which prey on chicks.

- Altered hydrology. Modifications to wetland habitats for flood control, agriculture, or to make them suitable as municipal water sources may compromise their value as habitat for wetland birds.
- Non-native invasive plants. Several species of invasive alien plants can reduce value of wetland habitat for waterbirds, particularly California grass (*Urochloa mutica*), water hyacinth (*Eichornia crassipes*), mangrove (*Rhizophora mangle*), and Indian fleabane (*Pluchea indica*).
- Avian diseases. Avian botulism is a paralytic disease caused by ingestion of a toxin produced by the bacteria *Clostridium botulinum*. Botulism outbreaks occur regularly in Hawaiian wetlands, and often are triggered by anaerobic conditions in warm water with decomposing vegetation and invertebrates. Birds can be treated if detected early, but outbreaks sometimes cause substantial mortality.
- Environmental contaminants. Fuel and oil spills in or near wetland habitats are a threat to Hawaiian waterbirds.
- Human disturbance and hunting. The Hawaiian Stilt, Hawaiian Gallinule, and Hawaiian Coot were popular game birds until hunting was prohibited in 1939, and hunting contributed to population declines.
- Climate change. Hawaiian waterbirds are vulnerable to climate change, particularly rising sea level, because they occur primarily in low-lying coastal wetlands. Rising water levels and storm surge could flood nests and inundate nesting areas. Incursions of salt water into freshwater wetlands appear to diminish habitat suitability.

Conservation Actions to Date: The Hawaiian Gallinule was declared an endangered species by the Federal government in 1967, and the Hawaiian Coot and Hawaiian Stilt were added to the Federal endangered species list in 1970. All three species also are considered endangered by the State of Hawai'i. Many important wetlands have been legally protected by several agencies and organizations, including: six national wildlife refuges managed by the U.S. Fish and Wildlife Service at Hanalei and Hulē'ia on Kaua'i, James Campbell and Pearl Harbor on O'ahu, Kakahai'a on Moloka'i, and Keālia Pond on Maui; State waterbird sanctuaries managed by the Hawai'i Division of Forestry and Wildlife at Kawai'ele on Kaua'i, Kawainui Marsh, Hamakua Marsh, Paiko Lagoon, and Pouhala Marsh on O'ahu, and Kanahā Pond on Maui; 'Aimakapā Pond managed by the National park Service on Hawaii; and Nu'upia Ponds at Marine Corps Base Hawai'i and Niuli'i Pond at Lualualei Naval Magazine. Several private landowners also manage wetlands for the benefit of Hawaiian waterbirds, including Kamehameha Schools, Kaelepulu Wetland Preserve in Kailua, and the Midler family on Kaua'i. These wetlands are managed to varying degrees to provide habitat conditions favored by waterbirds through actions including water level control, removal of non-native plants, and prescribed burning. Non-native predators are controlled at many sites, including all the national wildlife refuges, many of the State Waterbird Sanctuaries, Nu'upia Ponds, and at additional sites such as Ohiapilo and the Kaunakakai Wastewater Treatment Plant on Moloka'i. Artificial nesting islands have been created to

Hawaiian Coot nest on artificial island, Moloka'i. Photo A. Dibben-Young provide further protection from predators at Pearl Harbor NWR, Kaelepulu, and Marine Corps Base Hawaii, and at Kaunakakai Wastewater Treatment Plant using bodyboards. Several planning efforts and partnerships have been undertaken to improve and coordinate protection and management of wetlands, including the Pacific Coast Joint Venture and Chevron (Ducks Unlimited 2006, USFWS 2011). Habitat restoration is currently underway at several sites, notably Kawainui Marsh on Oahu and the Mānā Plain on Kaua'i, both of which have great potential to support large numbers of waterbirds. An attempt was made to re-establish Hawaiian Gallinules on Molokai by releasing six marked birds at Kakaha'ia NWR in 1983, but no birds have been observed there since 1986 when five were shot for food (Dibben-Young 2011). The sixth bird was recovered by USFW personnel. Various research has been conducted, some of which remains unpublished and difficult to obtain, on habitat requirements, movements, breeding biology, and conservation of Hawaii's endangered waterbirds (see references).

Planning/Research Needs:

- Further analyze existing data from the State waterbird count from 1950 to present to estimate population size and trend for each species on each island. Population estimates and trends were produced by the USFWS (2011) using data from 1976-2008, but more recent and longer-term estimates are needed. Reed et al. (2011) used a modeling approach to estimate population trends from 1956-2007, which exposed problems with missing data that precluded analysis of coots and stilts on Kaua'i. However, it should be possible to improve estimates of population size and trend by using other methods that can include all available data.
- Improve survey methods and recording form used in the biannual state-wide waterbird survey. Guidance was developed by the USFWS in 2005 to help improve consistency, but further refinements are needed, including review of wetlands that are included (and excluded).
- Improve survey methods for the Hawaiian Gallinule. Research has shown that playbacks increase the detectability of gallinules and result in more accurate population estimates (Desrochers et al. 2008), but this methodology has not yet been incorporated into the biannual waterbird count. Alternatively, a correction factor could be developed and applied to data collected using the current methods.
- Conduct long-term demographic studies to determine basic reproductive biology, population trends, survival rates, longevity, and limiting factors.
- Improve relations with private landowners of Ni'ihau and restore access to conduct waterbird surveys and assess populations.

5-Year Conservation Goals:

- Continue protection and management of important wetland habitats.
- Increase the number and distribution of wetlands in Hawaii that are useful to waterbirds.
- Re-establish a breeding population of Hawaiian Gallinules on Maui and Moloka`i.
- Produce current and accurate estimates of population size and trend of each species on each island.
- Develop more effective methods to reduce predation and explore the use of predator–proof fences.

Conservation Actions:

- Habitat Restoration.
    - Continue efforts to manage wetland habitat and hydrology on the Mānā Plain of Kaua'i, where wetlands were drained historically for sugar cane production.
    - Continue management of Kawainui Marsh on O'ahu. This large wetland is recognized as a Ramsar site but currently supports few native waterbirds and is largely choked with alien plants.
- Predator Control.
    - Prevent establishment of mongooses on Kauaʻi and Lānaʻi using all available methods. Improve biosecurity at airports and seaports.
    - Construct predator-proof fences at Kanahā Pond on Maui and at James Campbell, Honouliuli, and Waiawa National Wildlife Refuges on O'ahu to increase nesting success of waterbirds and eliminate the need for continual predator control. Before fence construction, each site will require a scoping and feasibility study to determine the optimum size and placement of a fence and the estimated cost, a cost-benefit analysis comparing other forms of management, and regulatory compliance.
    - Develop improved methods of controlling bullfrogs and invasive fishes.
- Translocation. Translocate Hawaiian Gallinules to Maui and Moloka`i in order to re-establish additional breeding populations and decrease the risk of extinction.

Summary and Estimated Costs of Conservation Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Habitat management at Mānā Plain, Kaua'i	1-5	$300,000	1,500,000
Habitat management at Kawainui Marsh, Oahu	1-5	$300,000	1,500,000
Prevent establishment of mongooses on Kauaʻi and Lānaʻi	1-5	$150,000	$750,000
Construct and maintain a predator-proof fence at Kanahā Pond, Maui	1-5		$1,000,000
Construct and maintain a predator-proof fence at James Campbell NWR, O'ahu	1-5		$1,000,000
Construct and maintain a predator-proof fence at Honouliuli NWR, O'ahu	1-5		$1,000,000
Construct and maintain a predator-proof fence at Waiawa NWR, O'ahu	1-5		$1,000,000
Establish Hawaiian Gallinule populations on Maui and Moloka'i	2-5	$150,000	$600,000
Analyze existing survey data to determine current population size and trend for all 3 species	1-2	$20,000	$40,000
Develop improved methods for surveying Hawaiian Moorhens using playbacks	1-2	$15,000	$30,000

Potential Partners: U.S. Fish and Wildlife Service-Refuges, Hawaii Division of Forestry and Wildlife, Department of Hawaiian Home Lands, Ducks Unlimited, Pacific Coast Joint Venture, Kamehameha Schools, Kaelepulu Wetland Preserve.

Ancillary Species: The endangered Hawaiian Duck or Koloa (*Anas wyvilliana*) and the endangered Nēnē or Hawaiian Goose (*Branta sandvicensis*) occur in some of the same wetlands on Kauai and would benefit from the same actions. Predator exclusion or control could render some wetlands suitable for reintroduction of the endangered Laysan Duck (*Anas laysanensis*). Numerous species of migratory waterfowl and shorebirds use the same habitats that are important to the endemic Hawaiian waterbirds. Some of the more common migrants are Northern Pintail (*Anas acuta*), Northern Shoveler (*Anas clypeata*), American Wigeon (*Anas americana*), Lesser Scaup (*Aythya affinis*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Tringa incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), Ruddy Turnstone (*Arenaria interpres*), and Sanderling (*Calidris alba*).

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Focal Species: Hawaiian Crow or ʻAlalā (*Corvus hawaiiensis*)

Synopsis: The ʻAlalā has been extinct in the wild since 2002, but the number of birds in captivity has grown to over 100. The future of the species will depend on whether a viable wild population can be re-established by releases of captive-bred birds. Previous releases in the 1990s did not result in establishment of a wild population. Careful selection of a release site, restoration and management of forest habitat, predator control, and an adaptive approach to release methods will be needed to achieve successful re-introduction.


ʻAlalā. Photo Jack Jeffrey.

Geographic region: Hawaiian Islands
Group: Forest birds
Federal Status: Endangered
State status: Endangered
IUCN status: Extinct in the Wild
Conservation score, rank: 202/20, At-risk
Watch List 2007 Score: RED
Climate Change Score: High

Population Size and Trend: The ʻAlalā is extinct in the wild, but 109 birds exist in captivity as of 30 September 2012, including 58 males and 51 females, of which 15 are juveniles hatched in 2012 (ZSSD 2012). In 2012 a total of 20 ʻAlalā pairs were set up for breeding. The captive population has increased steadily in size from 24 birds in 1999 to its present size. The wild population was in decline by the early 1900s and by the 1960s only scattered relict populations existed (Banko et al 2002). In 1976, the wild population was estimated at 76 ± 18 (Scott et al. 1986). The last known wild birds, a pair, disappeared in 2002 (USFWS 2009).

Range: Extinct in the wild. Historically, the ʻAlalā was only known from Hawaiʼi Island, but subfossils indicated this or a closely related species also occurred on Maui (Banko 2009). On Hawaiʼi, it was restricted to the slopes of Hualālai and Mauna Loa Volcanoes (Perkins 1903, Munro 1944, Banko and Banko 1980). Since the 1960s, nesting was restricted to between 730 and 1,737 m in elevation on Hualālai and the western slope of Mauna Loa (Banko and Banko 1980). Based on subfossils, at least five crow species occurred in Hawaiʻi; only the ʻAlalā crow survives (James and Olson 1991).

Essential Biology: The ʻAlalā is medium-sized crow, from dark brown to black in color, with the wings lighter in color than the body and tail. The bill is relatively thick and the nares are covered by long bristly feathers (Banko et al. 2002). Males and females are similar, though males are larger and heavier (555±13 g) than females (485±16 g; Banko et al. 2002). Juveniles resemble adults, but may appear "fluffy" and retain a bright red mouth lining for about 18 months after hatching. Like many crows, ʻAlalā are raucous and gregarious. Vocalizations are extremely varied, including loud humanlike shrieks and howls and softer growls and mutterings (Banko et al. 2002).

Information about the species' habitat needs, behavior, movements, and life history are incomplete because most of what is known about the ʻAlalā is from observations of fragmented and declining populations (Banko et al. 2002, USFWS 2009). ʻAlalā were found in dry woodlands and mesic ʻōhiʻa (*Metrosideros polymorpha*) and ohia-koa (*Acacia koa*) forests

(Banko et al. 2002). The habitat with the highest breeding densities of ʻAlalā during the period 1970 to 1982 was relatively undisturbed ʻōhiʼa-koa forest; ʻAlalā avoided disturbed forest (Giffin et al. 1987). Dense understory vegetation appears to be important to ʻAlalā in avoiding predation by the ʻIo or Hawaiian Hawk (*Buteo solitarius*; USFWS 2009). The ʻAlalā feeds on fruits, invertebrates gleaned from tree bark and other substrates, and eggs and nestlings of other forest birds. Nectar, flowers, and carrion are minor diet components. ʻAlalā have been observed to eat at least 26 species of plants in the wild (Sakai and Carpenter, Sakai et al. 1986, Banko et al. 2002, Culliney et al. 2012), and preferences by captive ʻAlalā for some of these species and a few others also have been recorded (Kuehler et al. 1995). Jacobi and Price (2007) identified the following species as preferred food plants because they were behaviorally preferred by ʻAlalā, nutritionally rich, or produced a high abundance of fruit per plant: ʻōlapa (*Cheirodendron trigynum*), ʻōhā kēpau (*Clermontia* spp.), pilo (*Coprosma* spp.), ʻieʼie (*Freycinetia arborea*), kāwaʻu (*Ilex anomala*), pūkiawe (*Styphelia tameiameiae*), alani (*Melicope* spp.), kōlea (*Myrsine* spp.), ʻaiea (*Nothocestrum longifolium*), māmaki (*Pipturus albidus*), hōawa (*Pittosporum* spp.), kōpiko (*Psychotria hawaiiensis*), ʻākala (*Rubus hawaiiensis*), and ʻōhelo (*Vaccinium* spp).

Nest construction usually begins in March and eggs are laid in April. Recorded nests have been predominantly in ʻōhiʼa, although other trees and ʻieʼie vines may be used (Tomich 1971, Banko et al. 2002). Breeding pairs form long-term bonds, and both sexes participate in nest construction, but only females incubate eggs and brood young. Clutch size ranges from two to five (usually three), although typically only one or two nestlings fledge. Pairs will re-lay upon loss or removal of the first clutch, allowing for increased reproduction in captivity. Incubation lasts 19-22 days. Juveniles fledge approximately 40 days after hatching, but are poor flyers initially and may remain on or near the ground for several days. Wild juveniles depend on their parents for at least eight months and remain with their family group until the following breeding season (Banko et al. 2002).

The median home range recorded was 480 hectares (1,186 acres; USFWS 1999), and the shortest distance between active nests observed was 300 meters (984 feet; USFWS 2009). After the breeding season, wild ʻAlalā often disappeared for extended periods, and their actual home ranges probably were larger than documented. When the species was more abundant, flocks of ʻAlalā were observed to move seasonally in response to weather and availability of ʻieʼie and other fruits (Munro 1944). ʻAlalā are known to have lived 18 years in the wild (one female) and 25 years in captivity (one male; Banko et al. 2002). Age at first breeding is approximately 2 years for females and 2 to 3 years for males. The annual survival rate of wild adult ʻAlalā was estimated to be 81% from observations of banded birds (NRC 1992). This estimate represents a period of population decline, and survival presumably was higher in the past when populations were more stable.

Primary Threats:

- <u>Small Population Size</u>. Small populations are inherently more vulnerable to extinction because of the higher risks posed by random demographic fluctuations and localized catastrophes such as hurricanes, fires, and disease outbreaks (Wiley and Wunderle 1994), and potentially genetic issues (Keller and Waller 2002). Lethal deformities are occurring at a higher than normal rate in the captive ʻAlalā population, suggesting inbreeding depression may be occurring (Zoological Society of San Diego, unpubl. data).
- <u>Habitat degradation</u>. Unlike mainland corvids, ʻAlalā did not adapt well to human-disturbed habitats, and habitat destruction and degradation probably was the most important cause of population declines (Giffin 1983, Scott et al. 1986, Giffin et al. 1987,

NRC 1992, Banko et al. 2002). Native forest was lost and degraded at low and high elevations by agriculture, logging, ranching, and non-native ungulates. This resulted in a compression of the belt of dry and mesic forest over which ʻAlalā ranged tracking fruit and rainfall. Feral ungulates degraded native forest by browsing, causing soil erosion, preventing regeneration, spreading and facilitating the invasion of alien plants, and creating breeding habitat for mosquitoes (USFWS 2009). Ungulates also open up closed canopy forests which probably increased the vulnerability of ʻAlalā to ʻIo predation.

- Predation. ʻAlalā nests are vulnerable to feral cats (*Felis catus*) and rats, particularly the black or ship rat (*Rattus rattus*), which are good climbers. ʻAlalā fledglings often remain on or near the ground for several days after leaving the nest, when they are vulnerable to a wider range of predators including small Indian mongooses (*Herpestes auropunctatus*), dogs (*Canis familiaris*), and feral pigs (*Sus scrofa*; USFWS 2009). The ʻIo or Hawaiian Hawk also is known to prey on juvenile and adult ʻAlalā. Predation by ʻIo was the leading cause of death during releases of ʻAlalā in Kona in the 1990s, although some of those birds may have been weakened by disease (USFWS 2009).
- Disease. Toxoplasmosis is a disease caused by an intracellular protozoan parasite, *Toxoplasma gondii*, and is widespread throughout the world and can affect all warm-blooded animals (Elmore et al. 2010, Innes 2010). The role that toxoplasmosis played in the decline of the wild Alalā population is unknown, but captive ʻAlalā are highly susceptible to toxoplasmosis, which was diagnosed in five of the 27 birds released in the 1990s and was the second largest source of mortality (after predation), causing the death of least three birds (Work et al. 2000, USFWS 2009). Cats are the only definitive host for the sexual stages of *T. gondii*, and are thus the primary reservoir of infection. One cat can shed millions of oocytes that can persist for months in damp soil (Elmore et al. 2010, Innes 2010). Asexual tissue cysts form in cats and intermediate hosts that become infected through contact with oocytes, and also can serve as a source of infection. ʻAlalā thus could contract toxoplamosis through direct contact with cat feces, contact with soil containing oocysts, or from preying on or scavenging carcasses of intermediate hosts such as rodents or insects (Work et al. 2000, Innes 2010). Danner et al. (2007) found that 37% of feral cats captured on Mauna Kea were infected with *T. gondii*.

  The lethality of avian malaria for ʻAlalā in the wild is unknown, but the decline in the ʻAlalā population between 1890 and 1910 coincided with declines in other native birds in mid-elevation forests and may have been due to malaria outbreaks (Munro 1944). Seasonal movements by ʻAlalā may have increased their exposure to diseases; mosquitoes and avian malaria cannot survive at high elevations (above 1,500 m) due to cool temperatures.

  West Nile virus is another mosquito-borne pathogen that infects a wide range of bird species and to which corvids are especially susceptible (Kilpatrick et al. 2006). West Nile virus spread rapidly across North America from 2000 to 2005 (Marra et al. 2004), but it has not been recorded in Hawaiʼi (Kilpatrick et al. 2004). The high level or mortality exhibited by other corvids exposed to West Nile virus and subsequent population declines suggests that arrival of this disease in Hawaiʼi would seriously compromise recovery efforts for the ʻAlalā (USFWS 2009).
- Persecution by Humans. Many ʻAlalā were reportedly shot around farms between 1890 and the 1930s because they were believed to raid crops (Munro 1944). Despite legal protection in 1931, malicious shooting of ʻAlalā on private lands continued into the 1980s (Giffin et al. 1987). Habitat restoration (fencing and ungulate eradication) needed for the

establishment of wild populations is unpopular with some hunters and communities. Some hunters have been known to shoot the ‘Alalā because they make loud noises when they see pigs or hunters, and this has affected the hunter’s ability to catch pigs (State of Hawaii 2012b, pp. 62, 128).

- <u>Disturbance</u>. Wild ‘Alalā could be sensitive to disturbance by humans, other ‘Alalā and ‘Io, especially at the nest (Banko and Banko 1980, Banko et al. 2002).

Conservation Actions to Date: The ‘Alalā has been legally protected by the State of Hawai‘i since 1931 and was recognized as federally endangered in 1967. The first recovery plan for the ‘Alalā was published in 1982 (USFWS 1982) and in 1991 the USFWS commissioned the National Research Council of the National Academy of Sciences to undertake a review of the status of the ‘Alalā and to recommend appropriate recovery actions. A report was published in 1992 (NRC 1992) and the USFWS developed a new long-term management plan for the species’ recovery (USFWS 1993). The ‘Alalā Recovery Team was formed in 1992 to provide recovery recommendations, and a related group, the ‘Alalā Partnership, was formed to facilitate implementation of conservation actions on private lands. A revised recovery plan was completed in 2009 (USFWS 2009).

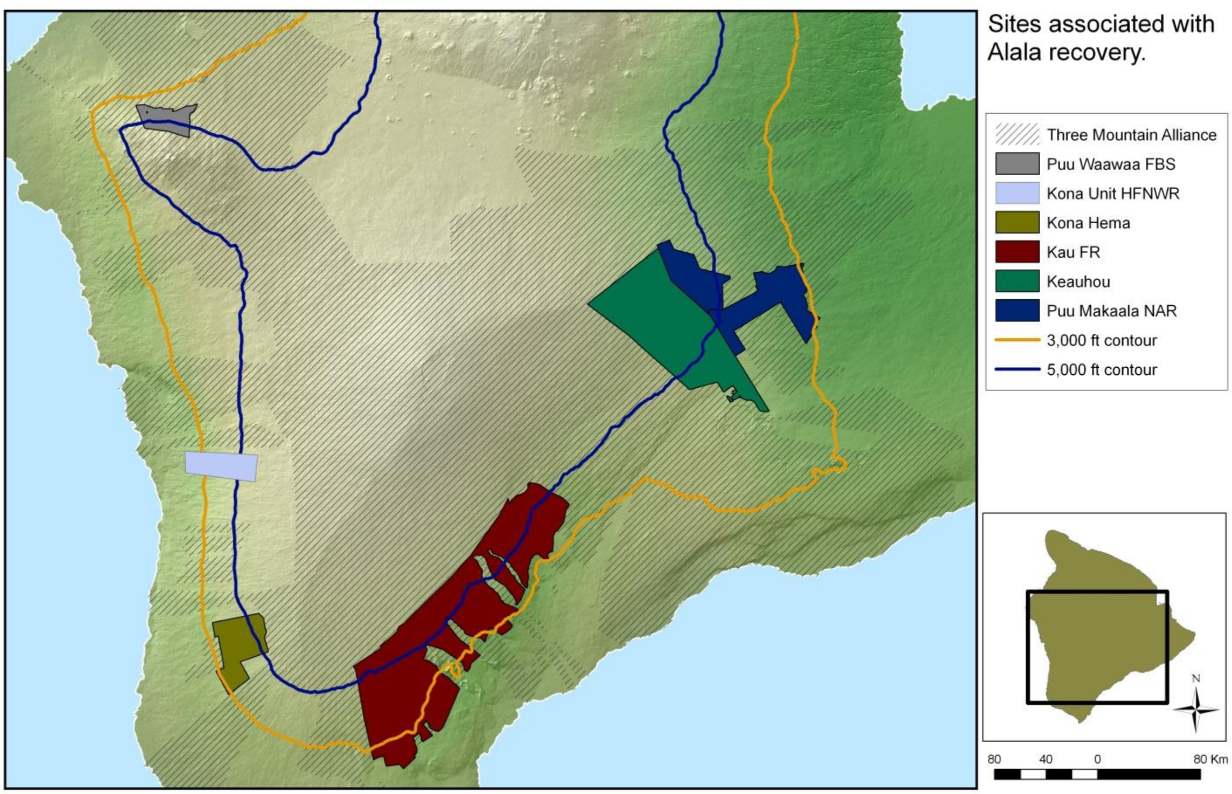
Beginning in 1958, concern over rapid declines in the wild led the State of Hawai’i to begin opportunistically acquiring sick or injured ‘Alalā for rehabilitation in captivity. Between 1970 and 1981, a total of 12 ‘Alalā were brought into captivity, and they were transferred from various locations to Olinda, Maui, in 1986. In 1993, The Peregrine Fund (TPF) assumed management of the ‘Alalā program. A new captive propagation facility dedicated to reproduction of ‘Alalā and other endangered Hawaiian forest birds was completed on Hawai’i in 1996 and designated the Keauhou Bird Conservation Center (KBCC). In 1996, TPF assumed operations of the Olinda Endangered Species Propagation Facility from the State of Hawai’i, and renamed it the Maui Bird Conservation Center (MBCC). The Zoological Society of San Diego took over the operation of both KBCC and MBCC in 2000, and titled the combined program the Hawaiian Endangered Bird Conservation Program. Fledgling production has increased substantially over the last several years (2008-2012) and production of between 15 and 20 fledglings annually now appears sustainable.

Releases of captive-bred ‘Alalā were conducted in Kona in the 1990s in an attempt to re-establish a wild population. Between 1993 and 1998, The Peregrine Fund, with support from the USFWS and the USGS, released 27 juveniles into an area of suboptimal habitat on the McCandless Ranch that supported the only remaining wild ‘Alalā population, which initially consisted of 11 adults and a juvenile but which declined throughout the release period. Habitat management was not implemented prior to or during the releases, but predators were controlled. Intensive field studies of the wild population and released juveniles were conducted between 1992 and 2002. Twenty-one of these birds subsequently died from a variety of causes, although some lived for four years in the wild. ‘Io predation was suspected in the loss of seven birds, and thee birds died from toxoplasmosis. The remaining six birds were recaptured in 1998 and 1999 and re-integrated back into the captive population (USFWS 2009).

In 1984, DOFAW created the 1,541 ha (3,806 ac) Pu’u Wa’awa’a Forest Bird Sanctuary on the northern slope of Hualālai for the protection of native birds including the ‘Alalā. In 1997, the USFWS purchased 2,145 ha (5,300 ac) on the western slope of Mauna Loa primarily for the ‘Alalā, which became the Kona Forest Unit of Hakalau Forest National Wildlife Refuge (NWR), in order to begin intensive habitat improvements in the core of the ‘Alalā’s former range. Legal disputes on access and other topics with the former landowners impeded management of the refuge for years, but fencing was completed in 2012 and ungulate eradication is being planned.

In 1999, a draft Environmental Assessment was prepared examining the potential of five sites on Hawai'i to support an ʻAlalā release program (USFWS 1999). In 2007, a vegetation assessment of six potential release sites was conducted (Jacobi and Price 2007) and the ʻAlalā Recovery Team ranked these sites based on this information and other criteria. The Kūlani-Keauhou area was ranked as the best site and the southwestern Kaʻū Forest Reserve ranked second. Kūlani is now part of the Pu'u Maka'ala Natural Area Reserve, and Keauhou is owned by Kamehameha Schools. Parts of the Kūlani- Keauhou area have been fenced and ungulate free for 20 years, which has resulted in significant habitat recovery. Other sites evaluated included the Kona Forest Unit of Hakalau Forest NWR, Kona Hema Preserve (TNC), central Kaʻū Forest Reserve, and Kapāpala Forest Reserve. Restoration of Keauhou, Pu'u Maka'ala Natural Area Reserve, and Kona Hema is ongoing. In 2012, an Environmental Assessment was completed for fencing, ungulate control, and other management actions in the Kaʻū Forest Reserve (State of Hawai'i 2012).

In 2010, an ʻAlalā Restoration Working Group was formed with members from the USFWS, DOFAW, ZSSD, and the Three Mountain Alliance (TMA), with the goal of planning for a second release, which is scheduled for 2014. The Kūlani-Keauhou area has been selected as the site for the initial releases, and the Kaʻū Forest Reserve as a site for future releases once the habitat has been sufficiently restored. Drafting of a release plan to restore the species to the wild was contracted to Pacific Rim Conservation in April 2012. An ʻAlalā Outreach program was initiated in 2010 to facilitate public acceptance and support for the release of captive birds and for management in the Kaʻū Forest Reserve. Lack of community support was a major obstacle to past recovery efforts for the ʻAlalā. Because of the wide-ranging nature of the ʻAlalā, and its historical vulnerability to shooting, public support is essential.



Sites associated with Alala recovery.

Planning/Research Needs:

- Complete a restoration plan by April 2013 to guide the establishment of a wild population.
- Complete a Safe Harbor Agreement with Kamehameha Schools.
- Complete analysis of data collected during 1990s release program to help guide development of the restoration plan.
- Develop methods to teach predator avoidance to captive ‘Alalā prior to their release.

5-Year Conservation Goals:

- Maintain health and productivity of the captive ‘Alalā population.
- Continue habitat management at Kūlani- Keauhou.
- Release captive birds at Kūlani- Keauhou and monitor their status, movements, and any nesting attempts.
- Restore native habitat in the Ka‘ū Forest Reserve so it is suitable as a release site for Alalā.
- Gain public support through public outreach for re-establishment of a wild Alalā population.

Conservation Actions:

- Captive Breeding. Maintain the captive ‘Alalā population and allow for its continued growth in 2013 by constructing additional aviaries.
- Habitat management.
    - Maintain fences at Kūlani-Keauhou to ensure the area remains ungulate free. Monitor for ungulate ingress and remove any animals detected.
    - Construct fences in the Ka‘ū Forest Reserve to create management unit(s) at least 4,000 ha in size. Once fences are completed, eradicate ungulates, then inspect and repair fences, monitor for ungulate ingress and removal any animals as needed. Outplant native food plants if necessary based on the results of plant surveys.
- Predation.
    - Choose release sites with adequate understory vegetation to provide ‘Alalā with adequate cover to escape from ‘Io.
    - Survey release sites for the presence of ‘Io and avoid nests and areas of high ‘Io density to the maximum extent practicable. ‘Io likely occur throughout the release areas but their density and activity levels may vary somewhat.
    - Control non-native predators (feral cats, rats, mongooses) within an area of at least 1 km^2 area centered on release site(s).
    - Train captive-bred ‘Alalā before release to recognize ‘Io as predators and to respond with appropriate defensive or evasive behaviors.
- Disease.
    - Control feral cats to prevent ‘Alalā from contracting toxoplasmosis.
    - Monitor health of released ‘Alalā and quickly treat any birds that show signs of toxoplasmosis, malaria, or poxvirus.
- Releases of Captive‘Alalā.
    - Construct field aviary(ies) and other infrastructure at Kūlani- Keauhou. More than one aviary may be needed if it is decided that multiple release sites are preferable to reduce interference among cohorts from different years.
    - Release ‘Alalā in each of five years, monitor their movements, health, behavior, and any nesting attempts.

- Public Outreach. Continue outreach to increase public acceptance of landscape scale management required for successful releases and the restoration of ʻAlalā to the wild.

Summary and Estimated Costs of Conservation Actions, 2013-2017:

Conservation Action	Years	Annual Cost	Total Cost
Construct additional aviaries at KBCC	1	$200,000	$200,000
Build release aviary and prepare infrastructure at Kūlani- Keauhou	1-2	$100,000	$200,000
Control feral cats, rats, and mongooses at Kūlani-Keauhou	2-5	$100,000	$500,000
Release ʻAlalā and monitor them	1-5	$300,000	$1,500,000
Fencing and ungulate removal in Kaʻū FR	2-5	$1,500,000	$6,000,000
Outreach	1-5	$100,000	$500,000

Potential Partners: Hawai'i Division of Forestry and Wildlife, U.S. Fish and Wildlife Service, Zoological Society of San Diego, U.S. Geological Survey Pacific Island Ecosystems Research Center, Kamehameha Schools, Three Mountain Alliance, National Park Service, University of Hawai'i, and the The Nature Conservancy of Hawai'i.

Ancillary Species: Conservation actions aimed at the ʻAlalā , including fencing, ungulate control, forest restoration, and predator control, would benefit all native bird species that use forest habitat on the island of Hawai'i, including the ʻOmaʻo (*Myadestes obscurus*), Hawaiʻi ʻElepaio (*Chasiempis sandwichensis*), Hawaiʻi ʻAmakihi (*Hemignathus virens*), Hawaiʻi Creeper (*Oreomystis mana*), Hawaiʻi Ākepa (*Loxops coccineus*), ʻAkiapolaʻau (*H. munroi*), ʻIʻiwi (*Vestiaria coccinea*), and ʻApapane (*Himatione sanguinea*).

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Focal Species: O'ahu 'Elepaio (*Chasiempis ibidis*)

Synopsis: The O'ahu 'Elepaio is an adaptable species that has persisted in low elevation, disease-plagued forests dominated by alien plants on the most developed of the Hawaiian Islands. The most serious threat to the species is predation on nests by alien rats, which take eggs, chicks, and even incubating females. Rat control has been the primary conservation tool and can be effective at reducing predation, but it must be implemented on a larger scale to reverse declines of more 'elepaio populations. O'ahu 'Elepaio in some areas are evolving to nest higher off the ground in response to rat predation. Forest restoration with native trees that are less attractive to rats might help decrease the need for rat control.

Female O'ahu 'Elepaio feeding nestlings. Photo Eric VanderWerf

O'ahu 'Elepaio habitat, Wailupe Valley. Photo E. VanderWerf

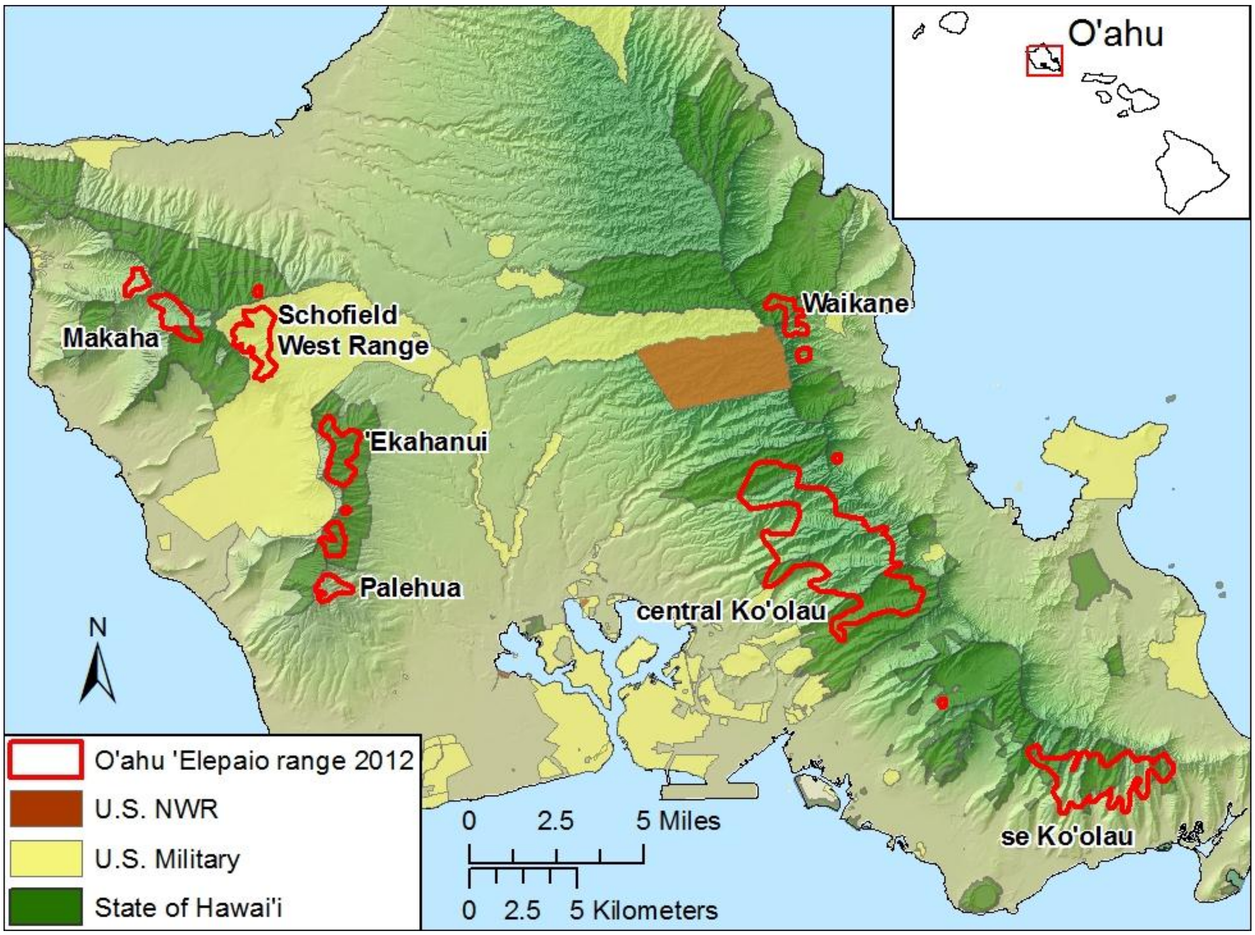
Status: The O'ahu 'Elepaio was formerly considered a subspecies (*Chasiempis sandwichensis ibidis*), but in 2010 it was split into a separate species based on morphological, genetic, and behavioral evidence (VanderWerf 2007, VanderWerf et al. 2009). It is listed as endangered under the U.S. Endangered Species Act and by the State of Hawai'i using its previous taxonomy. The Kaua'i 'Elepaio (*C. sclateri*) and Hawai'i 'Elepaio (*C. sandwichensis*) are relatively common and widespread on their respective islands.

Geographic region: Hawaiian Islands
Taxonomic Group: Forest Birds
Federal Status: Endangered
State status: Endangered
IUCN status: Endangered
Conservation score: 20/20, At-risk
Watch List 2007 Score: Red
Climate Change Vulnerability: High

Population Size and Trend: The current population estimate is 1,261 birds (95% CI=1,181-1,343), based on surveys conducted in the Wai'anae Mountains from 2006-2009 (VanderWerf et al. 2011a) and in the Ko'olau Mountains from 2011-2012 (E. VanderWerf unpubl. data). Of this total, 300 were located in the Wai'anae Mountains and 961 (95% CI=881-1,043) were located in the Ko'olau Mountains. The sex-ratio is male-biased in almost all areas, and the population consists of about 477 breeding pairs and 307 single males. In the 1990s, the population was estimated to be 1,974 birds, with roughly half the total in each mountain range (VanderWerf et al. 2001). The number of 'elepaio in the Wai'anae Mountains has declined drastically in the past 20 years, but the number in the Ko'olau Mountains has remained more stable.

Range: The current range of the O'ahu 'Elepaio is estimated to be 5,187 ha (12,812 acres), of which 3,947 ha are located in the Ko'olau Mountains and 1,240 ha are located in the Wai'anae

Mountains (VanderWerf et al. 2011a, E. VanderWerf unpubl. data). The range is highly fragmented, and because ‘elepaio do not disperse far, these fragments are isolated from each other. The largest subpopulations are in the central Ko’olau (523 birds) and southeastern Ko’olau (403 birds) Mountains, with smaller subpopulations in ‘Ekahanui (100 birds), Schofield Barracks West Range (104 birds), Palehua (41 birds), Waikane and Kahana Valleys (24 birds), and several tiny fragments containing 1-5 birds each. Size of the range was estimated to be 5,486 ha (13,550 ac) in the 1990s, which is only 4% of the presumed prehistoric range and 25% of the range occupied in 1975 (VanderWerf et al. 2001). The range has declined further in the Wai’anae Mountains (VanderWerf et al. 2011a), but it has remained relatively stable in the Ko’olau Mountains.



Essential Biology: The O‘ahu ‘Elepaio is a small (11-13 g) monarch flycatcher (Monarchidae) endemic to O’ahu. Adults are brown above, white below with dark streaks, and have white wings bars and white tail tips. ‘Elepaio have a two-year delay in plumage maturation in both sexes; first and second-year birds are reddish brown and lack the white markings of adults (VanderWerf 1998, 2001). The song is a squeaky whistle from which the Hawaiian name is derived.

O’ahu ‘Elepaios prefer areas with a tall forest canopy and a dense understory and are most abundant in riparian habitat in valleys (VanderWerf et al. 1997, 2001). They occur in a variety of forest types ranging from wet to dry. Elepaios have adapted to forests dominated by alien plants, but nests in fruit-bearing alien trees suffer high rates of predation (VanderWerf

2009). The nesting season is primarily from January-June. Both sexes build the nest, incubate the eggs, and feed the nestlings. Only the female incubates at night, leading to higher predation on females by nocturnal rats (VanderWerf 2009). The clutch size is usually two eggs, occasionally one or three. Eggs hatch after 18 days, and chicks fledge 16 days after hatching. Without rat control nest predation is common, but rat control has resulted in increases in nest success (33% vs. 62%), fecundity (0.69 ± 0.05 vs. 0.33 ± 0.06 fledglings per pair), and female survival (10-25% increase; VanderWerf 2009, VanderWerf et al. 2011b).

Elepaios are non-migratory, sedentary, and defend all-purpose territories year-round (VanderWerf 1998, 2004). Territory size varies with habitat structure and population density, and averages 0.6-2.0 ha (1.5-5.0 ac). Dispersal is driven by interspecific competition, and ‘Elepaio disperse far enough to find a vacant territory, often only 300-500 meters (VanderWerf 2008). ‘Elepaio are long-lived for a small Passerine (up to 20 years). Mate fidelity and site fidelity are high, and a pair may occupy the same territory together for their entire lives.

Primary Threats:

- Introduced Predators. Predation on nests by alien black rats (*Rattus rattus*) is the most serious threat to the O’ahu ‘Elepaio (VanderWerf and Smith 2002, VanderWerf 2009). Rats take eggs, nestlings, and even adult females from the nest. Rat control programs can result in substantial increases in nest success and survival of females, if properly implemented (VanderWerf 2009, VanderWerf et al. 2011b). Young elepaios sometimes leave the nest before they can fly well and may spend 1-2 days on or near the ground, where they are vulnerable to a range of alien predators, including feral cats (*Felis domesticus*), small Indian mongooses (*Herpestes auropunctatus*), and feral pigs (*Sus scrofa*). O‘ahu Elepaios in some areas are evolving to place nests higher in trees in response to predation by rats, where they are safer (VanderWerf 2012).
- Disease. Elepaios have greater immunity to alien diseases than some of the Hawaiian honeycreepers, but avian pox (*Poxvirus avium*) and avian malaria (*Plasmodium relictum*) cause some mortality and may weaken or disable birds and reduce reproductive ability (VanderWerf 2009, VanderWerf et al. 2011a). All areas of O‘ahu are subject to mosquito-borne diseases; there are no high-elevation refugia from disease like on other islands because the mountains on O‘ahu are lower (VanderWerf et al. 2006). O‘ahu ‘Elepaios have persisted despite high disease prevalence and may be evolving resistance to avian poxvirus and avian malaria.
- Invasive Alien Plants. ‘Elepaio are able to forage and nest in forest dominated by alien plants, but nest predation is high in such areas because many alien trees bear fruit or nuts that are attractive to rats and support high rat abundance, increasing nest predation risk (VanderWerf 2009). Preventing the spread of alien trees such as strawberry guava (*Psidium cattleianum*), christmasberry (*Schinus terebinthifolius*), mango (*Mangifera indica*), and Java plum (*Syzygium cumini*) into native forest and restoring native trees would help to reduce the threat from nest predation.
- Feral pigs. Feral pigs are an indirect threat to O‘ahu ‘Elepaio by facilitating the spread of invasive alien plants that support high rat populations. The presence of feral pigs also may limit the use of poison bait for controlling rats (USFWS 2006).
- Wildfires. Wildfires are a threat to O‘ahu ‘Elepaio by accelerating habitat degradation and spread of alien plant species not used by ‘Elepaio, such as *Eucalyptus* spp. Wildfires

are a threat primarily in drier areas of O‘ahu, such as Schofield Barracks West Range and Makua Military Reservation (USFWS 2006).

- Social. Rat control to protect O‘ahu ‘Elepaio nests from predation has been conducted using traps and poison bait stations. In some areas there has been concern about possible consumption of bait by feral pigs and subsequent human consumption of pig meat. Temporary hunting closures or exclusion of feral pigs from areas with bait using fences could alleviate this concern. Outreach programs aimed at increasing public awareness of the threat posed by rats to native species and the need for rat control might help provide the political will-power to undertake large-scale rat control.

Conservation Actions to Date: The O‘ahu ‘Elepaio was listed as endangered by the U.S. Fish and Wildlife Service and the State of Hawai’i in 2000 (USFWS 2006). Critical habitat also was designated in 2000. Most areas where O‘ahu ‘Elepaio still occur are zoned for conservation and are protected from development, but habitat degradation remains a problem. In 2008, 3,716 acres of land in Moanalua Valley, which forms the core of the largest remaining O’ahu ‘Elepaio population, were purchased from a private landowner by the Trust for Public Land with funding from the U.S. Army Compatible Use Buffer Program, the U.S. Fish and Wildlife Service, and the State of Hawai’i, and then transferred to the state of Hawai’i for management as a forest reserve. Another important area was protected in 2010, when 3,592 acres of land encompassing the Nature Conservancy’s former Honouliuli Preserve, including the ‘Ekahanui area, were purchased from a private landowner by the Trust for Public Land with funding from the U.S. Army Compatible Use Buffer Program, the U.S. Fish and Wildlife Service, and the Hawai’i Legacy Land Conservation Fund, and then transferred to the state of Hawai’i for management as a forest reserve.

Rat control has proven to be an effective method of increasing nest success and survival of breeding females, if properly implemented, and has become the cornerstone of conservation efforts for the O‘ahu Elepaio (VanderWerf and Smith 2002, VanderWerf 2009, VanderWerf et al. 2011b). Ground-based rodent control using snap traps and diphacinone bait stations has been conducted in several areas and by several agencies, including: the Honolulu Watershed Forest Reserve since 1997 by Pacific Rim Conservation in collaboration with the Hawai’i Division of Forestry and Wildlife; at Schofield Barracks West Range and Makua Military Reservation since 1998 by the U.S. Army Environmental Division; in Ekahanui since 2000 by The Nature Conservancy of Hawai’i and the U.S. Army; in Lualualei Naval Magazine from 2002-2004 by the U.S. Navy; in Makaha Valley from 2004 to 2009 by the U.S. Army and the City and County of Honolulu Board of Water Supply; in Moanalua Valley since 2005 by the U. S. Army; at Palehua since 2007 by The Nature Conservancy of Hawai’i and the U.S. Army, and in Waikane Valley from 2007-2009 by the U.S. Army. The efficacy of these rat control efforts has varied, however, and rat control programs in Makaha and Waikane were discontinued because they were not effective and the number of ‘elepaio had declined (VanderWerf et al. 2011b).

Research has focused on surveys to determine the distribution and abundance of the species and to locate areas where management is needed (VanderWerf et al. 2001, 2011), monitoring response of ‘elepaio populations to rat control (VanderWerf and Smith 2002, VanderWerf 2009, VanderWerf et al. 2011b), mist-netting and banding to facilitate demographic monitoring and measuring of disease prevalence (VanderWerf et al. 2006). Examination of a 17-year data set from the southeastern Ko’olaus revealed that O‘ahu ‘Elepaio are evolving to nest higher off the ground as a result of selection by rats against low nests (Vanderwerf 2012). Nest success also has increased over the same period, providing some hope that this natural population response will aid in recovery.

Planning/Research Needs:

- Explore other methods of rat control and compare their cost-efficiency, including large grids of snap traps and self-resetting rat traps.
- Investigate whether ‘elepaio nest height is increasing in other parts of O‘ahu.
- Investigate whether O‘ahu ‘Elepaio are evolving resistance or tolerance to avian poxvirus and avian malaria.
- Conduct public outreach about the threat posed by rats to native species and the need for larger scale rat control.
- Determine accuracy of estimates for survival of juvenile O‘ahu ‘Elepaio to improve demographic models.

5-Year Conservation Goals:

- Increase the scale of rat control.
- Improve the cost-effectiveness of rat control methods.
- Begin restoration of native forest habitat to reduce predation by rats on ‘elepaio nests.

Conservation Actions:

- Predator Control
  - Continue rat control in the following O‘ahu ‘Elepaio populations: 1. southeastern Ko’olau, 2. Schofield Barracks West Range, 3. Moanalua Valley, 4. ‘Ekahanui, and 5. Palehua.
  - Investigate self-resetting rat traps as a means of decreasing cost of rat control.
  - Support efforts by the 'Ōhulehule Forest Conservancy and a private landowner to resume rat control in Waikane Valley.
- Habitat Restoration and Ungulate Control
  - Complete ungulate fence in Schofield Barracks West Range and remove all feral pigs.
  - Support efforts by the 'Ōhulehule Forest Conservancy and a private landowner to begin native forest restoration in Waikane Valley.
  - Begin restoring native forest inside a demonstration ungulate fence in Wailupe Valley as a test of reducing the need for rat control.
- Social.
  - Support public education and outreach about need for rat control.
  - Continue meetings of the Hawai’i Toxicant Working Group, encourage broader input and participation by conservation practitioners.

Summary of 5-year Actions, 2012-2016:

Conservation Action	Year(s)	Annual cost	Total Cost
Continue rat control in Wailupe Valley	1-5	$30,000	$150,000
Continue rat control in Moanalua Valley, Ekahanui, Schofield Barracks, and Palehua	1-5	$120,000	$600,000
Resume rat control and ‘Elepaio monitoring in Waikane Valley	1-5	$13,000	$65,000

Purchase 50 self-resetting rat traps, measure and compare cost-efficiency to other control methods	1-2	$15,000	$30,000
Restore native forest habitat in fenced demonstration area in Wailupe Valley	1-5	$10,000	$50,000
Eradicate feral pigs from fenced area of Schofield Barracks West Range	1-3	$100,000	$300,000

Potential Partners: Hawai'i Division of Forestry and Wildlife, U.S. Fish and Wildlife Service, U.S. Army, Pacific Rim Conservation, Ko'olau Mountains Watershed Partnership, Wai'anae Mountains Watershed Partnership, 'Ōhulehule Forest Conservancy.

Ancillary Species: Control of alien rats would benefit other native bird species that use forest habitat on O'ahu, including 'Apapane (*Himatione sanguinea*) and O'ahu 'Amakihi (*Hemignathus chloris*).

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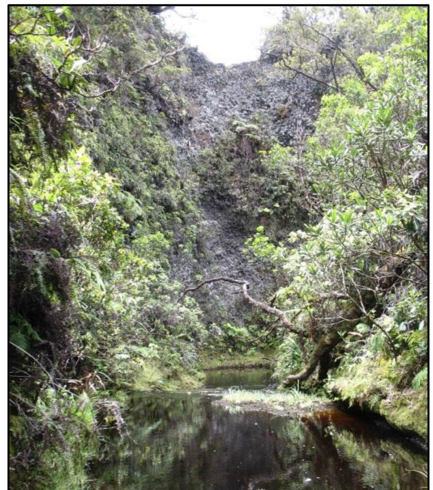
Focal Species: Puaiohi or Small Kaua‘i Thrush (*Myadestes palmeri*)

Synopsis: The Puaiohi is endemic to Kaua'i and is restricted to remote areas of the rugged 'Alaka'i Plateau. It nests in hollows or on ledges of fern-covered cliffs along narrow streams. The species may always have been rare, and availability of suitable nest sites may limit the range and population size. Habitat management to prevent degradation by non-native plants and feral ungulates is a key to long-term conservation. Artificial nest structures are being investigated as a way of increasing nest site availability and decreasing nest predation.

Puaiohi at nest. Photo Eric VanderWerf



Typical Puaiohi nesting habitat. Photo KFBRP

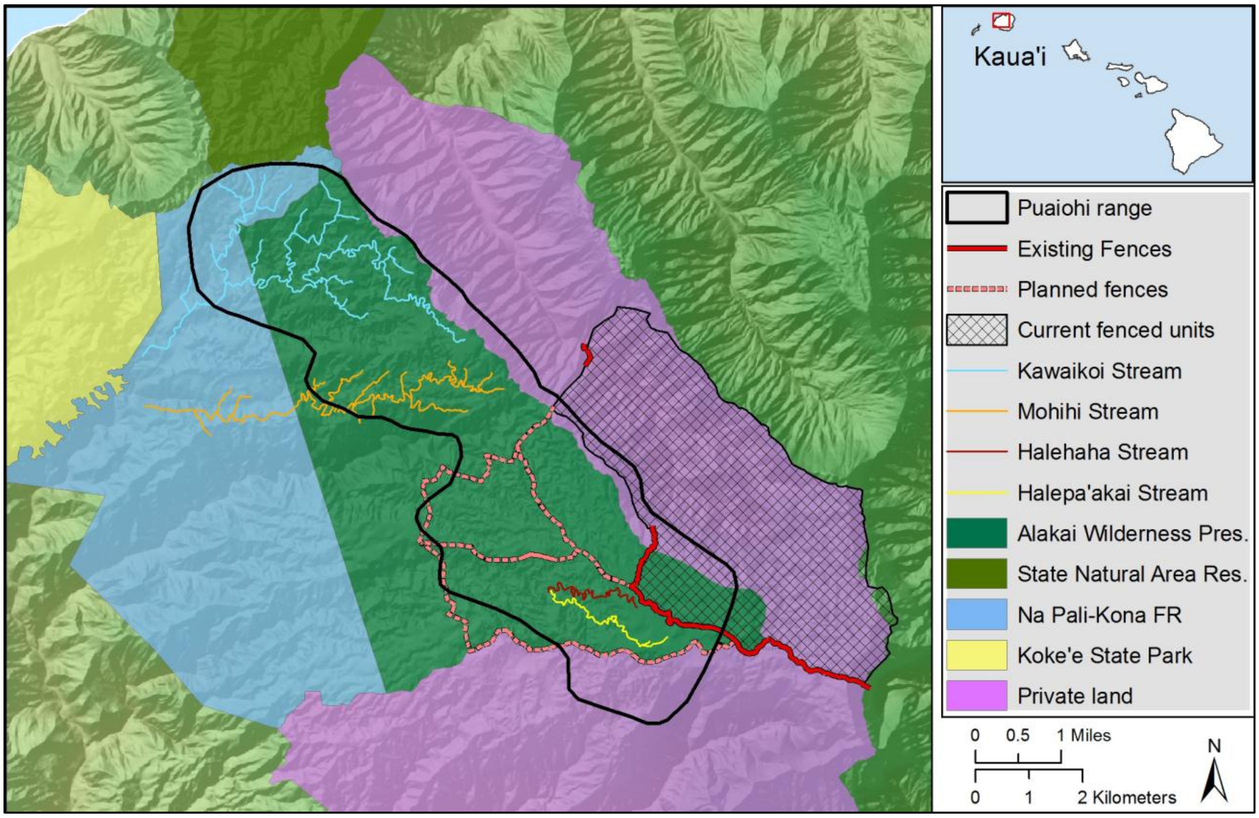
Juvenile Puaiohi. Photo Eric VanderWerf

Geographic region: Kaua‘i, Hawaiian Islands
Group: Forest Birds
Federal Status: Endangered
State status: Endangered
IUCN status: Critically Endangered
Conservation score, rank: 18/20, At-risk
Watch List 2007 Score: RED
Climate Change Vulnerability: High

Population Size and Trend: The Puaiohi population was estimated to be about 500 birds in 2006 (range 200-1,000; Kaua'i Forest Bird Recovery Project [KFBRP] unpubl. data). The habitat used by Puaiohi is difficult to survey and calculating an accurate population estimate has been challenging. The population trend appears to be stable. In 2011, a new survey method (occupancy modeling; Mackenzie et al. 2006) was field tested and it is hoped that this method will yield a more precise population estimate and provide a more robust method for monitoring trends.

Range: The breeding population is restricted to an area of < 20 km^2 on the 'Alaka'i Plateau, and 75% of the population is estimated to occur in just 10 km^2 (KFBRP unpubl. data). Density across the species' range varies from 0.5 to 11.0 pairs per km of stream (KFBRP unpubl. data).

Essential Biology: The Puaiohi is a medium-sized (37-43 g) thrush endemic to Kauaʻi. Adults are olive-brown above, gray below, with a white-eye-ring and outer rectrices. The legs are pink and the bill is black (Snetsinger et al. 1999). Males and females are similar. Juveniles have distinctive spots and scalloping on the breast and wings. The song, given only by the male, consists of an introductory whistle and a trill, followed by several sharp descending notes. The call of both sexes is a raspy hiss (Snetsinger et al. 1999).



The Puaiohi occurs along deeply incised streams and associated ridges above 1,050 m (3,500 ft) elevation in the southern and central Alaka'i Plateau (Scott et al. 1986, Snetsinger et al. 1999). Puaiohi are found in wet native montane forest dominated by ʻōhiʻa (*Metrosideros polymorpha*), ʻōlapa (*Cheirodendron trigynum*), lapalapa (*C. platyphyllum*), ʻōhia ha (*Syzygium sandwicensis*), kāwaʻu (*Ilex anomala*), and kōlea (*Myrsine lessertiana*), with a diverse understory of native plants including ʻōhelo (*Vaccinium calycinum*) and kanawao (*Broussaisia arguta*). Puaiohi feed on insects and fruits of native plants, particularly ʻōlapa, lapalapa, ʻōhia ha, kanawao, ʻōhelo, paʻiniu *(Astelia* spp.), pūkiawe *(Styphelia tameiameiae),* kāwaʻu, and pilo (*Coprosma* spp.) (Snetsinger et al. 1999). Puaiohi forage primarily in the lower canopy, often on terminal fruit or leaf clusters. Arthropods are gleaned from leaves, extracted from moss or bark, and removed from ripe fruits (Perkins 1903, Snetsinger et al. 1999).

Puaiohi usually nest in hollows or on ledges of fern-covered cliffs along narrow streams, and rarely in tree cavities or on large horizontal limbs (Snetsinger et al. 2005) or artificial structures. Nesting occurs from March to mid-September, with a peak from April to June (Snetsinger et al. 2005). Females readily renest after nest failure and can attempt five or more nests in a season (Snetsinger et al. 2005, Tweed et al. 2006). The female builds the nest, incubates the eggs, and broods young. Clutch size is usually two, and eggs hatch after 13 to 15 days of incubation. Both parents feed the nestlings. Pairs sometimes raise more than one brood per year, and the male may continue to feed fledglings while the female initiates another nesting attempt. Second-year and hatch-year birds occasionally assist in nest defense and feeding nestlings and fledglings (Snetsinger et al. 1999). Young often remain near the ground for two to four days after fledging, where they are vulnerable to predation. Annual productivity is variable, ranging from 0.4 to 4.9 fledglings per pair (Snetsinger et al. 2005, KFBRP unpubl. data). Adult survival varies from 69–74% and that of juveniles from 19-25% (Snetsinger et al. 2005, KFBRP unpubl. data).

Primary Threats:

- Disease - Diseases carried by the alien southern house mosquito (*Culex quinquefasciatus*) limit the distribution of many native Hawaiian passerines, including the Puaiohi, to higher elevations where mosquitoes are less common (van Riper et al. 1986, Atkinson et al. 1995, Atkinson and LaPointe 2009). Puaiohi appear to have greater immunity to alien diseases than many Hawaiian honeycreepers, but their absence from lower elevation suggests some sensitivity. Prevalence of avian malaria (*Plasmodium relictum*) in Puaiohi has been 15-20% for the past 15 years and there is evidence that some Puaiohi may survive the infection (Atkinson et al. 2001, Atkinson and Utzurrum 2010).
- Habitat Degradation - Puaiohi depend on intact native forest for foraging and nesting and their habitat has been, and continues to be, degraded by invasive alien plants that displace native plants used for foraging, and by feral ungulates, particularly feral pigs (*Sus scrofa*) and goats (*Capra hircus*) (Foster et al. 2004, Woodworth et al. 2009). Feral ungulates degrade native forest by browsing, causing soil erosion, spreading invasive plant seeds, facilitating invasion by alien plants, and creating breeding habitat for mosquitoes (Cabin et al. 2000, Scott et al. 2001, USFWS 2006). Because the Puaiohi is frugivorous, loss of native food plants is particularly detrimental and invasive plants have drastically changed the structure of native forests. Kalihi ginger (*Hedychium gardnerianum*), strawberry guava (*Psidium cattleianum*), and Australian tree fern (*Cyathea cooperi*) all suppress native food plants. Daisy fleabane (*Erigeron karvinskianus*) can cover nesting cliffs, reducing their suitability as nest sites (Woodworth et al. 2009).
- Predation - Predation by rats (*Rattus* spp.) may be a serious threat to Puaiohi. Although their habit of nesting on steep cliffs may provide some protection, nest predation can be as high as 38% (Tweed et al. 2006). Snetsinger et al. (2005) demonstrated that nests of wild pairs protected by rat bait stations fledged significantly more birds than untreated nests. In contrast, Tweed et al. (2006) reported that ground-based rodent control proved ineffective at protecting nests where at least one adult was a captive-released bird, even in areas where rats had been reduced to barely detectable levels. The difference between these two studies could be related to annual or spatial variation in rat abundance. The tendency of young Puaiohi to remain close to the ground for several days after fledging probably makes them vulnerable to predation by rats and feral cats (*Felis catus*). Rats may also take the female off the nest. Two species of owls, the native Pueo (*Asio flammeus sandwichensis*) and the introduced Barn Owl (*Tyto alba*) also occur on Kaua‘i and are known to prey on passerines (Snetsinger et al. 1994).
- Hurricanes - Major hurricanes struck Kaua‘i in 1983 and 1992 and degraded native forests by knocking down large trees, creating gaps into which alien plants could expand, and spreading invasive plants. Because Puaiohi occupy narrow stream valleys, which

presumably offer some protection from high winds, it is difficult to assess the population level effects of hurricanes. However, Puaiohi were likely extirpated from at least two areas on the edge of their range because of these hurricanes.

- Small Population - Single island endemics like the Puaiohi are inherently more vulnerable to extinction than widespread species because of the higher risks posed by random demographic fluctuations and localized catastrophes such as hurricanes, fires, disease outbreaks (Wiley and Wunderle 1994), and potentially genetic issues.
- Climate Change. Rising temperatures associated with climate change may exacerbate the threat of disease by facilitating an increase in the elevation at which disease transmission occurs (Reiter 1998, Benning et al. 2002, Harvell et al. 2002). Malaria transmission already can occur at least periodically across all parts of the island, and GIS simulations have shown that an increase in temperature of 2°C, which is a conservative figure based on recent data (IPCC 2007), would allow regular disease transmission in 85% of the area on Kaua'i where it is now only periodic (Benning et al. 2002). Disease prevalence in more common species has increased at several locations within the range of Puaiohi, indicating exposure to disease is increasing (Atkinson and Utzurrum 2010). Climate data on Kaua'i show a warming pattern at 4,000 ft elevation and a decline in frequency of high water events that could flush mosquito larvae from streams, possibly resulting in an increase in mosquito breeding habitat (T. Giambelluca and C. Atkinson in prep.).

Conservation Actions to Date: The Puaiohi was federally listed as endangered in 1967 (USFWS 2006). Studies to determine life history and demography of the Puaiohi were conducted from 1996 to 2000 by the U.S. Geological Survey and have been ongoing since by the KFBRP, administered by the Hawai'i Division of Forestry and Wildlife (DOFAW). Invasive alien plants are being controlled in the Alaka'i and Koke'e areas by The Nature Conservancy and Kōke'e Resource Conservation Program. The Kaua'i Watershed Alliance (KWA) completed strategic ungulate fence segments in 2010 to protect an 810-ha (2,000-acre) management unit in the southeastern Alaka'i Wilderness Preserve; ungulates have almost been eradicated from this area. The KWA also has ambitious plans for three more fenced units that would protect an additional 1,215 ha (3,000 acres) in adjacent areas of the 'Alaka'i that encompass the core of Puaiohi range. Fencing in the Hono O Nā Pali Natural Area Reserve also is being planned.

A captive breeding and release program for Puaiohi has been implemented by the Hawai'i Endangered Bird Conservation Partnership (partners include the Zoological Society of San Diego, DOFAW, and U.S. Fish and Wildlife Service). From 1999 to 2012, 222 Puaiohi were released at Kawaikoi, Mohihi, and Halepa'akai Streams (Kuehler et al. 2000, Woodworth et al. 2009, Lieberman and Kuehler 2009, ZSSD 2011). Captive-bred released Puaiohi have fledged young with wild and captive-bred mates (Tweed et al. 2003, 2006). However, recruitment of captive birds into the wild breeding population may be limited by the local density of the wild birds. No new sub-populations have been permanently established, and suitable habitat may be saturated. The efficacy of captive releases is difficult to assess but seems low. Some birds, may be recruiting


Captive-bred Puaiohi at release. Photo E. VanderWerf

into the breeding population after dispersing and go undetected based on movement patterns of released birds (Tweed et al. 2003).

Artificial nest cavities have been explored as a means of increasing nest site availability, decreasing nest predation, and expanding the range of Puaiohi, but few artificial cavities have been used thus far. Thirty-three artificial nest boxes were first placed in the Kawaikoi and Halepa'akai drainages in 2002 by DOFAW, but only one was ever used and the design was not rat-resistant. The nest box program was expanded in 2007 and 2008 in the Kawaikoi, Halepa'akai, and Halehaha drainages (VanderWerf and Roberts 2008), and several nest box designs were tested in the laboratory for rat-resistance (Pitt et al. 2011). In 2011, two artificial cavities were used. The KFBRP is continuing to investigate artificial nest boxes as a management tool.


Puaiohi in nest box, June 2011. Photo E. VanderWerf

Planning/Research Needs:
- A lack of information regarding population size, distribution, habitat requirements, and the efficacy of the release program has hindered informed management decisions.
- Continue and refine occupancy survey methods to provide a more accurate population estimate, determine if changes have occurred since 2005, and document the presence of captive-released birds.
- Investigate Puaiohi preference for different artificial next box designs, continue to monitor existing nest boxes, deploy more boxes of preferred design(s), explore social attraction.
- Continue monitoring of Puaiohi reproductive success and survival.
- Conduct overwinter radiotelemetry of fledglings to determine survival, dispersal and habitat use.
- Use remote imagery and data from vegetation, food plant, rat, and mosquito surveys to develop habitat suitability maps, and determine if suitable but unoccupied habitat exists.
- Consider translocation of Puiaohi to other islands with more disease-free habitat where native thrushes have gone extinct.

5-Year Conservation Goals:
- Increase the amount of ungulate and weed-free habitat in the Alaka'i Wilderness Preserve.
- Increase understanding of Puaiohi habitat requirements.
- Produce accurate estimates of Puaiohi population size, trend, and range.
- Determine the efficacy of the captive release program.
- Perfect artificial nest structure designs that are preferred by Puaiohi and rat resistant.

Conservation Actions:
- Disease. Fencing and feral pig removal will reduce disease prevalence by reducing breeding habitat for mosquitoes.
- Habitat Management.
    - Complete ungulate removal within the KWA fence in the eastern 'Alaka'i.

  - Support efforts by the KWA to fence and remove ungulates from three management units encompassing 1,215 ha (3,000 acres) in the Alaka'i Wilderness Preserve.
  - Fence and remove ungulates from the Hono O Nā Pali Natural Area Reserve and select parts of the Na Pali-Kona Forest Reserve.
  - Continue to control invasive alien plants in the Koke'e/'Alaka'i area.
- Non-native Predators.
  - Determine artificial nest box designs that are preferred by Puaiohi and rat-proof and assess their utility as a management tool.
  - Deploy bait stations and snap traps in protective housings around natural nests and around any artificial nest structures used by Puaiohi.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Regulatory compliance for additional KWA fencing in the Alaka'i Wilderness Preserve	1	$80,000	$80,000
Build KWA fence and remove ungulates from 3,000 acres in the Alaka'i Wilderness Preserve	2-5	$900,000	$3,600,000
Fence and remove ungulates from the Hono O Nā Pali Natural Area Reserve	1-3	$400,000	$1,200,000
Invasive plant control	1-5	$300,000	$1,500,000
Continue occupancy surveys throughout range, estimate population size	1-4	$75,000	$150,000
Continue life history research and monitoring	1-5	$100,000	$500,000
Continue investigation of nest boxes	1-3	$75,000	$225,000
Control predators around nests	1-5	$30,000	$150,000

Potential Partners: Hawai'i Division of Forestry and Wildlife, Zoological Society of San Diego, U.S. Fish and Wildlife Service, Kaua'i Watershed Alliance, University of Hawai'i, Koke'e Resource Conservation Program, U.S. Geological Survey Pacific Island Ecosystems Research Center, Pacific Rim Conservation, American Bird Conservancy.

Ancillary Species: Management for the Puaiohi would benefit all native bird species that use forest habitat on the island, including the Kaua'i 'Elepaio (*Chasiempis sclateri*), Kaua'i 'Amakihi (*Hemignathus kauaiensis*), 'Anianiau (*Hemignathus parvus*), 'Akikiki (*Oreomystis bairdi*), 'Akeke'e (*Loxops caeruleirostris*), 'I'iwi (*Vestiaria coccinea*), and 'Apapane (*Himatione sanguinea*).

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Focal Species: Northwestern Hawaiian Islands Passerines:

- Millerbird (*Acrocephalus familiaris*)
- Laysan Finch (*Telespiza cantans*)
- Nihoa Finch (*Telespiza ultima*)

Synopsis: These three species occur only on tiny, uninhabited islands in the remote northwestern region of the Hawaiian Archipelago. There formerly were two subspecies of Millerbird, one on Laysan (*A. f. familiaris*), which was extinct by 1923, and another on Nihoa (*A. f. kingi*), which was discovered in the same year. In 2011 and 2012, a total of 50 Millerbirds were translocated from Nihoa to Laysan, and the birds are now breeding there, but the population is very small and its long-term survival is not yet certain. Both finches are Hawaiian honeycreepers and are primarily restricted to their namesake islands, though small numbers of translocated Laysan Finches persist at Pearl and Hermes Reef. Keys to the conservation of these species are continued biosecurity and habitat management on the islands where they currently occur, and creation of additional populations on other islands to reduce extinction risk.


Nihoa Millerbird. Photo Eric VanderWerf


Nihoa Finch male. Photo Eric VanderWerf


Laysan Finch male. Photo C. Rutt

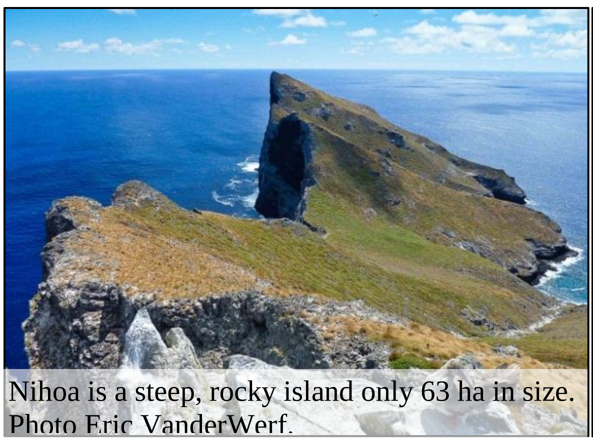
<u>Geographic region</u>: Northwestern Hawaiian Islands
<u>Taxonomic Group</u>: Passerines
<u>Federal Status</u>: Endangered
<u>State status</u>: Endangered
<u>IUCN status</u>: Critically Endangered (Millerbird and Nihoa Finch), Vulnerable (Laysan Finch)
<u>Conservation score, rank:</u> 18/20, At-risk
<u>Watch List 2007 Score</u>: Red
<u>Climate Change Vulnerability</u>: High

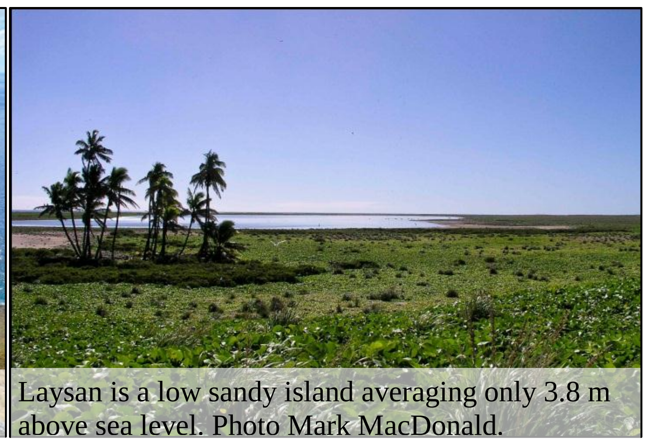
Population Size and Trend:
<u>Millerbird</u>. Estimates of the Millerbird population size on Nihoa have fluctuated widely during 1967-2011, from as few as 31 birds to a maximum of 814 (Kohley et al. 2011). The most recent estimate was 384 in 2012. However, these estimates must be viewed with caution because of the large errors resulting from the transect-based monitoring method used (Conant et al. 1981), and this has made it difficult to detect changes in population size (Gorresen et al. 2012). Genetic analyses indicate the effective population size is much smaller than the actual population size and that there has been some loss of genetic diversity (Fleischer et al. 2007, Addison and

Diamond 2011). In 2011 and 2012, a total of 50 Millerbirds was removed from Nihoa and translocated to Laysan to create a second population. All birds survived the journey each year, and breeding began within a few weeks of release. The population size on Laysan is changing rapidly, but in September 2012 it was thought to be 63 birds, consisting of 14 adults from the 2011 translocation cohort, 26 adults from the 2012 translocation cohort, and 23 fledglings (USFWS and American Bird Conservancy [ABC], unpubl. data).

Nihoa Finch. Estimates of the Nihoa Finch population size have fluctuated from 945-4647 birds during the years from 1967-2011. The most recent estimate in 2012 was 4475±909 birds. The population size appeared to be fairly stable from 2009-2011 at 2400-2900 birds (VanderWerf et al. 2011), but the 2012 estimate was substantially higher. These estimates have greater relative precision than those for the Millerbird because the finches are easier to detect than Millerbirds, but the fluctuating numbers and large errors associated with estimates still have made it difficult to determine the population trend.

Laysan Finch. The mean population estimate on Laysan from 1968 through 1990 was 11,044±3,999 (SD; Morin and Conant 1994). In 1998, year of the latest published estimate, the population was estimated to be 9,911±1,755 (Morin and Conant 2002). On four islets of Pearl and Hermes Atoll where this species was translocated, the total population was estimated to be 373 birds in 1998 (Morin and Conant 2002) and 1,043 ± 253 in 2007 (Kropidlowski, 2007). These islands were partly inundated by the 2011 Japan tsunami and severe storms the same year, and the finches have not been surveyed since then so the current status and size of these populations is unknown.


Nihoa is a steep, rocky island only 63 ha in size. Photo Eric VanderWerf.

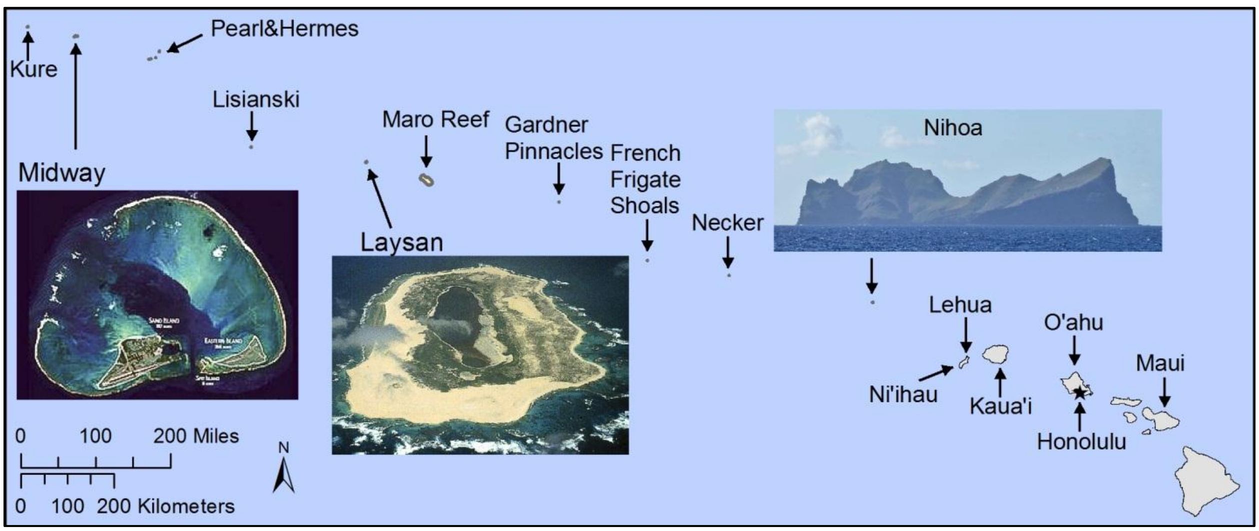

Laysan is a low sandy island averaging only 3.8 m above sea level. Photo Mark MacDonald.

Range:

Millerbird. The Millerbird is found only on the small islands of Nihoa and Laysan in the remote northwestern region of the Hawaiian Archipelago. Nihoa is a high, rocky island with a maximum elevation of 277 m (910 feet) and is only 63 hectares (156 acres) in size. Laysan is somewhat larger at 415 ha (1,025 acres), and is a low-lying atoll with a maximum elevation of only 12 meters above sea level. The Laysan Millerbird was extinct by 1923 after all vegetation on the island was destroyed by alien rabbits and human activities, but in 2011 and 2012 a total of 50 Millerbirds was translocated from Nihoa to Laysan. The population on Laysan is still very small and is not yet securely established.

Nihoa Finch. The Nihoa Finch is restricted to the island of Nihoa, which is 63 hectares (156 acres) in size. Finches occur throughout the island. Introduced populations on Tern Island and East Island at French Frigate Shoals were extirpated by the early 1980s.

Laysan Finch. The Laysan Finch is found primarily on Laysan, a 415-ha (1,025-acre) island with an average elevation of 3.8 meters (12 feet). Finches are restricted to approximately 200 ha (450 ac) on Laysan that is vegetated. Since 1967, translocated Laysan Finches have occupied the 12-ha (25-ac) and two-hectare (5-ac) vegetated areas of Southeast Island and Grass Island (respectively) at Pearl and Hermes Reef, but these islands were partly inundated by the 2011 Japan tsunami. Some birds are known to have survived the inundation but the population has not been surveyed. Between 1973 and 1998, introduced populations also existed on North Island and Seal-Kittery Island at Pearl and Hermes Reef, but those populations were extirpated by 1998. Laysan Finches were introduced to Midway beginning in 1891 and persisted there until they were extirpated in 1944 by rats (Fisher and Baldwin 1946).



Essential Biology:

Millerbird. The Millerbird is a small (16-19 g), gray-brown Old World Warbler (Sylviidae) with a long tail, strong legs, and a thin, straight bill. Males are slightly larger than females, though there is some overlap (MacDonald et al. 2010). The Millerbird consisted of two island-specific subspecies (Fleischer et al. 2007), one from Laysan (*A. f. familiaris*), which was extinct by 1923, and one from Nihoa (*A. f. kingi*), which was discovered in 1923 (Wetmore 1924).

Millerbird pairs defend territories ranging in size from 0.19–0.40 ha, and show a high degree of year-to-year territory fidelity (Morin et al. 1997, MacDonald 2011). Millerbirds are somewhat secretive and spend much of the time in dense low bushes, particularly pōpolo (*Solanum nelson*) and ‘ilima (*Sida fallax*). They also forage in dense stands of fan-palms (*Pritchardia remota*) and are attracted to small freshwater seeps and puddles for drinking and bathing. On Laysan, they prefer dense thickets of naupaka (*Scaevola taccada*). The Millerbird is a generalist insectivore that gleans native and non-native insects from shrubs and other plants. It also forages in leaf litter, on the soil surface, and has been observed eating insects from bird carcasses (Morin et al. 1997). Captive feeding trials conducted on Nihoa in 2009 and 2010 demonstrated that Millerbirds will consume any suitably sized arthropods (<4 cm length), including flies, moths, beetles, and cockroaches (Kohley et al. 2010).

The Millerbird breeding season usually extends from January through September, but timing appears to be variable and may depend on rainfall and prey availability. Bird translocated to Laysan began nesting in September shortly after being released. On Nihoa nests are built in available dense shrubs, particularly pōpolo and ʻilima. Laysan Millerbirds reportedly nested in bunchgrass around Laysan lake (Morin and Conant 2007), but the Millerbirds recently translocated from Nihoa are nesting in naupaka. Clutch size is usually two eggs and both sexes incubate, brood chicks, and provision nestlings and juveniles. Hatching success, fledging success, and survival to reproductive age are unknown (Morin et al. 1997), but this information is being collected from the birds now breeding on Laysan.

<u>Nihoa Finch</u>. The Nihoa Finch is similar and closely related to the Laysan Finch, but is slightly smaller and has a smaller bill (Morin and Conant 2002). Males are more brightly colored and females have more streaking, but there is much variation, some of it probably age-related.

Nihoa Finches are omnivorous and are known to eat seeds, fruit, leaves, flowers, invertebrates, eggs, and carrion. They are somewhat curious but are not as bold as Laysan Finches. Nihoa Finches forage in all types of vegetation and also on bare soil and rock. They are especially fond of native *Pritchardia* fan palms, taking fruit, nectar, and arthropods. Nihoa Finches use all habitats on the island, and are often attracted to small freshwater seeps and puddles for drinking and bathing.

Nihoa finches nest exclusively in rock crevices or piles of loose rock (Morin and Conant 2002). The clutch size is usually 3 (range 2-5), but little is known about nesting behavior or success. There is no information on adult survival or movements.

<u>Laysan Finch</u>. The Laysan Finch is a large (32-34 g), sexually dimorphic Hawaiian honeycreeper with a thick bill. Adult males are yellow on the head, breast, and back, with a gray neck and white belly. Females are grayer, especially on the back, with brownish streaks. Both sexes require two years to acquire adult plumage; first-year birds are browner and more heavily streaked (Morin and Conant 2002).

The Laysan Finch is omnivorous and is bold and inquisitive in search of food. It is known to eat seeds, fruit, leaves, flowers, invertebrates, eggs, and carrion, and forages in all types of vegetation, on bare soil, rock, and sand, and may enter seabird burrows. Plant species with which it is often associated include the bunch grass kāwelu (*Eragrostis variabilis*), naupaka, ʻalena (*Boerhavia repens*), pohuehue (*Ipomoea pes-caprae*), and nohu or puncture vine (*Tribulus cistoides*; Morin and Conant 2002). It is particularly attracted to humans and human objects and can become trapped inside tents, buckets, and tarps.

The nesting season usually extends from March-July, but timing appears to be variable and may depend on rainfall and prey availability. On Laysan, finches nest almost exclusively in kāwelu, the native bunch grass. On Pearl and Hermes, where kāwelu is uncommon, finches nest in a wider variety of vegetation and in man-made objects and marine debris such as plastic buckets, fishing buoys, and crates (Morin and Conant 2002). The female builds the nest, incubates, and broods the young, while the male plays a larger role in feeding the young, by regurgitation. Mean clutch size is 3.2 eggs. Apparently capable of raising more than one brood per season, but the frequency is unknown (Morin and Conant 2002). Males may not breed until two years of age, once they acquire adult plumage.

Primary Threats: All three species face a similar suite of threats, but the severity of threats varies somewhat among the species depending on aspects of their biology and the environment of the islands on which they occur. The most serious potential threat to all three species is the introduction of non-native plants, predators, pathogens, and competitors. The small range and population size of these species also makes them vulnerable to extinction from a variety of natural demographic and stochastic factors.

- Invasive alien plants. Although these birds are adaptable in habitat use and might integrate some non-native plants into their diet, certain invasive plants could alter habitat structure and diversity to such an extent that they would degrade habitat quality and reduce carrying capacity of the islands. The alien southern sandspur (*Cenchrus echinatus*) is such a plant and was expensive and time-consuming to eradicate from Laysan (Flint and Rehkemper 2002). A few individuals of this plant were discovered on Nihoa in 2011 and removed (VanderWerf et al. 2011), and little regrowth was observed in 2012. Eradicating this invasive grass is crucial to preventing further habitat alteration on Nihoa. Golden crownbeard (*Verbesina encelioides*) is another habitat-altering invasive that is established at Midway, Kure, and Southeast Island at Pearl and Hermes Atoll. It can favor Laysan Finches during nesting because it provides dense cover but once this annual dies back it leaves a desolate landscape with no forage or cover because it displaces all native plants.
- Non-native predators. The introduction of predators, particularly rats (*Rattus* spp.), by shipwrecks or in supplies and equipment transported to the islands is a serious potential threat to all three birds. Because they nest on or near the ground, all nests would be accessible to rats. Laysan Finches translocated from Laysan to Midway in 1891 thrived there until 1944 when the introduction of black rats caused their extirpation.
- Non-native Arthropods. Although all three bird species eat a variety of insects, introduction of certain arthropods could have serious negative effects on vegetation structure, plant diversity, and ecosystem-functioning through herbivory on native plants and their seeds and as competitors for other insects as food. The non-native gray bird grasshopper (*Schistocerca nitens*) was reported from Nihoa in 1977 (Beardsley 1980), and probably has altered the vegetation, and subsequently the food resources on which the Millerbirds and Nihoa Finch depend (Latchininsky 2008). The native shrub ʻāweoweo (*Chenopodium oahuense*) was formerly a common habitat component on Nihoa but is now rare (MacDonald 2011, Farmer et al. 2011). Several ant species are known to drastically alter island ecosystems and can be extremely difficult to eradicate.
- Disease. The Laysan Finch is known to be highly susceptible to avian poxvirus (*Poxvirus avium*) and avian malaria (*Plasmodium relictum*), which in Hawai'i are carried by the southern house mosquito (*Culex quinquefasciatus*; Warner 1968, van Riper et al. 1986, Morin and Conant 2002). There is no information about these diseases in the Nihoa Finch, but considering its close relationship with the Laysan Finch it presumably is similarly susceptible. The susceptibility of the Millerbird to mosquito-borne diseases also is unknown, but it belongs to a family widely distributed across the Paleotropics, where avian malaria is indigenous, so it might be more tolerant of disease. Mosquitoes and the diseases they carry are not known to occur on Nihoa or Laysan, but they are present on Midway and all the larger Hawaiian Islands and thus are relevant to selecting sites for translocations.
- Climate Change and Sea Level Rise. Climate change and associated sea-level rise is a serious long-term threat to all birds on atolls in the Northwestern Hawaiian Islands,

including the Laysan Finch and the Millerbird on Laysan. Recent projections estimate a rise in sea level of 1-2 meters by the end of the 21st century (Vermeer and Rahmstorf 2009), which would result in substantial loss of suitable habitat on Laysan, which has a mean elevation of Laysan is 3.8 meters (12 feet), by inundation, physical damage, and salt water incursion (Berkowitz et al. 2012, Krause et al. 2012). Increases in frequency and intensity of storms also projected in many climate changes scenarios would exacerbate sea level rise. Laysan Finch populations at Pearl and Hermes are at even greater risk; the mean elevation at Southeast Island is just over one meter (3 feet), so that during spring tides, most of the island would be inundated.

- Small Population Size and Range. Species with single, small populations are inherently more vulnerable to extinction than widespread species because of the higher risks posed by random fluctuations in population size, sex ratio, and other demographic parameters. Small populations are also more at risk from catastrophes such as hurricanes, fires, droughts, and disease outbreaks (Wiley and Wunderle 1994), and genetic issues (Keller and Waller 2002). Nihoa is dry and variation in rainfall and subsequent plant growth is thought to drive the large fluctuations in Millerbird and Nihoa Finch abundance. The larger population size of the Laysan Finch makes it somewhat less vulnerable. Genetic variation in the Millerbird is extremely low and recent research showed that the species has lost alleles over the last 15 years (Fleischer et al. 2007, Addison and Diamond 2011). The low genetic variation has not been demonstrated to be affecting the species viability, however, and is not surprising given the founder effect inherent in the original colonization and the genetic bottlenecks experienced for many years due to the population fluctuations.

Conservation Actions to Date:
All three species were federally listed as endangered on 11 March 1967 (USFWS 1984). Protection of the Northwestern Hawaiian Islands began in 1909, when the Hawaiian Islands Reservation was established by President Theodore Roosevelt. In 1940, the islands' status was changed to a national wildlife refuge. On 15 June 2006, the Papahānaumokuākea Marine National Monument was established and is managed jointly by the State of Hawai‘i, the U.S. Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration.

There has been extensive habitat restoration on Laysan since rabbits denuded the island, causing the extinction of the original Laysan Millerbird. Management has included removal of invasive alien plants such as sandspur (*Cenchrus echinatus*) and Indian fleabane (*Pluchea indica*), and restoration of native plants such as the bunch grass *Eragrostis variabilis* and the loulu fan palm *Pritchardia remota*. Concern that control of the invasive species *Verbesina encelioides* at Pearl and Hermes would eliminate nest cover for Laysan Finches led Refuge staff to install 30 nest boxes (hollow cement blocks) in 2001 (Wegmann and Kropidlowski, 2001). These boxes were well received and during the 2003 breeding season 21 of the 30 boxes showed signs of use. An additional 29 boxes were added in 2003 and almost all were being used in 2007.

Research on the life history and demography of the Laysan Finch has been conducted at Laysan and Pearl and Hermes (Morin 1992, Morin and Conant 2002, McClung 2005). Monitoring methods for all species have been developed (Conant et al. 1981, Morin and Conant 1994) and are being improved (Gorresen et al. 2012). Conant and Morin (2001) used population viability analysis to argue that the probability of extinction for the Nihoa Millerbird is very high, that management actions were unlikely to increase carrying capacity on Nihoa, and that the most effective way to increase the population size and decrease the risk of extinction was to establish additional populations.

Islands were evaluated and ranked as potential near-term and long-term translocation sites for the Millerbird, Nihoa Finch, and Laysan Finch (Morin and Conant 2007). For the Millerbird, Laysan was recommended as clearly the best site for establishment of an additional population, followed by Lisianski, Kure, and Midway, though which of those islands was next best was not entirely clear. Among high islands, Lehua was judged to have the greatest potential. For the Nihoa Finch and Laysan Finch, Lisianski, Kure, Necker, and Midway were ranked highly.

In September 2011 and August 2012, 50 Millerbirds were translocated from Nihoa to Laysan to create a second population. Results have been encouraging thus far, with birds forming pairs almost immediately after release and breeding successfully in 2012 (USFWS and ABC unpubl. data). Close monitoring of this nascent population is ongoing as of this writing.

Planning/Research Needs:

- Selection of Translocation Sites. Millerbirds have been translocated to the island deemed most suitable (Laysan; Morin and Conant 2007), but translocation sites still must be selected for the Nihoa Finch and the Laysan Finch. Although the previous translocation site assessment produced partially ambiguous recommendations (Morin and Conant 2007), the island assessments are still useful and can be combined with additional information now available to select the best island(s) for each species. Subfossils indicate that Laysan and Nihoa Finches co-existed previously on at least Molokaʻi prior to human arrival, and that at least two other now-extinct species of *Telespiza* were found in the main Hawaiian Islands (James and Olson 1991).
- Disease. Some islands that would otherwise be suitable for translocation of Millerbirds and finches have mosquitoes, poxvirus, and avian malaria, such as Midway and Lehua. Determining the feasibility of mosquito eradication and subsequent mosquito recolonization would allow better evaluation of various islands as translocation sites. Once Millerbirds are thriving and abundant on Laysan, a disease susceptibility study should be undertaken. If this species proves to be resistant to these mosquito-borne pathogens, a wider array of potential translocation sites could be considered.
- Monitoring. Improved monitoring methods that use a variable circular plot design are being developed for Nihoa (Gorresen et al. 2012) and were field tested in 2011 and 2012. They are anticipated to produce more precise population estimates that will allow better assessment of population trend. Similar improvements could be implemented for Laysan Finches. The previous, transect-based monitoring method (Conant et al. 1981) also was used to monitor abundance of the alien grasshopper on Nihoa. Once monitoring is switched entirely to the new VCP method an alternative method of monitoring grasshopper abundance will be needed, and should include measures of herbivory and plant cover.
- Millerbird. Additional demographic studies are needed on both Nihoa and Laysan to provide more information on population structure, dispersal, survivorship, nesting phenology and success, and other life history and behavioral characteristics.
- Laysan Finch. Assess which management options (e.g., additional translocations, supplementation of existing small populations on Pearl and Hermes, or both) would be most beneficial in terms of extinction risk reduction. The tiny islets at Pearl and Hermes probably cannot support a viable population in the long-term in their current state. The

vegetation is dominated by non-native *Verbesina encelioides*, which dies back each year, leaving little habitat for finches. Habitat management could make them more suitable. Compilation and publication/dissemination of unpublished data and observations would help to inform management decisions and determine whether additional demographic research is needed.

- Nihoa Finch. Demographic studies are needed to provide information on population structure, dispersal, survivorship, and nesting phenology and success, though lack of this information should not preclude translocation.

5-Year Conservation Goals:

- Maintain biosecurity on Nihoa, Laysan, and all other Northwestern Hawaiian Islands.
- Continue habitat management on Laysan, including removal of alien plants.
- Ensure the new population of Millerbirds on Laysan is self-sustaining, through continued monitoring, and if necessary, augmentation by translocating additional birds from Nihoa.
- Plan and carry out at least one translocation each of the Nihoa Finch and Laysan Finch.
- Determine the Millerbird's susceptibility to avian malaria and avian pox.

Conservation Actions:

- Invasive alien plants.
    - Eradicate the incipient population of the invasive alien grass *Cenchrus echinatus* from Nihoa. Visiting the island in spring before the plants have set seeds would increase the chance of eradication. If visits are made after seed-set, then pre-emergent herbicide may be required to prevent germination of seeds in the soil. Visits must be made for several consecutive years to deal with germination of seeds already in the soil.
    - Eradicate alien plants from Laysan, including *Pluchea indica* and *Verbesina encelioides*, and continue habitat restoration and management.
- Non-native arthropods. Develop and implement a method of monitoring abundance of the grasshopper on Nihoa, including herbivory levels and plant species cover.
- Create Additional Populations.
    - Continue to monitor the newly created Millerbird population on Laysan to ensure it becomes self-sustaining or whether additional translocations are needed.
    - Translocate Nihoa Finches to another island.
    - Translocate Laysan Finches to another island.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Continue habitat management on Laysan, including eradication of invasive plants	1-5	$300,000	$1,500,000
Eradicate incipient population of the invasive alien grass *Cenchrus echinatus* from Nihoa	1-3	$30,000	$90,000
Monitor Millerbirds on Laysan	1-2	$100,000	$200,000
Monitor Millerbirds on Nihoa	1-5	$30,000	$150,000
Determine feasibility of mosquito eradication and recolonization on Midway and Lehua	1-2	$50,000	$100,000
Select translocation sites for Nihoa and Laysan	2-3	$40,000	$80,000

finches and develop translocation plans			
Translocate Nihoa Finches to another island and monitor them post-release	4-5	$300,000	$600,000
Translocate Laysan Finches to another island and monitor them post-release	4-5	$300,000	$600,000

Potential Partners: U.S. Fish and Wildlife Service, Papahānaumokuākea Marine National Monument, American Bird Conservancy, Hawai'i Division of Forestry and Wildlife, Pacific Rim Conservation, Pacific Bird Conservation.

Ancillary Species: Protection, restoration, and biosecurity on Nihoa, Laysan, and other islands will benefit numerous species of endemic landbirds, seabirds, and migratory shorebirds that inhabit these islands, including: the endangered Laysan Duck (*Anas laysanensis*), Bonin Petrel (*Pterodroma hypoleuca*), Bulwer's Petrel (*Bulweria bulwerii*), Wedge-tailed Shearwater (*Puffinus pacificus*), Christmas Shearwater (*Puffinus nativitatis*), Tristram's Storm-Petrel (*Oceanodroma tristrami*), White-tailed Tropicbird (*Phaethon lepturus*), Red-tailed Tropicbird (*Phaethon rubricada*), Masked Booby (*Sula dactylatra*), Brown Booby (*Sula leucogaster*), Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Gray-backed Tern (*Sterna lunata*), Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Black Noddy (*Anous minutus*), Blue Noddy (*Procelsterna cerulea*), White Tern (*Gygis alba*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Tringa incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), and Ruddy Turnstone (*Arenaria interpres*).

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Focal Species: Palila (*Loxioides bailleui*)

Synopsis: The Palila is a specialized Hawaiian honeycreeper with a population of only 1,263 birds that are restricted to 45 km^2 of remnant high elevation māmane forest on Mauna Kea. Palila numbers have declined annually since 2003 because of long-term drought and habitat degradation by feral sheep introduced for hunting. Lawsuits resulted in Federal court orders in 1979, 1987, and 1998 that mandated removal of feral ungulates from Palila Critical Habitat, but a substantial number of feral sheep remain. Following a settlement agreement in 2009, fencing efforts are underway and sheep eradication is expected to follow, but natural forest regeneration and active restoration will take time. Greater public and local government support are needed.

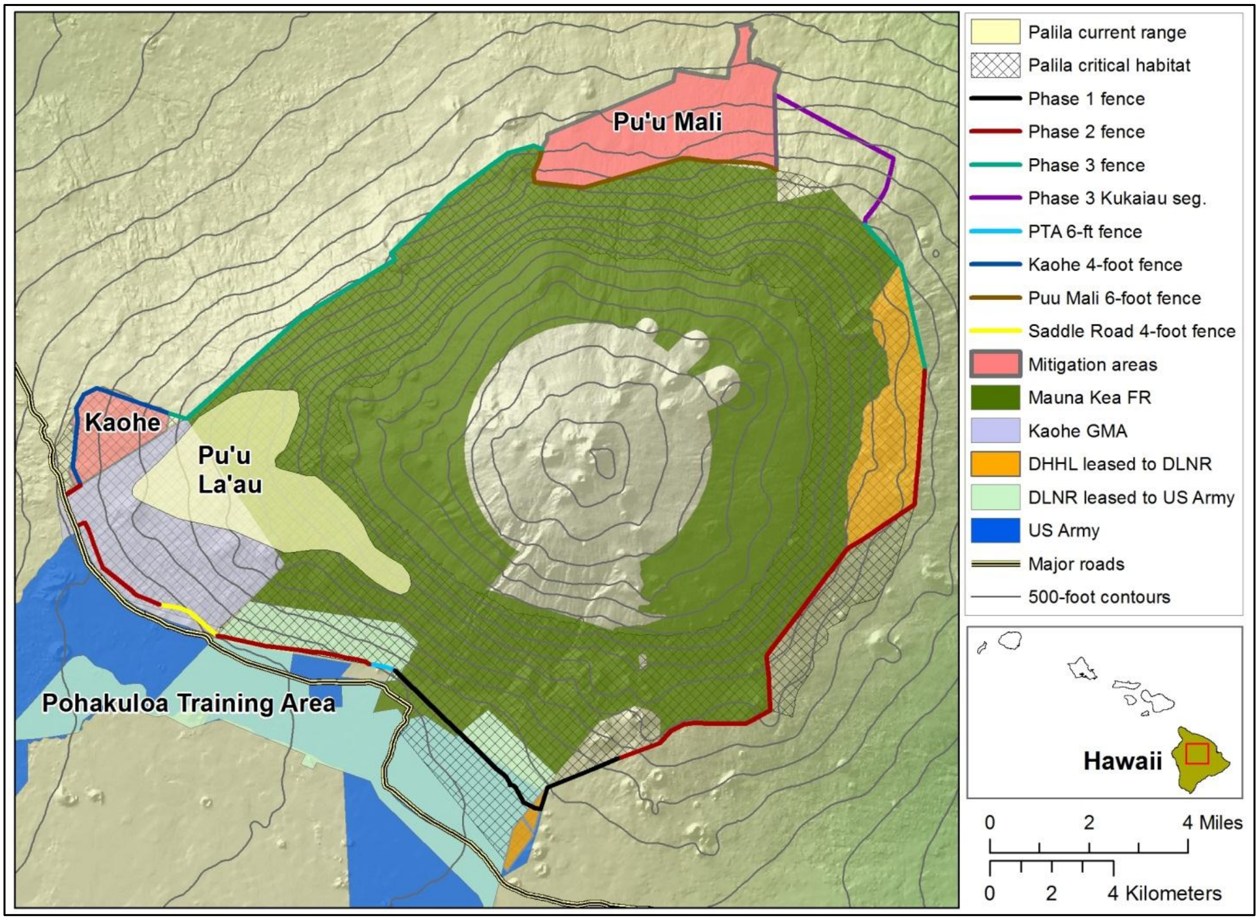

Adult male Palila. Photo Eric VanderWerf.


Māmane forest, Mauna Kea. Photo David Leonard.

Geographic region: Hawaiian Islands
Group: Forest Birds
Federal Status: Endangered
State status: Endangered
IUCN status: Critically endangered
Conservation score, rank: 20/20, At-risk
Watch List 2007 Score: Red
Climate Change Vulnerability: High

Population Size and Trend: Range-wide population surveys have been conducted annually since 1980 (Johnson et al. 2006, Leonard et al. 2008, Banko et al. in press). Population estimates fluctuated between 2,000 and 7,000 birds from 1980 to 2004, but no statistically significant trends were detected (Johnson et al. 2006). However, Leonard et al. (2008) documented a significant decline beginning in 2003 that has continued through 2011. From 2003 to 2011, population estimates declined each year by an average of 586 ± 106 birds for a mean annual loss of 17% ± 3.5 or 79% overall (Banko et al. in press). The 2011 population estimate was 1,263 individuals.

Range: Palila occurred in lowland habitats on Kaua'i and O'ahu when Polynesians arrived in Hawai'i less than 800 years ago (Olson and James 1991). When Europeans arrived in 1778, Palila had been extirpated from Kaua'i and O'ahu but were still found over about 1,300 km^2 of Hawai'i Island. Over the last 60 years, the species' range on Hawai'i has been dramatically reduced. The last individuals were seen on Mauna Loa in 1950 (Banko 1986). Today, all of the breeding population occurs in <45 km^2 on the southwestern slope of Mauna Kea, about 1% of their historical range Scott et al. 1984, Pratt et al. 1997, Banko et al. in press.



Essential Biology: The Palila is a finch-billed Hawaiian honeycreeper whose life history and survival are linked to māmane (*Sophora chrysophylla*), an endemic dry-forest tree in the legume family. Palila have a yellow head and breast, greenish wings and tail, a gray back, and white underparts. Males have a black mask, and females have less yellow on the head and a gray mask. Juveniles have wing bars. Song and calls consist of bubbly, canary-like warbles (Banko et al. 2002). Adults aggregate in small flocks prior to the breeding season, and fledglings often join flocks after nesting.

Palila are found in dry subalpine forest from 2,000-3,000 m in elevation dominated by māmane and naio (*Myoporum sandwicense*) trees (Banko et al. 2002), as well as ‘ilahi (*Santalum paniculatum*) ‘akoko (*Chamaesyce olowaluana*), and pilo (*Coprosma montana*). Important understory shrubs include ‘a’ali’i (*Dodonaea viscosa*), pūkiawe (*Styphelia tameiameiae*), na’ena’e (*Dubautia arborea*), and ‘akala (*Rubus hawaiensis*). Green māmane seeds make up most of the diet of adults and nestlings, but māmane flowers, buds, and leaves, and naio berries also are consumed, especially when māmane seeds are scarce. Density of Palila is strongly related to māmane pod availability (Scott et al. 1984, 1986; Hess et al. 2001, Banko et al. 2002). Caterpillars and other insects are frequently fed to nestlings and also are eaten by adults. Māmane seeds contain secondary compounds that are toxic to most vertebrates (Banko et al. 2002). Palila appear to be immune to these compounds, but their concentration may vary among trees, causing Palila to prefer certain trees. Consequently, more trees are needed to support Palila than would be predicted based on the number of pods harvested during a day (Banko et al. 2009). In addition, māmane flowers asynchronously at different elevations and trees distributed across an elevational gradient increase the availability of māmane seeds to Palila. The elevational distribution of māmane is the most important predictor of suitable Palila habitat (Scott et al. 1984) and Palila are restricted to the largest remaining expanse of māmane forest on Mauna Kea (Scott et al. 1984, Jacobi et al. 1996, Johnson et al. 2006, Leonard et al. 2008, Banko et al. in press). The availability of green māmane seeds strongly influences adult survival and the number of nesting attempts in a given year; in poor years, not all pairs will attempt to nest.

Palila form long-term pair bonds and males perform low advertisement flights. Females build nests, usually in large, mature māmane trees, and males defend a small territory around the nest tree. Females incubate the eggs, brood the nestlings, and feed young with food delivered by males, but males feed nestlings directly later in the nesting cycle. First-year males sometimes help a pair by defending the nest and feeding the female and nestlings, and usually are related to the female or male. Fledglings are dependent on their parents for three to four months. Although pairs often renest after nest failure and they sometimes renest after fledging a brood, Palila typically have a low reproductive capacity and thus are slow to recover from perturbations.

Primary Threats:

- Non-native Ungulates/Habitat Degradation. Non-native ungulates have degraded Palila habitat for 200 years and are the most important threat to Palila. Low elevation māmane forest was converted to pasture for cattle ranching, and feral goats (*Capra hircus*), feral sheep (*Ovis aries*), and mouflon (*O. musimon*) have degraded high elevation habitat by browsing and stripping bark off māmane trees and suppressing regeneration (Bryan 1937, Scowcroft and Giffin 1983, Scott et al. 1984), although periodic reductions in sheep can result in recovery of māmane in some areas (Hess et al. 1999).
- Climate Change. Drought reduces māmane seed production and likely contributes to the mortality of mature trees (Juvik et al. 1993), especially those stressed by browsing (Banko et al in press), pathogens (Gardner and Trujillo 2001), and competition from invasive grasses and weeds (Banko et al. 2009). Drought conditions have persisted on Mauna Kea since 2000 but have been most severe since 2006 (Banko et al. in press). The Palila's dry, subalpine habitat is expected to become even drier (Chu and Chen 2005, Cao et al. 2007, Giambelluca and Luke 2007, Chu et al. 2010).
- Non-native Predators. Introduced predators, primarily feral cats (*Felis catus*) but also black rats (*Rattus rattus*), depredate approximately 11% of Palila nests and will take incubating and brooding females (Amarasekare 1993, Laut et al. 2003).
- Invasive species. Introduced grasses and other weeds compete for resources with māmane trees, suppress seedlings, and increase fire risks. An invasive fungus, *Armillaria mellea*, may be killing māmane trees (Gardner and Trujillo 2001). Alien wasps parasitize caterpillars that Palila feed to their nestlings.
- Wild Fires. Fire risk is high in this dry forest habitat. In August 2010, a fire destroyed about 500 ha of degraded Critical Habitat. The recent invasion of alien fireweed (*Senecio madagascariensis*) has increased fire threat, sometimes filling in areas that are only patchily covered by invasive grasses.
- Human Conflict. A small but vocal minority, primarily hunters, has opposed ungulate control in Palila Critical Habitat. This opposition has slowed and complicated effective management. Local government officials have resisted eradication efforts.

Conservation Actions to Date: The Palila was recognized as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1967 and by the State of Hawai'i in 1982, with critical habitat designated in 1977 (USFWS 2006). Federal court rulings in 1979, 1987, and 1998 mandated the removal of all ungulates from Critical Habitat. The Division of Forestry and Wildlife has conducted periodic sheep removal via aerial shooting since 1987 and maintains a liberal hunting policy in Palila Critical Habitat, but the number of sheep removed has increased over time and the current strategy is not effective at reducing sheep numbers. In 2009, EarthJustice filed a motion to enforce the previous ungulate eradication orders, which resulted in a settlement decree under which the State of Hawaii is currently pursuing fencing and ungulate eradication.

Research has been conducted since 1996 to identify limiting factors and threats to the Palila and develop recovery techniques (Banko et al. 2001, 2009). Habitat restoration began in 2008. Federal mitigation for realigning Saddle Road through a portion of critical habitat called for: (1) re-establishing a Palila population on the northern slope of Mauna Kea; (2) removing cattle from former māmane woodland on the northern and western slopes of Mauna Kea; (3) rehabilitating habitat on Mauna Loa in Pōhakuloa Training Area (U.S. Army) for eventual re-establishment of Palila; (4) controlling predators in portions of Critical Habitat; (5) and investigating fire ecology in Palila habitat to develop a fire-management plan. Saddle Road mitigation also funded studies of alien insects that may threaten Palila food resources and limited monitoring of non-native animals and plants on Mauna Kea.

Two mitigation parcels totaling 2,648 ha have been fenced and are nearly free of sheep, goats, and cattle. Active habitat restoration is ongoing at both sites and as of 2011, over 35,000 māmane and other native seedlings have been outplanted and techniques are being developed to increase the rate of restoration. The Army has fenced and removed feral ungulates from over 2,000 ha of māmane habitat on Mauna Loa. Predator control was conducted by USGS from 1998-2005 and by DOFAW since January 2008; 133 cats and 59 mongooses have been removed since 2008. A fire ecology study was completed (Thaxton and Jacobi 2009) and funds to build water tanks have been provided by the USFWS. The State has initiated construction of 67 km of fence that will protect 91% of Palila Critical Habitat with funds provided by the USFWS. The State is attempting to control fountain grass, cape ivy, and banana poka (*Passiflora tarminiana*) and monitor for the presence of incipient populations of the most pernicious weeds (e.g., gorse [*Ulex europaeus*]). A plan to eradicate sheep, goats, and cattle was drafted by DOFAW in October 2011. The Three Mountain Alliance recently fenced almost 2,500 ha of māmane habitat on Mauna Loa that may eventually be able to support Palila.

Palila have been bred in captivity by the Zoological Society of San Diego, although to date, captive production has been insufficient to contribute to recovery. Attempts have been made to re-establish Palila on Mauna Kea's northern slope using translocation and captive-releases (Banko et al. 2009). Translocations were conducted in 1997, 1998, 2004-2006, and captive-bred birds were released in 2003-2005 and 2009. A few pairs nested in the area but most birds did not persist, though a few were still present in March 2011.

Planning/Research Needs:

- Develop effective methods for rapidly eradicating sheep and monitoring their abundance and progress toward eradication.
- Develop a plan for monitoring habitat response to sheep eradication, evaluating Palila habitat carrying capacity, and the spread of new invasive weed species.

- Ensure that the capacity exists for long-term restoration efforts and to monitor the demographic response of Palila to management activities.
- Develop techniques to expand and improve māmane restoration (e.g., with vs. without irrigation, stocking densities, “companion” plant species, removing grass and weed cover).
- Develop methods to effectively combat invasive weeds that compete with māmane and increase fire threats, and to mitigate the impacts of diseases of māmane.
- Investigate factors that limit māmane distribution, productivity, and survival (e.g., what determines tree line, given that plantings at 10,000 ft. elevation are thriving; how will māmane respond to increasing drought; does grass and weed removal result in increased productivity?).
- Investigate climate trends and develop models for understanding how patterns of drought are likely to change and how the vegetation may respond.
- Develop programs for involving the public in forest restoration and for providing educational outreach.

5-Year Conservation Goals:

- Increase public support for Palila conservation and resolve conflicts with hunters and local government over hunting.
- Protect and restore Palila Critical Habitat by fencing, ungulate eradication, native forest restoration, and invasive alien plant control.
- Control feral cats in the area supporting the highest density of Palila and where Palila reintroduction is planned or natural expansion is to be encouraged.
- Evaluate, select, and begin restoring a site to support a second Palila population.

Conservation Actions:

- <u>Habitat Restoration</u>. DOFAW’s Mauna Kea Forest Restoration Project conducts forest restoration, weed control, predator control, and some fence inspection and maintenance. This project does not have a dedicated funding source.
    - Complete 67 km of new ungulate-proof fence around the lower perimeter of Palila Critical Habitat to protect 22,165 ha of māmane forest, which is 91% of Palila Critical Habitat. About 27 km of this fence is completed, 31 km will be completed in the next 24 months, and funds are in hand to build the remaining 26 km of fence. After construction, this fence must be inspected and repaired in perpetuity.
    - An ungulate eradication plan has been drafted. Eradication of feral sheep will cost an estimated $361,000 and require two years. Monitoring for ingress of ungulates must be conducted in perpetuity.
    - Continue and expand forest restoration by out-planting and experimenting with other restoration techniques in the Puu Mali Mitigation Area and other sites, focusing on areas that will maximize the elevational range of māmane.
- <u>Predator Control</u>. Continue and increase feral cat trapping efforts on the western slope of Mauna Kea, especially during April-July, when most Palila nesting occurs.
- <u>Invasive Plants</u>. Increase efforts to control invasive alien plants in Palila habitat, especially fountain grass (*Pennisetum setaceum*) and fireweed. Continue to survey for and control incipient populations of other invasive plants such as gorse.

- Wild Fire. Complete construction of fire control and suppression infrastructure. Implement a forest ranger or surveillance program to help prevent fires and suppress them quickly when they occur. Initial funding from USFWS but more may be needed.
- Public Education. Conduct outreach to increase the public's understanding of the need to eradicate ungulates to prevent extinction of the Palila. Continue to build ties with the community by providing opportunities to volunteer and by showcasing successes.
- Captive Propagation/Reintroduction. Continue refining propagation and release techniques. Evaluate potential sites for the establishment of a second population and draft plans outlining the management actions necessary for establishing a viable population via translocation and the release of captive birds.

Summary and Estimated Costs of Conservation Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Mauna Kea Forest Restoration Project (habitat restoration, fence maintenance, predator control, weed control)	1-5	$400,000	$2,000,000
Ungulate eradication	1-2	na	$361,000
Fence inspection and monitoring ungulate ingress	2-5	$75,000	$300,000
Public outreach	1-5	$50,000	$250,000
Re-introduction site evaluation and selection	1-2	$50,000	100,000
Re-introduction site restoration	2-5	$150,000	$600,000

Potential Partners: Hawaii Division of Forestry and Wildlife, U.S. Fish and Wildlife Service, U.S. Geological Survey Pacific Island Ecosystems Research Center, Department of Hawaiian Homelands, Mauna Kea Watershed Alliance, Three Mountain Alliance, Zoological Society of San Diego, American Bird Conservancy.

Ancillary Species: Ungulate eradication, habitat restoration, and control of alien predators would benefit all native bird species that use māmane forests, including the ‘Io or Hawaiian Hawk (*Buteo solitarius*), Hawai’i ‘Elepaio (*Chasiempis sandwichensis*), ‘I‘iwi (*Vestiaria coccinea*), ‘Apapane (*Himatione sanguinea*), and Hawai’i ‘Amakihi (*Hemignathus virens*). The endangered ‘Akiapōlā‘au (*Hemignathus munroi*) and Hawai‘i Creeper (*Oreomystis mana*), which formerly occurred in the area, could be re-introduced to restored forests on Mauna Kea. The ‘Ua‘u (*Pterodroma sandwichensis*) also could be reintroduced in areas where predators are controlled.

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Focal Species: ‘I’iwi (*Vestiaria coccinea*)

Introduction: The ‘I’iwi, with its long curved bill and brilliant scarlet plumage, is an iconic species and is perhaps the most recognized Hawaiian bird. It is a widespread species that occurs on several islands, but it is very susceptible to mosquito-borne diseases and is largely restricted to high elevation native forests. Few conservation actions have been specifically directed at the ‘I’iwi, but it has benefited from habitat management aimed at several endangered honeycreepers. The ‘I’iwi has declined recently, especially at lower elevations, and was petitioned for listing under the U.S. Endangered Species Act in 2010. Protection and management of native forests above the current range of mosquitoes is the most important tool in ‘I’iwi conservation.

‘I’iwi. Photo Jack Jeffrey

Geographic region: Hawaiian Islands
Group: Forest Birds
Federal Status: Conservation Concern
State status: Endangered on Oahu and Molokai
IUCN status: Vulnerable
Conservation score, rank: 18/20, At-risk
Watch List 2007 Score: RED
Climate Change Vulnerability: High

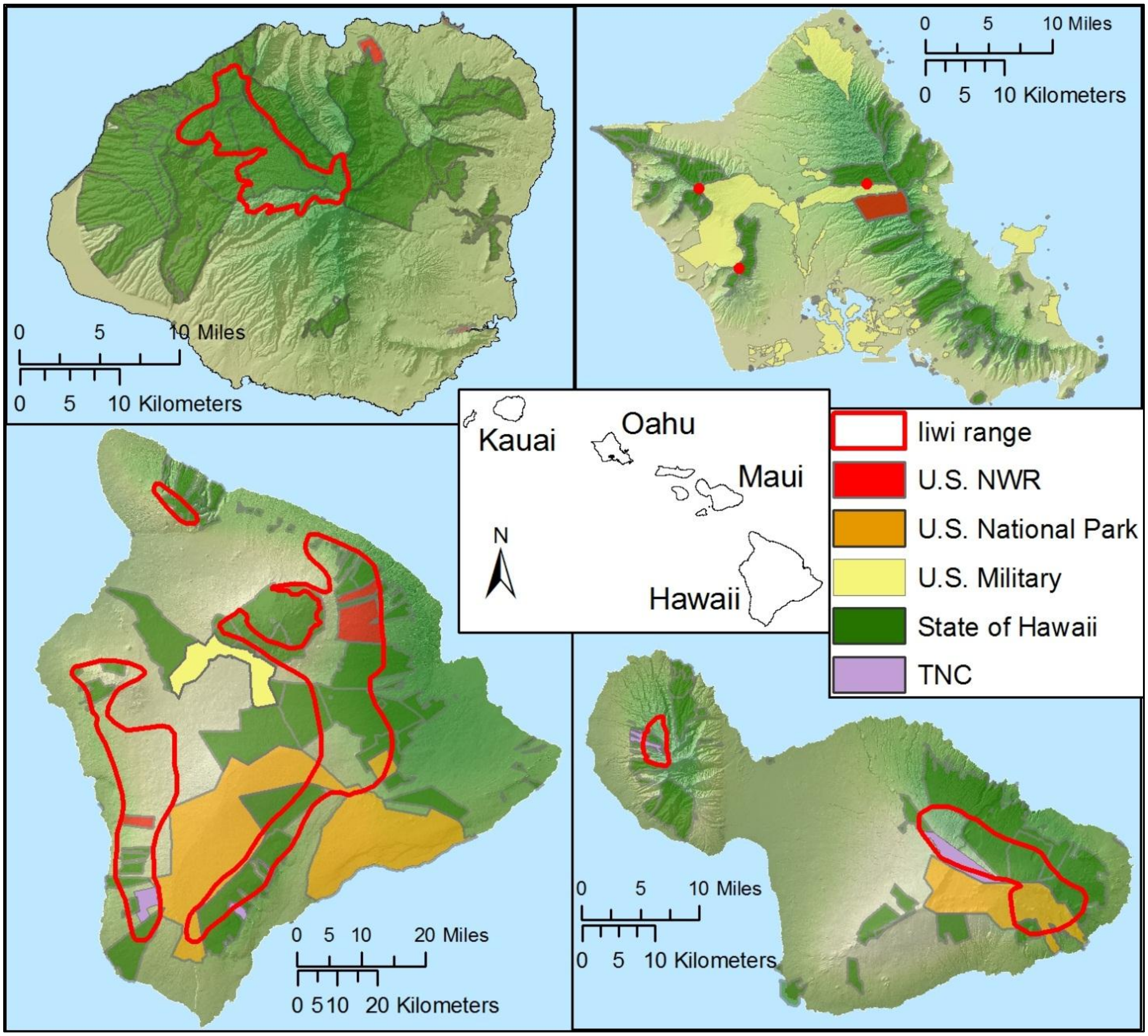
Population Size and Trend: The current ‘I’iwi population is estimated to be 362,000 birds, with by far the largest number occurring on Hawaii (Table 1). Long-term monitoring indicates that most populations are declining, but numbers at Hakalau Forest National Wildlife Refuge (NWR) and the windward side of east Maui are stable or increasing (Camp et al. 2009, 2010). The Kaua’i population is declining rapidly (Camp et al. 2009, Gorresen et al. 2009). Very few ‘I’iwi remain on Oahu and Molokai, where they are observed only rarely.

Table 1. Summary by island of ‘I’iwi population size, range, and overall trend.

	Kaua’i	Oahu	Moloka’i	Lana’i	Maui	Hawai’i
Population	4,000	<10	<10	Extirpated	18,000	340,000
Range	101 km^2	?	?	Extirpated	223 km^2	~2,000 km^2
Trend	Declining	Declining	Declining	Extirpated	Increasing	Stable

Range: ‘I’iwi occur primarily above 1,250 m elevation on the islands of Hawai’i, Maui, and Kaua’i. They occur below 1,000 m in some areas, but at much lower densities. On Hawai’i, ‘I’iwi are widespread in both windward and leeward regions. On Maui, ‘Iiwi are largely restricted to the windward (northeastern) slope of Haleakala Volcano; a few birds may persist on west Maui. On Kaua’i, ‘I’iwi have declined in range recently and are now restricted to the higher portions of the ‘Alaka’i Plateau (Gorresen et al. 2009). Relict populations may occur on O’ahu and Moloka’i. On O’ahu, up to six ‘I’iwi were seen at Schofield Barracks in 1996 (VanderWerf and Rohrer 1996), but numbers dwindled to zero by December 2002. The last sightings on O’ahu occurred at Palikea in 2009 and 2010, in both cases a single second-year bird was seen, suggesting possible breeding on the island. On Moloka’i the last observation was in

2004 (Gorresen et al. 2009). Historically, ‘I’iwi were common on all the main Hawaiian Islands, even at low elevations (Perkins 1903).



Essential Biology: The ‘I‘iwi is a medium-sized (16-20 g), mostly nectarivorous Hawaiian honeycreeper. Males and females are scarlet red, with a black tail and wings, and a long, decurved pink bill (Fancy and Ralph 1998). Juveniles are yellow mottled with black. ‘I‘iwi give a variety of loud, squeaky or gurgling calls and sometimes mimic other birds. During the breeding season ‘I‘iwi are often found in pairs, after breeding they may form small flocks.

‘I‘iwi are found in wet and mesic forests dominated by ‘ōhi‘a (*Metrosideros polymorpha*) and koa (*Acacia koa*), with the best habitat also containing kōlea (*Myrsine lessertiana*), naio (*Myoporum sandwicense*), and tree ferns (*Cibotium* spp.). ‘I‘iwi also forage in high-elevation dry forests dominated by māmane (*Sophora chrysophylla*), but breeding is uncommon in that habitat (Fancy and Ralph 1998). ‘I‘iwi may fly long distances in search of flowering ‘ōhi‘a and māmane trees and are important ‘ōhi‘a pollinators (MacMillen and Carpenter 1980, Ralph and Fancy 1995, Kuntz 2009). Their diet consists of nectar and insects taken from a variety of native and non-native flowers (Fancy and Ralph 1998). Common native species used for foraging include ʻōhiʻa, koa, māmane, naio, kōlea, ʻakala (*Rubus hawaiensis*), ʻalani (*Melicope* spp.), kanawao (*Broussaisia arguta*), kokiʻo keʻokeʻo (*Hibiscus arnottianus*), and several lobelias. Nectar from the invasive banana poka (*Passiflora mollissima*) is a food source in some areas (Fancy and Ralph 1998). Individuals will defend ʻōhiʻa trees with abundant flowers. ʻIʻiwi are very mobile, making long flights (up to 15 km per day) in search of nectar resources (Fancy and Ralph 1995, Kuntz 2009). These long distance flights have not been observed recently and migrations into the mosquito range may be detrimental (Hart et al. 2011). It has been suggested that the curved bill of the ʻIʻiwi is adapted to take nectar from curved lobelia flowers (Smith et al. 1995).

ʻIʻiwi have a long breeding season (November – July) that is tied to the availability of ʻōhiʻa flowers (Ralph and Fancy 1994). Males in breeding condition can be found all year, and females with brood patches are found December–July (Eddinger 1970, Kuntz 2009). Both sexes defend a small nesting territory. The open cup nest is built in terminal branches of an ʻōhiʻa tree, mostly by the female. Only the female incubates the eggs, typically two, and broods the young. The male provisions the females and feeds the young. Juveniles are dependent on parents for less than four months during which time young birds follows their parents and call incessantly (Fancy and Ralph 1998). ʻIʻiwi will renest after failure, and some pairs may raise more than one brood per year (Kuntz 2009).

Primary Threats:

- Disease. Avian malaria (*Plasmodium relictum*) and avian poxvirus (*Poxvirus avium*), which are transmitted by the non-native southern house mosquito (*Culex quinquefasciatus*), limit the distribution of many Hawaiian forest birds (Warner 1968, van Riper et al. 1986, Atkinson and LaPointe 2009). The malarial parasite and mosquito larvae develop more slowly at colder temperatures, restricting sensitive bird species to cold, high elevation refugia. ʻIʻiwi are particularly vulnerable to avian malaria (Atkinson et al. 1995); one bite from a mosquito infected with malaria caused mortality in 9 of 10 juvenile ʻIʻiwi, and 100% of 10 other ʻIʻiwi bitten more than once died of malaria (Atkinson et al. 1995). One surviving bird developed immunity and survived further challenges from multiple mosquito bites. Despite this, there is little evidence that ʻIʻiwi populations are developing disease resistance, although the presence of ʻI'iwi below 1,000 m in elevation on Oahu suggests they may be disease resistant. The long flights made by ʻI'iwi in search of flowering trees may take them into low-elevation forests where mosquitoes are present, resulting in a chronic drain on ʻI'iwi numbers even in high elevation reserves.
- Habitat Loss and Degradation. Cutting of native forest for logging, cattle ranching, and silviculture of non-native trees has reduced the amount of forest habitat and fragmented it in many areas. Most areas of native forest important to these species have been legally protected in some way, but some "protected" areas receive little or no management and habitat degradation by invasive plants and non-native ungulates remains a problem.
- Non-native ungulates. Feral ungulates, including cattle (*Bos Taurus*), feral sheep (*Ovis aries*), mouflon sheep (*O. musimon*), feral goats (*Capra hircus*), and axis deer (*Cervus axis*) have degraded habitat quality by browsing, causing soil erosion, disrupting forest regeneration, spreading alien plant seeds, and facilitating the invasion of alien plants (Cabin et al. 2000, Scott et al. 2001, USFWS 2006). Rooting and wallowing by feral pigs (*Sus scrofa*) has destroyed understory vegetation that provides an important source of

nectar for 'I'iwi, hindered recruitment of native trees, and provided breeding sites for mosquitoes that carry diseases.

- Invasive non-native plants. Invasive plants have invaded native forests and reduced habitat quality in all but the most remote areas on each island. Some of the worst invasive plants are strawberry guava (*Psidium cattleianum*), blackberry (*Rubus argutus*), gorse (*Ulex europaeus*), banana poka (*Passiflora mollissima*), holly (*Ilex aquifolium*), Christmasberry (*Schinus terebinthifolius*), kahili ginger (*Hedychium gardnerianum*), Australian tree fern (*Cyathea cooperi*), kikuyu grass (*Pennisetum clandestinum*), fountain grass (*Pennisetum setaceum*), and *Eucalyptus* spp. 'I'iwi may forage on some non-native plants, but the decrease in floral diversity that often results from invasion by alien plants is problematic for 'I'iwi because it can reduce nectar availability at different seasons.
- Non-native Predators. Although there is little direct evidence of predation on 'I'iwi, rats (*Rattus* spp.), cats (*Felis silvestris*), small Indian mongooses (*Herpestes auropunctatus*), and Barn Owls (*Tyto alba*) are known to be predators of other Hawaiian forest birds (Atkinson 1977, Snetsinger et al. 1994, VanderWerf 2009).
- Climate Change. An increase in prevalence of avian malaria in response to rising temperatures has already been reported at Hakalau Forest NWR on Hawai'i (Freed et al. 2005) and in two areas of the 'Alaka'i Plateau on Kaua'i (Atkinson and Utzurrum 2010). At Hakalau, malaria prevalence in 'I'iwi increased from 0% in 1988-1992 to 8% in 2001-2002. Global climate change will likely continue to exacerbate the threat of disease by increasing the elevation at which regular transmission of avian malaria and avian pox virus occurs (Reiter 1998, Harvell et al. 2002, Hay et al. 2002). On Kaua'i, which has little area over 1,500 m, malaria transmission already can occur at least periodically across all parts of the island, and GIS simulations have shown that an increase in temperature of 2°C, which is a conservative figure based on recent data (IPCC 2007), would allow regular disease transmission in 85% of the area where it is now only periodic (Benning et al. 2002).

Conservation Actions to Date:

In August 2010, the Center for Biological Diversity petitioned the USFWS to list the 'I'iwi under the Endangered Species Act because of climate change and disease, its declining population, and a lack of sufficient protection of existing regulatory mechanisms. In January 2012, the USFWS announced it had determined that the petition presented sufficient information indicating that listing may be warranted and would initiate a 12-month review of the species' status.

Few conservation actions have been specifically directed at the 'I'iwi, but protection and management of native forests in general and actions aimed at several endangered forest birds also has benefitted the 'I'iwi. On Hawai'i, fencing, ungulate removal, invasive plant control, and native forest restoration at Hakalau Forest NWR have contributed to a growing 'I'iwi population (Camp et al. 2010). Other important habitat for 'I'iwi on Hawai'i has been protected and managed to varying degrees by several agencies and organizations, including the USFWS in the Kona Forest NWR, the National Park Service (NPS) in the Kahuku and Mauna Loa Strip sections of Hawaii Volcanoes National Park, the Three Mountain Alliance in the Ola'a-Kilauea Management Area and other areas, The Nature Conservancy (TNC) in the Kona Hema Preserve, and the Hawai'i Natural Area Reserve System (NARS) and Division of Forestry and Wildlife (DOFAW) in the Pu'u Wa'awa'a State Forest Bird Sanctuary, Pu'u O'umi, Manukā, and Pu'u Maka'ala natural area reserves, and several forest reserves. Fencing and removing ungulates from Palila (*Loxioides bailleui*) critical habitat by the DOFAW will benefit ‘I’iwi by allowing regeneration of high elevation māmane (*Sophora chrysophylla*) forest and increasing the availability of nectar over a wider range of elevations (see Palila species profile for more details). On Maui, fencing, removal of ungulates, and control of alien plants by the NPS in Haleakalā National Park, the Hanawī NAR, and TNC in Waikamoi Preserve has resulted in a growing ‘I’iwi population (Camp et al. 2009). On Kaua’i, invasive alien plant control has been conducted by TNC and the Kōke‘e Resource Conservation Program. The Kaua‘i Watershed Alliance (KWA) recently completed strategic ungulate fencing to protect an 810-ha (2,000-acres) management unit in the southeastern ‘Alaka‘i Wilderness Preserve and adjacent private lands; ungulates have almost been eradicated from this area. The KWA also has ambitious plans for three more fenced units that would protect an additional 1,215 ha (3,000 acres) of habitat important to the ‘I’iwi in the ‘Alaka’i Wilderness Preserve (see the Kaua’i honeycreepers profile for more details). On O’ahu, there have been no actions directed specifically at ‘I’iwi, but management by the U.S. Army Natural Resources Program, including fencing, ungulate removal, and invasive plant control, at Palikea and Schofield Barracks would benefit any remaining ‘I’iwi. Similarly, on Moloka’i management at Kamakou Preserve and adjacent areas by TNC has protected ‘I’iwi habitat.

Planning/Research Needs:

- Investigate whether ‘I’iwi are developing disease resistance in the lower-elevation portions of their range. Evolution of malaria resistance has been documented in the Hawai’i ‘Amakihi (Woodworth et al. 2005, Foster et al. 2007).
- Determine if genetic markers or specific phenotypes are associated with disease resistance or tolerance. If disease-tolerant individuals can be identified, they could be used in translocations to establish new populations or to augment existing populations that lack disease tolerance.
- Conduct surveys of potential mosquito breeding habitat and continue to monitor prevalence of avian malaria and avian pox virus. Malaria prevalence increased over the past 15 years in the range of ‘I’iwi on Hawai’i (Freed et al. 2005) and Kaua’i (Atkinson and Utzurrum 2010), but the location of mosquito breeding sites is not well known in some areas. If mosquito breeding sites can be located, it may be possible to treat or eliminate them.
- Capture ‘I’iwi on O’ahu and collect blood samples to test for malarial antibodies.
- Continue monitoring ‘I’iwi abundance by conducting periodic range-wide surveys using established methods (Camp et al. 2009), and expand monitoring efforts to include more frequent surveys of low density areas and along elevational gradients. Conducting surveys more frequently and in more areas would improve estimates of detection probability, leading to more accurate and precise measures of range and abundance and greater ability to determine trends.
- Determine if sufficient native understory plants are available in ungulate-free forests to minimize the need for ‘I‘iwi to make long-distance searches for nectar.
- Conduct life history studies to quantify demography, including dispersal patterns, survivorship, and nesting phenology.

5-Year Conservation Goals:

- Complete the species status review and, if warranted, list the ‘I’iwi under the U.S. Endangered Species Act and the Hawai’i endangered species list.

- Continue and expand native forest restoration and management to include all areas that are important to the ‘I’iwi by ensuring that existing fences are maintained, constructing new fences, removing feral ungulates, and controlling invasive alien plants.
- Acquire or legally protect and then manage additional areas of high elevation native forest.
- Devise methods of minimizing or mitigating the effects of climate change on the ‘I’iwi, particularly the anticipated increase in transmission of mosquito-borne diseases.
- Increase public support for forest bird conservation through outreach.

Conservation Actions: Because the ‘I’iwi is so sensitive to avian disease, protection and management of high elevation forests is essential to its conservation. Long-term monitoring has shown that ‘I’iwi populations were stable to increasing in areas where ungulate removal and habitat restoration are occurring, but declining in areas where no management is conducted (Camp et al. 2009, 2010).

- Habitat Management.
  - Complete ungulate removal within the KWA fence in the eastern ‘Alaka’i.
  - Support efforts by the KWA to fence and remove ungulates from three management units encompassing 1,215 ha (3,000 acres) in the Alaka’i Wilderness Preserve.
  - Fence and remove ungulates from the Hono O Nā Pali Natural Area Reserve and select parts of the Na Pali-Kona Forest Reserve.
  - Continue to control invasive alien plants in the Koke’e/’Alaka’i area.
  - Complete fences around the Kahikinui FR and Nakula NAR on Maui, eradicate feral ungulates, control invasive plants, and restore native forest.
  - Repair fences and remove feral pigs from all management units at Hakalau Forest NWR. Hakalau was formerly pig-free but fences were not adequately maintained because of funding and staffing shortfalls and pigs reinvaded, compromising decades of habitat restoration work.
  - Continue forest restoration at Hakalau Forest NWR. Over 500,000 trees have been planted at Hakalau since 1987.
  - Fence parts of the Ka’u FR, eradicate ungulates, control invasive plants, and outplant native species. Ka’u supports the second largest expanse of native forest in Hawai’i but it has been degraded and is in need of management (State of Hawai’i 2012).
  - Eradicate ungulates, control invasive plants, and outplant native species in the Kahuku section of Hawai’i Volcanoes National Park adjacent to the Ka’u FR.
  - Remove ungulates, control invasive plants, and outplant native species in the part of the Kona Forest NWR that was fenced in 2012.
  - Remove feral ungulates and banana poka and other invasive plants from Pu’u Wa’a Wa’a State Forest Bird Sanctuary.
  - Restore forest connectivity on eastern Mauna Kea by fencing and removing ungulates in the Kanakaleonui corridor owned by the Department of Hawaiian Homelands between Hakalau Forest NWR and Palila Critical Habitat.
- Habitat Protection. Support acquisition of McCandless Ranch lands currently for sale adjacent to the Kona Forest NWR on Hawai’i.
- Disease. Determine mosquito distribution within ‘I’iwi range, especially on Kaua’i, and identify any mosquito breeding sites that could be managed. Monitor prevalence of avian malaria in ‘I’iwi and identify disease-resistant individuals. Fencing and feral pig removal also will reduce disease prevalence by reducing breeding habitat for mosquitoes.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Years	Annual Cost	Total Cost
Complete regulatory compliance for additional fencing in the Alaka'i Wilderness Preserve, Kaua'i	1	$80,000	$80,000
Fence and remove ungulates from 3,000 acres in the Alaka'i Wilderness Preserve, Kaua'i	2-5	$900,000	$3,600,000
Invasive plant control in the Koke'e-'Alaka'i area, Kaua'i	1-5	$250,000	$1,500,000
Complete fences, remove ungulates, and restore habitat in Kahikinui FR+Nakula NAR	1-5	$350,000	$1,750,000
Fence repair/replacement, inspection, and maintenance at Hakalau Forest NWR	1-5	$200,000	$1,000,000
Remove feral pigs from fenced units of Hakalau Forest NWR	1-5	$500,000	$2,500,000
Control invasive plants at Hakalau Forest NWR	1-5	$200,000	$1,000,000
Build fence (~35 km) in Ka'u FR	1-3	$1,100,000	$3,300,000
Remove feral ungulates from Ka'u FR and begin habitat management (~4,850 ha)	2-5	$450,000	$1,800,000
Remove feral ungulates from Kona Forest NWR	1-3	$150,000	$450,000
Control invasive plants at Kona Forest NWR	1-5	$85,000	$425,000
Remove ungulates from Pu'u Wa'a Wa'a FBS	1-3	$75,000	$225,000
Control invasive plants at Pu'u Wa'a Wa'a FBS	1-5	$85,000	$425,000
Continue habitat restoration at TNC Kona Hema Preserve	1-5	$150,000	$750,000
Restore forest in the Kanakaleonui corridor on Mauna Kea	1-5	$300,000	$1,500,000
Mosquito surveys and disease monitoring on Kaua'i	1-2	$200,000	$400,000
Mosquito surveys and disease monitoring on Hawai'i	1-2	$300,000	$600,000
Range-wide surveys for 'I'iwi on each island, 1 island per year	1-5	$50,000	$250,000

Potential Partners: U.S. Fish and Wildlife Service, National Park Service, U.S. Geological Service Pacific Islands Ecosystem Research Center, Hawai'i Division of Forestry and Wildlife, Department of Hawaiian Homelands, Kaua'i Watershed Alliance, East Maui Watershed Partnership, Leeward Haleakala Watershed Restoration Partnership, Three Mountain Alliance, Mauna Kea Watershed Alliance, University of Hawai'i, Koke'e Resource Conservation Program, The Nature Conservancy of Hawai'i, Kamehameha Schools.

Ancillary Species: Because the 'I'iwi is widespread and occurs on multiple islands, it overlaps in range with all other Hawaiian forest birds. Conservation actions for the 'I'iwi will thus contribute to the conservation of the entire remaining endemic avifauna, including: the Hawaiian Hawk or 'Io (*Buteo solitarius*), Hawaiian Short-eared Owl or Pueo (*Asio flammeus sandwichensis*), Hawaiian Crow or 'Alalā (*Corvus hawaiiensis*), 'Kaua'i 'Elepaio (*Chasiempis sclateri*), O'ahu 'Elepaio (*C. ibidis*), Hawai'i 'Elepaio (*C. sandwichensis*), 'Oma'o (*Myadestes obscurus*), Puaiohi (*M. palmeri*), Maui Parrotbill (*Pseudonestor xanthophrys*), 'Akiapōlā'au (*Hemignathus munroi*), Kaua'i 'Amakihi (*H. kauaiensis*), O'ahu 'Amakihi (*H. chloris*), Hawai'i 'Amakihi (*H. virens*), 'Anianiau (*Magumma parva*), 'Akikiki or Kaua'i Creeper (*Oreomystis bairdi*), Hawai'i Creeper (*O. mana*), Maui Creeper (*Paroreomyza montana*), Hawai'i 'Ākepa

(*Loxops coccineus*), ʻAkekeʻe or Kauaʻi ʻĀkepa (*L. caeruleirostris*), Crested Honeycreeper or ʻAkohekohe (*Palmeria dolei*), and ʻApapane (*Himatione sanguinea*).

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Focal Species: Hawai‘i Island Honeycreepers
‘Akiapōlā‘au (*Hemignathus munroi*)
Hawai‘i Creeper (*Oreomytis mana*)
Hawai‘i ‘Ākepa (*Loxops coccineus*)

Synopsis: These three endangered and specialized honeycreepers are endemic to the island of Hawai’i. They have similar, highly fragmented ranges and face similar threats. The ‘Akiapōlā’au has a unique “Swiss army knife” bill that is used as both a chisel and forceps to extract prey from wood. The ‘Ākepa has an asymmetrical bill with crossed tips that are used to pry open leaf buds to obtain tiny caterpillars. These species are restricted by mosquito-borne diseases to cold, high-elevation native forests, but global warming may increase the range of mosquitoes and threaten their last refugia. Many areas of native forest have been degraded, and habitat restoration and management are important conservation actions.


‘Akiapōlā’au male. Photo Eric VanderWerf


Hawai’i ‘Ākepa male. Photo Eric VanderWerf


Hawai’i Creeper. Photo Jack Jeffrey

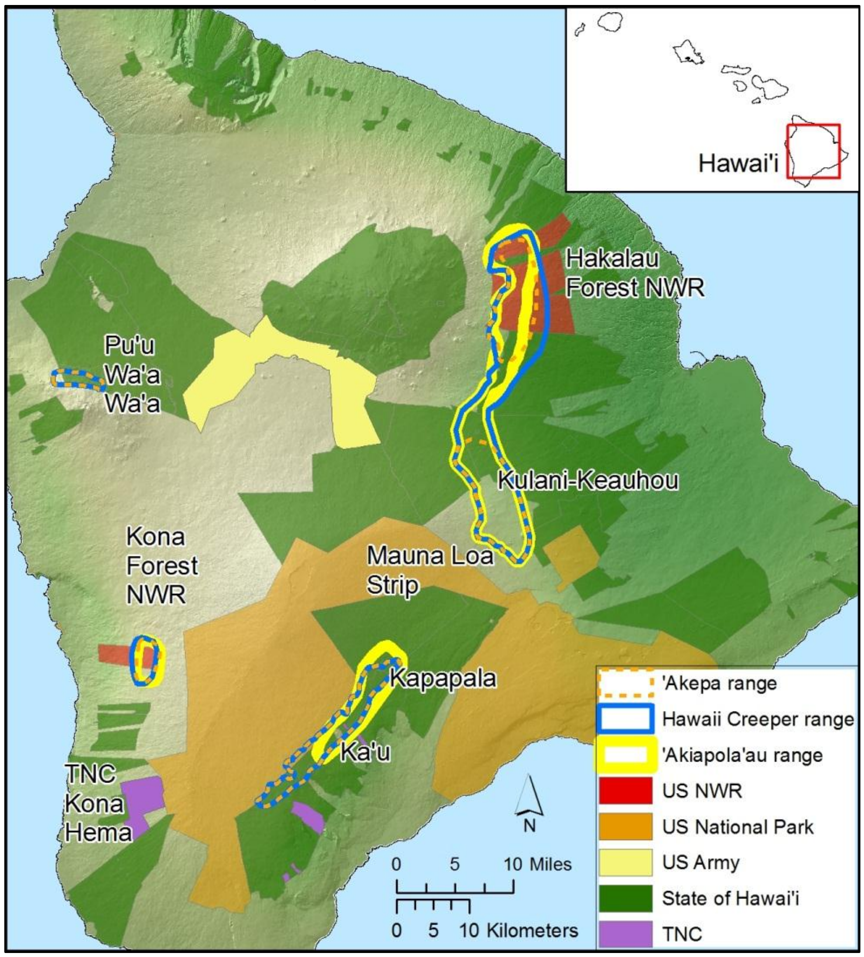
Geographic region: Hawai’i Island
Group: Forest Birds
Federal Status: Endangered
State status: Endangered
IUCN status: Endangered
Conservation score, rank: 19/20, At-risk
Watch List 2007 Score: RED
Climate Change Vulnerability: High

Population Size and Trend:
‘Akiapōlā’au – The total population is estimated to be 1,900 birds. The largest numbers are found at Hakalau Forest National Wildlife Refuge (NWR) and in the upper portions of the Ka‘ū Forest Reserve (FR), where trends are increasing and stable, respectively (Camp et al. 2009, 2010). The Kūlani-Keauhou area in the central windward region of the island also supports a high density of birds, but their trend is not clear because of variable estimates and inconsistency in survey effort (Gorresen et al. 2009). Populations on leeward Mauna Loa are declining at best and are possibly extirpated (Camp et al. 2009, Gorresen et al. 2009).

Hawai'i Creeper – The total population is estimated to be 14,000 birds. The largest numbers are found at Hakalau Forest NWR and in the upper portions of the Ka'ū FR, where trends are increasing and stable, respectively (Camp et al. 2009, 2010). Populations are likely declining in the central windward area and populations on the leeward side of Mauna Loa are dwindling and are relictual at best (Camp et al. 2009, Gorresen et al. 2009, Pratt et al. 2010).

Hawai'i 'Ākepa – The total population is estimated to be 12,000 birds. Numbers are thought to be stable or increasing at Hakalau Forest NWR, which supports approximately half of the entire population, though there has been debate about the status of this population (Camp et al. 2010, Freed and Cann 2010). The Ka'ū FR supports the second largest population, but variable density estimates make determining a trend difficult. Numbers in the central windward area of the island may be decreasing. Populations on the leeward side of Mauna Loa are very small and declining (Camp et al. 2009, Gorresen et al. 2009, Pratt et al. 2010).

Range: The ranges of these three species overlap broadly, with larger populations occurring on the windward (eastern) slopes of Mauna Kea and Mauna Loa. Their ranges are much smaller on the leeward (western) slopes, where all three species are declining or extirpated (Camp et al. 2009, Gorresen et al. 2009, Pratt et al. 2010). Historically, these species occupied all forested regions on the island (Lepson and Freed 1997, Pratt et al. 2001, Lepson and Woodworth 2002).



'Akiapōlā'au – Occurs in three disjunct populations, mostly between 1,500 and 2,000 meters (4,875–6,500 feet) elevation: 1) Mauna Kea and Mauna Loa, including Hakalau Forest NWR and the Kūlani-Keauhou area; 2) the Ka'ū and Kapāpala areas in the southern part of the island; and 3) a small population on leeward Mauna Loa at the Kona Forest NWR, which may be extirpated (Fancy et al. 1996, Camp et al. 2009). A subalpine population on western Mauna Kea has been extirpated since 2004.

Hawai'i Creeper – Occurs in four disjunct populations above 1,500 meters (5,000 feet) elevation (Camp et al. 2009): 1) northern and central windward region, including Hakalau Forest NWR and Kūlani-Keauhou; 2) the Kaʻū and Kapāpala forest reserves; 3) the central Kona region including the Kona Forest NWR, and 4) Pu'u Wa'a Wa'a Forest Bird Sanctuary on Hualālai (Camp et al. 2009, Pratt et al. 2010).

Hawai'i ʻĀkepa – Occurs in five disjunct populations all above 1,300 meters (4,300 feet) elevation (Camp et al. 2009): 1) northern windward Mauna Kea, including Hakalau Forest NWR; 2) Kūlani-Keauhou in the central windward region; 3) the Kaʻū-Kapāpala region on the southeastern slope of Mauna Loa; 4) the central Kona region, including the Kona Forest NWR; and 5) Pu'u Wa'a Wa'a Forest Bird Sanctuary on Hualālai (Pratt et al. 2010).

Essential Biology:

ʻAkiapōlāʻau – The ʻAkiapōlāʻau is a stocky Hawaiian honeycreeper endemic to the island of Hawaiʻi and is famous for its unique and specialized bill. Males are bright yellow on the head and underparts, yellow-green on the back and wings, with a small black mask. Females are olive above with grayish-yellow to yellow underparts (Pratt et al. 2001). The song is a long complex warble and calls include a loud "chu-weet" that is louder and huskier than other honeycreepers.

The ʻAkiapōlāʻau occurs primarily in mesic and wet montane forests dominated by ʻōhiʻa (*Metrosideros polymorpha*) and koa (*Acacia koa*) (Fancy et al. 1996), but it also uses regenerating koa forests >10 years old (Pejchar et al. 2005), and until recently it occurred in subalpine dry forests consisting of māmane (*Sophora chrysophylla*) and naio (*Myoporum sandwicense*) trees (Pratt et al. 2001). ʻAkiapōlāʻau forage on branches of koa, kōlea (*Myrsine lessertiana*), māmane, and naio trees, tapping branches with their thick lower bill to locate prey. Once a food item is located, the lower bill is used like that of a woodpecker bill to chisel a hole. The long, thin decurved upper bill is then used to extract the prey. The upper mandible also is used to probe cracks and crevices. ʻAkiapōlāʻau are primarily insectivorous, with lepidoptera larva, spiders, and beetle larva being the most important prey items (Pratt et al. 2001). The ʻAkiapōlāʻau is also unique among passerine birds in that drinks sap from holes it excavates in ʻōhiʻa trees (Pejchar and Jeffrey 2004).

This species is characterized by low annual productivity and high adult survival. Pejchar et al. (2005) found that over a two-year period pairs raised an average of 0.96 fledglings. The open cup nest is most often placed in an ʻōhiʻa tree. Clutch size is usually one, rarely two, and females perform all incubation and brooding. Males provide females and nestlings with the majority of food. Fledglings are dependent on their parents for four to five months, and family groups consisting of hatch-year and second-year young have been observed. Breeding has been documented year-round, although most activity occurs from February to July. The ʻAkiapōlāʻau often associates with mixed-species flocks after breeding, which also may include the Hawaiʻi ʻĀkepa, Hawaiʻi Creeper, and Hawaiʻi ʻAmakihi (*Hemignathus virens*; Hart and Freed 2003). Pejchar et al. (2005) found that territory size varied with habitat structure and amount of koa, with smaller territories in koa plantations (11.7 ha) and intact forest (12.3 ha) than in forest degraded by cattle grazing (23 ha), and that territory overlap was greater in koa plantations, leading to higher population density.

Hawaiʻi Creeper – The Hawaiʻi creeper is a small, inconspicuous Hawaiian honeycreeper endemic to the island of Hawaiʻi. Adult males and females are olive-green above, dull buff below, and have a dark gray mask around the eyes. Their similarity to Hawaiʻi ʻAmakihi, Hawaiʻi ʻĀkepa, and the introduced Japanese White-eye (*Zosterops japonicus*) complicates field identification (Lepson and Woodworth 2002). The song is a descending trill that is often given several times in a row.

The Hawai‘i Creeper occurs in mesic and wet montane forests dominated by ‘ōhi‘a and koa; highest densities are found in old-growth forests (Lepson and Woodworth 2002). It forages for insects, spiders, and other invertebrates on large or medium-size branches, mostly on koa and ‘ōhi‘a, but also on pilo (*Coprosma* spp.), ‘ōlapa (*Cheirodendron trigynum*), naio, and kāwa‘u (*Ilex anomala*).

The nesting season is from February-June (VanderWerf 1998, Woodworth et al. 2001). Most nests are open cups, but about 15 percent are placed in cavities or in bark crevices. The female builds the nest, incubates eggs, and broods nestlings. The male delivers food to the female on and off the nest. Both parents feed the young for approximately one month after fledging. Hawai‘i Creepers re-nest after failures and pairs have been documented raising two broods in a season. Nest success of Hawai‘i Creepers is low (VanderWerf 1998), but adults have high annual survival (Woodworth et al. 2001). During the breeding season the species' home range averages 4-7 hectares (10-17 acres) in size and a 10-20 meter (33-66 feet) territory around the nest is defended (VanderWerf 1998). Outside the breeding season, Hawai'i Creepers frequently join mixed-species foraging flocks (Hart and Freed 2003) and forage over home ranges that average 11 hectares (VanderWerf 1998).

<u>Hawai'i ‘Ākepa</u> – The Hawai‘i ‘Ākepa is a small (9 g), insectivorous Hawaiian honeycreeper now restricted to the island of Hawai‘i. ‘Ākepa formerly occurred on Maui (*L. c. ochraceus*) and O‘ahu (*L. c. rufus*), but those subspecies are extinct. Male ‘Ākepa exhibit delayed plumage maturation, obtaining their bright orange adult plumage after three years (Lepson and Freed 1995). Females are grayish green with a yellow breast band. The lower bill of the Hawai'i ‘Ākepa is slightly curved to one side, resulting in a crossed bill, a characteristic shared with the ‘Akeke‘e (*L. caeruleirostris*). The lower bill may be curved to the left or right, and, depending on the direction of the bill curve, individuals also possess an accompanying leg asymmetry; the leg opposite the curve in the bill is slightly longer than the other leg. Together, these adaptations likely improve the species foraging efficiency. The song is a high, descending trill, with repeated element that rise and fall, giving a lilting effect (Lepson et al. 1997).

The Hawaii ‘Ākepa occurs in mesic and wet montane forests dominated by ‘ōhi‘a and koa; highest densities are found in old-growth forests (Freed 2001). The species forages almost exclusively on the terminal leaf clusters of ‘ōhi‘a and among koa leaves and seed pods, where it uses its crossed bill to pry open leaf and flower buds in search of small arthropods, mostly spiders and caterpillars. This species is characterized by low annual productivity and high adult survival (Hart 2001).

‘Ākepa are obligate cavity nesters, with most nests placed in natural cavities found in old-growth ‘ōhi‘a and koa trees (Freed 2001); artificial nest boxes have been used rarely. The nesting season is from March-June. The female builds the nest, incubates eggs, and broods nestlings, and the male delivers food to the female on and off the nest (Lepson and Freed 1995). Both parents feed the young, which remain with their parents for two to three months after fledging. Most breeding activity occurs between March and June. Hawai‘i ‘Ākepa often join mixed-species foraging flocks, particularly those with Hawai‘i Creepers (Hart and Freed 2003).

Primary Threats: These three species share similar threats but their severity varies among the species according to their biology. The smaller population size of the ‘Akiapōlā‘au renders it more vulnerable to random demographic fluctuations and localized catastrophes such as volcanic eruptions, fires, disease outbreaks, and, potentially, genetic inbreeding.

- Habitat loss and degradation. Cutting of native forest for logging, cattle ranching, and silviculture of non-native trees has reduced the amount of native forest habitat and fragmented it in many areas. Most areas of native forest important to these species have been legally protected in some way, but some "protected" areas receive little or no management and habitat degradation by invasive plants and non-native ungulates remains a problem. Habitat fragmentation may hinder natural re-colonization by these species into unoccupied but suitable habitat. The ʻAkiapōlāʻau may be less limited by habitat loss than the other two species because it will forage in relatively young koa (Pejchar et al. 2005). ʻĀkepa are more vulnerable to habitat degradation because they are obligate cavity nesters, and their population density may be limited by availability of cavity nest-sites, which form only in large, old-growth ʻōhiʻa and koa trees (Freed 2001). In forest fragments, the large trees required for nesting by ʻākepa may be more susceptible to windfall and desiccation. Koa is relatively fast-growing, but slow growth of ʻōhiʻa limits regeneration.
- Invasive non-native plants. Invasive plants have invaded native forests and reduced habitat quality in virtually all areas of the island. Some of the worst invasive plants are strawberry guava (*Psidium cattleianum*), blackberry (*Rubus argutus*), gorse (*Ulex europaeus*), banana poka (*Passiflora mollissima*), holly (*Ilex aquifolium*), Christmasberry (*Schinus terebinthifolius*), fire tree (*Morella faya*), kahili ginger (*Hedychium gardnerianum*), kikuyu grass (*Pennisetum clandestinum*), fountain grass (*Pennisetum setaceum*), and *Eucalyptus* spp. The more common honeycreeper species may forage in non-native plants, but these three rare, specialized honeycreepers are restricted to native forest.
- Non-native ungulates. Browsing by feral cattle (*Bos taurus*), feral sheep (*Ovis aries*), and mouflon sheep (*O. musimon*) has degraded habitat quality in many areas and hindered recruitment of native trees. Rooting and wallowing by feral pigs (*Sus scrofa*) has destroyed understory vegetation in many areas, hindered recruitment of native trees, and provided breeding sites for mosquitoes that carry diseases. The axis deer (*Cervus axis*) was illegally released on Hawaii in 2011; this alien species has caused serious damage to native habitats on Maui and is able to jump over fences that exclude other ungulates.
- Diseases. Avian malaria (*Plasmodium relictum*) and avian poxvirus (*Poxvirus avium*), transmitted by the non-native southern house mosquito (*Culex quinquefasciatus*), limit the distribution of many Hawaiian forest birds (Warner 1968, van Riper et al. 1986, Atkinson and LaPointe 2009). The malarial parasite and mosquito larvae develop more slowly at colder temperatures, restricting sensitive bird species to cold, high elevation refugia. The ʻAkiapōlāʻau, Hawai'i Creeper, and Hawaiʻi ʻĀkepa are rare or absent below 1,350 meters (4,500 feet), suggesting they are particularly susceptible to mosquito-borne diseases.
- Non-native Predators. Predation is a threat to many Hawaiian forest birds, particularly their nests, but there is little direct evidence of predation on these species. At least three nests of the Hawaiʻi ʻĀkepa in low cavities are known to have been depredated by rats (P. Hart, unpubl. data), and it is possible that other inaccessible nests have been depredated. In other Hawaiian forest bird species, predation has been documented on nests by non-native black rats (*Rattus rattus*) and feral cats (*Felis silvestris*) (Fancy et al. 1996, Laut et al. 2003, VanderWerf 2009). Young birds that cannot yet fly well are also vulnerable to small Indian mongooses (*Herpestes auropunctatus*) and Barn Owls (*Tyto alba*).

- <u>Competition with Non-native Species.</u> Competition for food with non-native birds and invertebrates may be a threat, but the evidence is not clear. Freed and Cann (2009) argued that competition with the Japanese White-eye (*Zosterops japonicus*) has negatively affected growth and survival of native birds, particularly the Hawaiʻi ʻĀkepa. Yellow jackets wasps (*Vespula pennsylvanica*) also may compete for food with these insectivores.
- <u>Climate Change</u>. An increase in prevalence of avian malaria in response to increasing temperatures has already been reported at Hakalau Forest NWR (Freed et al. 2005). Global climate change will likely continue to exacerbate the threat of disease by increasing the elevation at which regular transmission of avian malaria and avian pox virus occurs (Reiter 1998, Benning et al. 2002, Harvell et al. 2002, Atkinson and LaPointe 2009b).

Conservation Actions to Date: The ʻAkiapōlāʻau, Hawaiʻi ʻĀkepa, and Hawai'i Creeper were listed as endangered under the U.S. Endangered Species Act in 1967, 1970, and 1975, respectively, and also are listed as endangered by the State of Hawai'i. Hakalau Forest NWR was acquired in 1985 specifically to protect habitat for these endangered honeycreepers and other forest birds and supports the largest populations of all three species. The second largest populations in the Kaʻū and Kapāpala areas have been provided varying degrees of protection by the Kahuku section of Hawai'i Volcanoes National Park and the Kaʻū and Kapāpala forest reserves. Other important habitat has been protected by the Kona Unit of the Hakalau Forest NWR, the Ola'a-Kilauea Management Area, and the Pu'u Wa'awa'a State Forest Bird Sanctuary. At Hakalau Forest NWR, over 500,000 native trees have been planted to increase forest area, especially at higher elevations of the refuge. Other restoration and management actions at Hakalau have included fencing almost half of the refuge, removal of all feral ungulates, and control of invasive alien plants. Habitat management including fencing, ungulate eradication, limited predator control, forest restoration, and habitat monitoring also has been conducted by the National Park Service, Hawai'i Natural Area Reserve System, Three Mountain Alliance, Mauna Kea Forest Restoration Project, Mauna Kea Watershed Alliance, and The Nature Conservancy of Hawai'i. Research with conservation implications has been conducted on demography, habitat use, disease, and other topics by the USGS Biological Resources Division, the University of Hawai'i at Manoa and Hilo, and other groups (van Riper et al. 1986, VanderWerf 1998, Woodworth et al. 2001, Hart 2001, Freed 2001, Jarvi et al. 2004, Freed et al. 2005, Pejchar et al. 2005, Woodworth et al. 2005, Foster et al. 2007).

Planning/Research Needs:

- Investigate whether these species are developing disease resistance in the lower-elevation portions of their ranges. Evolution of malaria resistance has been documented in the Hawai'i 'Amakihi (Woodworth et al. 2005, Foster et al. 2007).
- Determine if genetic markers or specific phenotypes are associated with disease resistance or tolerance. If disease-tolerant individuals can be identified, they could be used in translocations to establish new populations or to augment existing populations that lack disease tolerance.
- Investigate why populations of all three species have declined or disappeared on the Kona side of the island.
- Determine feasibility of translocating each species to managed areas in their former ranges, such as Puʻu Waʻawaʻa Sanctuary, the Mauna Loa strip section of Hawaiʻi Volcanoes National Park, the Kona Forest NWR, and TNC's Kona Hema Preserve.

- Conduct studies to further examine habitat selection and foraging ecology, particularly for the ‘Akiapōlā‘au in regenerating koa forests.
- For the Hawai’i ‘Ākepa, expand studies of artificial nest cavities to determine cavity type preferences, whether preferred artificial cavity types can be made rat-resistant, and evaluate their potential to facilitate range expansion and establishment of new populations.
- Improved monitoring, including more frequent surveys, mist-netting and banding, and nest monitoring, would help to improve ability to measure population trends and efficacy of conservation actions.

5-Year Conservation Goals:

- Continue and expand native forest restoration and management to include all areas that are important to these species by ensuring that existing fences are maintained, constructing new fences, removing feral ungulates, and controlling invasive alien plants.
- Acquire or legally protect and then manage additional areas of high elevation native forest.
- Devise methods of minimizing or mitigating the effects of climate change on these species, particularly the anticipated increase in transmission of mosquito-borne diseases.
- Increase public support for forest bird conservation through outreach.

Conservation Actions:

- <u>Habitat Restoration</u>. Manage forest habitat by fence construction and maintenance, feral ungulate removal, control of invasive alien plants, and outplanting of native species.
  - Repair fences and remove feral pigs from all management units at Hakalau Forest NWR. Hakalau was formerly pig-free but fences were not adequately maintained because of funding and staffing shortfalls and pigs reinvaded, compromising decades of habitat restoration work.
  - Continue forest restoration at Hakalau Forest NWR. Over 500,000 trees have been planted at Hakalau since 1987, mostly koa, and the earliest plantings are now being used by endangered honeycreepers.
  - Fence parts of the Ka‘ū FR that support endangered forest birds, eradicate ungulates, control weeds, and outplant native species. Ka‘ū supports the second largest populations of these endangered honeycreepers, but the habitat has been degraded and is in need of management (State of Hawai’i 2012).
  - Eradicate ungulates, control weeds, and outplant native species in the Kahuku section of Hawai’i Volcanoes National Park adjacent to the Ka‘ū FR.
  - Remove ungulates, control invasive plants, and outplant native species in the part of the Kona Forest NWR that was fenced in 2012.
  - Remove feral ungulates and banana poka and other invasive plants from Pu’u Wa’a Wa’a State Forest Bird Sanctuary. This area supports important remnant populations of Hawai’i Creeper and Hawaii ‘Ākepa, but the habitat has been degraded.
  - Restore forest connectivity on eastern Mauna Kea by fencing and removing ungulates in the Kanakaleonui corridor owned by the Department of Hawaiian Homelands between Hakalau Forest NWR and Palila Critical Habitat. The ‘Akiapōlā‘au occurred in this area until the 1990s, restoring a connection could allow natural range expansion.
- <u>Habitat Protection.</u> Support acquisition of McCandless Ranch lands currently for sale adjacent to the Kona Forest NWR.

- Disease. Removing pigs will reduce disease prevalence by decreasing suitable breeding habitats for mosquitoes.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Fence repair/replacement, inspection, and maintenance at Hakalau Forest NWR	1-5	$200,000	$1,000,000
Remove feral pigs from fenced units of Hakalau Forest NWR	1-5	$500,000	$2,500,000
Control invasive plants at Hakalau Forest NWR	1-5	$200,000	$1,000,000
Build fence (~35 km) in Ka‘ū FR	1-3	$1,100,000	$3,300,000
Remove feral ungulates from Ka‘ū FR and begin habitat management (~4,850 ha)	2-5	$450,000	$1,800,000
Remove feral ungulates from Kona Forest NWR	1-3	$150,000	$450,000
Control invasive plants at Kona Forest NWR	1-5	$85,000	$425,000
Remove ungulates from Pu’u Wa’a Wa’a FBS	1-3	$75,000	$225,000
Control invasive plants at Pu’u Wa’a Wa’a FBS	1-5	$85,000	$425,000
Continue habitat restoration at TNC Kona Hema Preserve	1-5	$150,000	$750,000
Restore forest in the Kanakaleonui corridor on Mauna Kea	1-5	$300,000	$1,500,000
Artificial nest box study for Hawai‘i ‘Ākepa	1-3	$100,000	$300,000
Surveys to better monitor species status and trend	1, 3, 5	$75,000	$225,000

Potential Partners: U.S. Fish and Wildlife Service, U.S. Geological Survey Pacific Island Ecosystems Research Center, Hawai’i Division of Forestry and Wildlife, Hawai’i Natural Area Reserves System, Department of Hawaiian Homelands, Three Mountain Alliance, Kamehameha Schools, and The Nature Conservancy of Hawai’i.

Ancillary Species: Management that would benefit these species also would benefit all native bird species that use forest habitat on the island of Hawai’i, including the Hawaiian Hawk or ‘Io (*Buteo solitarius*), Pueo or Hawaiian short-eared Owl (*Asio flammeus sandwichensis*), Hawaiian Crow or ‘Alalā (*Corvus hawaiiensis*), Hawai‘i ‘Elepaio (*Chasiempis sandwichensis*), ‘Oma’o (*Myadestes obscurus*), Hawai‘i ‘Amakihi , ‘I‘iwi (*Vestiaria coccinea*), and ‘Apapane (*Himatione sanguinea*).

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Focal Species: Maui rain forest honeycreepers
Maui Parrotbill or Kiwikiu (*Pseudonestor xanthophrys*)
Crested Honeycreeper or ‘Ākohekohe (*Palmeria dolei*)
Maui Creeper or Maui ‘Alauahio (*Paroreomyza montana*)

Synopsis: These three species of Hawaiian honeycreepers are endemic to Maui and are restricted to high elevation areas of native forest. They share the same habitat and also the same threats. The Maui Creeper is least specialized and occurs in some areas on non-native forest and is more widespread and more numerous. The Maui Parrotbill is more specialized and occurs at lower population density and is thus least numerous. Keys to the conservation of these species are continued management of existing native forest habitat, restoration of additional habitat, and translocations to create additional populations in restored habitat.


Maui Parrotbill. Photo E. VanderWerf


Crested Honeycreeper. Photo E. VanderWerf


Maui Creeper male. Photo Eric VanderWerf


Hanawī Reserve. Photo Eric VanderWerf.

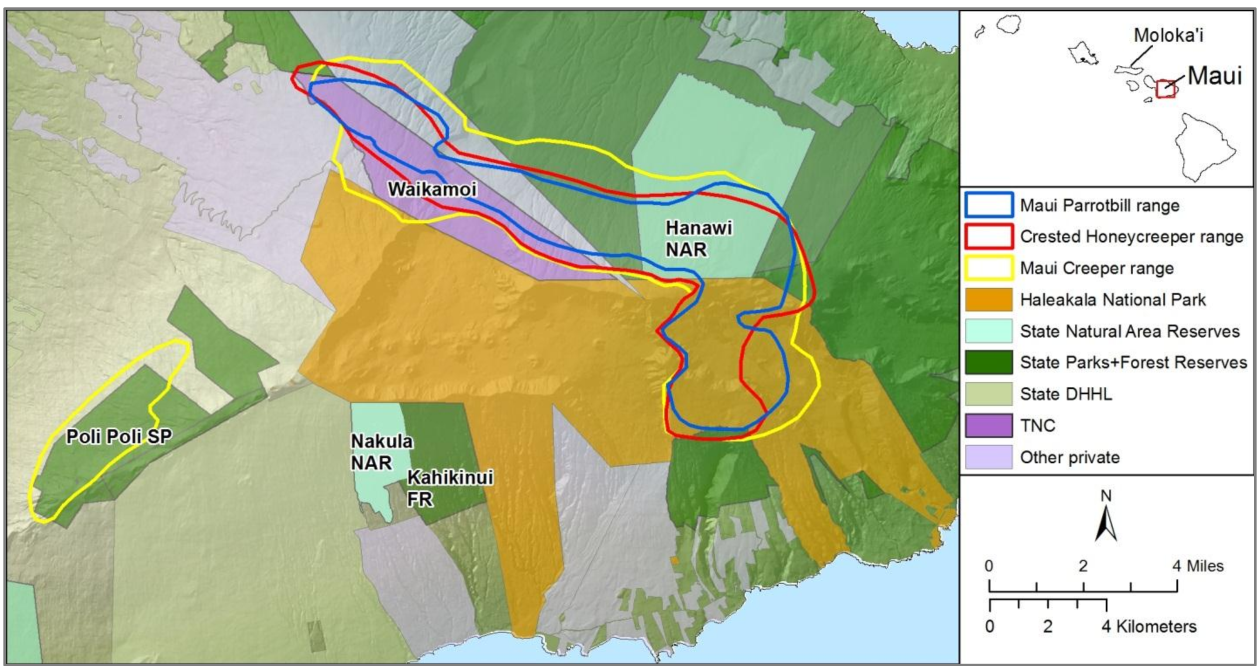
Geographic region: Hawaiian Islands
Group: Forest birds
Federal Status: Maui Parrotbill, ‘Ākohekohe Endangered, Maui Creeper Cons. Concern
State status: Maui Parrotbill, ‘Ākohekohe Endangered
IUCN status: Parrotbill, ‘Ākohekohe Critically Endangered, Maui Creeper Endangered
Conservation score, rank: 18/20, At-risk
Watch List 2007 Score: RED
Climate Change Vulnerability: HIGH

Population Size and Trend:
Maui Parrotbill – In 1980, the total population was estimated to be 502 ± 116 birds based on surveys of the species’ entire range (Scott et al. 1986). Population density (birds/km^2) was estimated to be 17.2 ± 4.2, 17.0 ± 4.2, and 11.8 ± 2.6 based on surveys in 1980, 1992-1996, and 1997-2001, respectively, suggesting a possible decline in abundance, but the large errors associated with the estimates caused the trend assessment to be statistically inconclusive (Camp et al. 2009, Gorresen et al. 2009). Brinck et al. (2102) estimated that abundance of Maui Parrotbills in the core of their range was 421 birds (95% CI 209-674) based on repeated surveys in 2006 and 2011, but this did not include Kipahulu Valley and Waikamoi Preserve. Population density is higher in the core of the species range; from 1995–1997, research in Hanawī Natural

Area Reserve (NAR) indicated that Maui Parrotbill density was approximately the same ($40/km^2$) as in 1980 (Simon et al. 2002). In 2010, intensive demographic monitoring of banded parrotbills found densities in the core of the range (190 ha surveyed) to be $33\text{-}36/km^2$ (Maui Forest Bird Recovery Project [MFBRP], unpubl. data).

Crested Honeycreeper – In 1980, the total population was estimated to be 3,753 ± 373 (Scott et al. 1986). Subsequent surveys from 1997-2001 over the species' entire range yielded higher densities, which resulted in a population estimate of 6,745 ± 1,546 individuals (Camp et al. 2009). Surveys in the core of the species' range in Hanawī NAR during 1980 and 1995-1997 also recorded increasing densities (183 and $289/km^2$, respectively; Scott et al. 1986, Simon et al. 2002), supporting the conclusion that abundance of ʻĀkohekohe has increased.

Maui Creeper – In 1980, the total population was estimated to be 34,839 ± 2,723 (Scott et al. 1986). Population density ($birds/km^2$) was estimated to be 731 ± 64, 1482 ± 77, and 1167 ± 74 based on surveys in 1980, 1992-1996, and 1997-2001, respectively, suggesting a possible increase in abundance, but surveys in 1980 were conducted after the peak in breeding, and the species' range may be contracting up slope (Camp et al. 2009). Brinck et al. (2102) estimated that abundance of Maui ʻAlauahio within the range the Maui Parrotbill (i.e., not their entire range) was 55,262 birds (95% CI 52,729-57,921) based on repeated surveys in 2006 and 2011.



Range:

Maui Parrotbill – The Maui Parrotbill currently is restricted to a single population occupying 50 km^2 between 1,200 and 2,350 m elevation on the northeastern slope of Haleakalā Volcano (Scott et al. 1986, Simon et al. 1997). It is most common from 1,700 to 2,100 m (Scott et al. 1986) and absent from most areas below 1,350 m (USFWS 2006). Surveys in 2001 indicated that parrotbills have persisted over roughly the same area identified in 1980 by Scott et al. (1986), although an upslope contraction of about 100 m appears to have occurred at the bottom of the species range (from 1,100 to 1,200 m elevation; Camp et al. 2009). Maui Parrotbill historically occurred in drier, low elevation forests on Maui and Moloka‘i (James and Olson 1991).

Crested Honeycreeper – The ‘Ākohekohe currently is restricted to a single population that has a range of 58 km^2 on the northeastern slope of Haleakalā Volcano, similar to that of the Maui Parrotbill but slightly larger (Scott et al. 1986). It occurs between 1,100 and 2,300 m elevation but is most abundant between 1,500 and 2,100 m (Conant 1981, Scott et al. 1986). The ‘Ākohekohe occurs at higher and lower elevations than the Maui Parrotbill. The ‘Ākohekohe was extirpated from Moloka’i in the early 1900s (Bryan 1908).

Maui Creeper – Most of the species’ population occurs on the northeastern slope of Haleakalā Volcano, where it is sympatric with the Maui Parrotbill and Crested Honeycreeper; a smaller population occurs on the drier, leeward slopes of Haleakalā in and around Poli Poli State Park (Baker and Baker 2000). Maui Creepers were found historically in Kahikinui on the southern slope of Haleakalā and on west Maui and Lāna’i. The Lāna‘i subspecies was last seen in 1937 and is considered extinct (Munro 1944, Hirai 1978). The range in east Maui appears to be contracting up-slope (Camp et al. 2009).

Essential Biology:

Maui Parrotbill – The Maui Parrotbill had no historically recorded Hawaiian name until 2010, when Kiwikiu was created for it with the help of Hawaiian linguists (MFBRP 2010). It is a medium-sized (20–25 g) Hawaiian honeycreeper with a short tail and a large, parrot-like bill (Simon et al. 1997). Adults are olive-green above with a yellow breast, belly, and cheeks, and a yellow supercilium. Males are larger and brighter than females and have larger bills. The song is a series of “*chewy, chewy, chewy*,” notes descending in pitch and volume (Simon et al. 1997).

Maui Parrotbills occur in mesic and wet native montane forests dominated by ‘ōhi‘a (*Metrosideros polymorpha*), ‘ōlapa (*Cheirodendron trigynum*), kōlea (*Myrsine lessertiana*), and kawa‘u (*Ilex anomala*), with a diverse understory of native plants including ‘ākala (*Rubus hawaiensis*), ‘ōhelo (*Vaccinium calycinum*), ‘alani (*Melicope* spp.), pūkiawe (*Styphelia tameiameiae*), and kanawao (*Broussaisia arguta*) (Simon et al. 1997, Stein 2007). They forage mainly on the woody portions of native shrubs and trees, using their powerful bill to dig, crush, and chisel bark and wood for insects and other arthropods, especially larvae and pupae of beetles and moths (Perkins 1903, Mountainspring 1987, Simon et al. 1997, Stein 2007). Perkins (1903) noted a preference for koa (*Acacia koa*), which is scarce is the current range.

Maui Parrotbill pairs defend year-round territories that average 2.3-5.1 ha (5.7-12.6 ac) in size (Pratt et al. 2001, Iknayan et al. 2010). The nesting season extends primarily from December to July, though nests have been found in all months except September. Most nests are built high (10.6 ± 3.0 m) in ‘ōhi‘a trees, typically close to branch tips. Clutch size is one egg and pairs raise only one fledgling per year. Fledglings remain with parents and are fed for several months. The female incubates the egg and broods the chick, the male feeds the female on the nest and provides most food for the dependent young (Simon et al. 1997). Nest success averages 19%, with inclement weather resulting in most nest losses (Mounce et al. 2011). Renesting is common after failure, and pair success (proportion of pairs observed with a fledgling) averages 46% per year (Mounce et al. 2011). Based on mark-recapture data, annual adult and juvenile survival are 0.84±0.04 and 0.76±0.09, respectively (Vetter et al. 2012), but more recent analyses indicate juvenile survival is lower (MFBRP unpubl. data).

<u>Crested Honeycreeper</u> – The ʻĀkohekohe is a large (24-29 g) nectarivorous honeycreeper (Berlin and Vangelder 1999). Adults have black plumage highlighted with red and silver feathers and a bushy white crest that curves forward over the bill. Calls include a variety of loud whistles and low, guttural sounds. They may forage alone, with a mate, or with 1–2 offspring, but are usually solitary outside the breeding season. ʻĀkohekohe are aggressive toward smaller honeycreepers, such as the ʻI'iwi (*Vestiaria coccinea*), and may defend flowering trees. They do not join mixed-species foraging flocks.

ʻĀkohekohe occur in wet and mesic montane rain forest dominated by ʻōhiʻa (see Maui Parrotbill for other plant species found in this habitat). They feed mostly on ʻōhiʻa nectar, but also take nectar seasonally from other trees and shrubs and glean insects from leaves, flower buds, and twigs (Vangelder 1996). They forage mainly in the upper and middle forest canopy.

ʻĀkohekohe maintain year-round territories around the nest or nectar sources. The breeding season extends from November – June, with a peak in March, and coincides with ʻōhiʻa bloom. Multiple broods are common, with up to 3 clutches laid per year (Vangelder 1996). The nest is built primarily by the female. Clutch size is 1–2 eggs (Vangelder 1996). The male defends the nesting territory and regurgitates food to female during courtship, incubation, and brooding. Both parents feed chicks by regurgitation. Young are independent 10–14 d after fledging and often associate with siblings or other juveniles. The percentage of nests that produced fledglings in Waikamoi Preserve was 80% and 36% in 1992–1993, with an average of 1.6 young per nest reared from successful nests (Vangelder 1996). In Hanawī NAR from 1994–1997, 78%, 87%, and 62% nests fledged young, with an average of 1.4 young fledged from successful nests.

<u>Maui Creeper</u> – The Maui Creeper is a small (12-14 g) insectivorous honeycreeper with a short, thin bill (Baker and Baker 2000). Adult males are olive-green above and bright yellow below. Adult females are less brightly colored. The song, given by males only, is an ascending "*k-weedy, k-weedy, k-weeet*" (Baker and Baker 2000). A sharp "chip" note is frequently given and used as contact call between group members. Maui Creepers are often found in small family groups of 2–6 birds consisting of 2 adults, 1 or 2 young from the current breeding season, and sometimes 1 or 2 young from the previous year.

Maui Creepers are found primarily in native montane mesic and wet forest dominated by ʻōhiʻa (see Maui Parrotbill for other species found in this habitat), but they also use sub-alpine māmane (*Sophora chrysophylla*) scrub, and mesic alien forest composed of various conifers, especially *Pinus* spp. (Baker and Baker 2000). Maui Creepers glean a variety of invertebrates from leaves, branches, small twigs, and trunks, especially the orders Homoptera and Lepidoptera in native forest and Coleoptera and Hemiptera in non-native forests (Foster 2005). They forage most often on ʻōhiʻa and koa, but also use a variety of other plant species and also take some nectar. They join mixed-species foraging flocks and sometimes examine sites excavated by Maui Parrotbills (Baker and Baker 2000).

Pairs defend home ranges year round, averaging 0.5-0.9 ha in size (1.2-2.2 ac; Iknayan et al. 2010). ʻAlauahio are socially monogamous and pair for life, although extra-pair copulations have been confirmed through genetic analysis (Baker and Baker 2000). Females choose the nest site and build an open-cup nest. Clutch size is two, and birds will renest after failure, but double brooding has not been documented. Only females incubate eggs and brood nestlings. Fledglings are fed for two to three months, and young remain with their parents in family groups for 18-20 months. Maui ʻAlauahio do not breed until their third year, and young birds may stay with their parents and help raise subsequent offspring.

Primary Threats:

- Habitat loss and degradation. Cutting of native forest for logging, cattle ranching, and silviculture of non-native trees has reduced the amount of native forest habitat and fragmented it in many areas. Most areas of native forest important to these species are now protected, but habitat degradation from invasive plants and non-native ungulates remains a problem even in protected areas. Habitat fragmentation may hinder natural re-colonization by these species into unoccupied but suitable habitat.
- Invasive alien plants. Invasive plants such as strawberry guava (*Psidium cattleianum*) and blackberry (*Rubus argutus*) have invaded native forests and reduced habitat quality in all but the most remote parts of the island. Other serious invasives are found at lower elevations but have not yet reached the range of these species, such as *Miconia calvescens*. The Maui Creeper is known to forage and nest in non-native plants in the Waikamoi and Poli Poli areas, but the more specialized Maui Parrotbill and Crested Honeycreeper are restricted to native forest.
- Non-native ungulates. Browsing by feral cattle (*Bos taurus*), feral sheep (*Ovis aries*), feral goats (*Capra hircus*), and axis deer (*Cervus axis*) has degraded habitat quality in many areas and hindered recruitment of native trees. Rooting and wallowing by feral pigs (*Sus scrofa*) has destroyed understory vegetation in many areas, hindered recruitment of native trees, and provided breeding sites for mosquitoes that carry diseases.
- Disease. Avian malaria (*Plasmodium relictum*) and avian pox virus (*Poxvirus avium*) carried by the alien southern house mosquito (*Culex quinquefasciatus*) limit the distribution of many native Hawaiian forest birds (van Riper et al. 1986, Atkinson et al. 1995, Atkinson and LaPointe 2009). These three birds are absent or rare in most areas of suitable forest below 1,350 m (Maui Parrotbill), 1,100 m (Akohekohe), and 1,600 m (Maui Creeper), likely because of disease (Simon et al. 1997, Berlin and Vangelder 1999, Baker and Baker 2000, USFWS 2006).
- Non-native Predators. Introduced predators are a serious threat to some Hawaiian forest birds, particularly during nesting (Atkinson 1977, VanderWerf 2009), but direct evidence of predation by non-native species is lacking in these three species. Feral cats (*Felis catus*) and Barn Owls (*Tyto alba*) are known to prey on birds at Hanawī NAR (Kowalsky et al. 2002). Black (*Rattus rattus*) and Pacific rats (*R. exulans*) are serious predators on adults and nests of other Hawaiian forest birds and are abundant in the habitats occupied by these species (Malcolm et al. 2008).
- Wildfires. The Poli Poli area on the leeward side of Haleakala, which supports an isolated population of the Maui Creeper, is drier and more susceptible to fire than the wetter forest on the windward side of the volcano. A wildfire burned 2,300 acres of largely alien forest at Poli Poli in January 2007, including part of the Maui Creeper range. The fire probably resulted in some loss of habitat, but the long-term impact of the fire on the Maui Creeper population is unknown (Mounce et al. 2007).
- Small Population Size and Range. Species with small populations and ranges are inherently more vulnerable to extinction than widespread species because of the higher risks posed by random demographic fluctuations and localized catastrophes such as hurricanes, fires, disease

outbreaks. As populations and ranges of island birds decline due to other threats, the extinction risk from catastrophic events also increases and conservation options narrow.

- Global Climate Change. Rising temperatures associated with climate chance may exacerbate the threat of disease by increasing the elevation at which regular transmission of avian malaria and avian pox virus occurs (Reiter 1998, Benning et al. 2002, Harvell et al. 2002, Hay et al. 2002, Loiseau et al. 2012). GIS modeling indicates that malaria transmission currently occurs at least periodically across 20% of the Maui Parrotbill range. An increase in temperature of 2°C, which is a conservative figure based on recent data (IPCC 2007), would decrease the area of disease-free forest within the species current range from 40 km^2 to 9 km^2 (Benning et al. 2002, Giambelluca et al. 2008, Hammond et al. 2009). Loss of such a large proportion of suitable habitat would likely result in extinction of the Maui Parrotbill (Pounds et al. 1999, Still et al. 1999).

Conservation Actions to Date:

The Maui Parrotbill and Crested Honeycreeper were listed as endangered in 1967. Life history and demographic studies of these species were conducted by USGS from 1994-1996 and have been ongoing since then by the MFBRP under the direction of the Hawai'i Division of Forestry and Wildlife (DOFAW). As of August 2010, about 75% of the range of the Maui Parrotbill and Crested Honeycreeper was fenced and ungulate free or ungulate eradication was underway. The entire range of these two species is within the East Maui Watershed Partnership (EMWP), and the entire range of the Maui Creeper falls within EMWP and the Leeward Haleakala Watershed Restoration Partnership (LHWRP). Invasive plant control is conducted by Haleakalā National Park, The Nature Conservancy (TNC), Maui Natural Area Reserves, EMWP, LHWRP. In 2009, the U.S. Fish and Wildlife Service (USFWS) provided funds to collect data necessary to initiate the establishment of a second Maui Parrotbill population on leeward east Maui. Funds from the USFWS, U.S. Forest Service (USFS), and the American Bird Conservancy (ABC)/National Fish and Wildlife Foundation (NFWF) are supporting fencing and restoration of the Kahikinui Forest Reserve (FR) and the Nakula NAR, the area selected to establish the second population. The Kahikinui area is drier and experiences fewer storms; once restored, it will provide additional high elevation, disease-free habitat, which is critical as climate change increases temperatures. A captive propagation program has successfully reared Maui Parrotbill, both from wild collected eggs and from captive pairs. Although recent production is insufficient to establish a second population, the San Diego Zoological Society is working to increase the productivity of the captive flock (Kuehler et al. 2001, ZSSD 2009). Conservation actions have not yet been taken specifically for Maui ʻAlauahio but it has been used to evaluate translocation methods for Hawaiian honeycreepers and stress response (Groombridge et al. 2004). Survey data has been re-analyzed by USGS to improve information about population size and trend, but these results are not yet available.

Planning/Research Needs:

All species would benefit from determining if genetic markers or genotypes are associated with disease resistance. If disease-resistant individuals can be identified, they could be used in translocations to establish new populations or to augment existing populations currently lacking disease resistance.

- Determine if genetic markers or specific phenotypes are associated with disease resistance or tolerance. If disease-tolerant individuals can be identified, they could be used in

translocations to establish new populations or to augment existing populations that lack disease tolerance.
- Analyze and publish existing data on nesting success, fecundity, and survival of all three species collected by the MFBRP.
- Survey the range and abundance of Maui Creepers in the Poli Poli area, which has not been surveyed since 1980, and examine the species use of non-native forest.
- Develop cost effective methods to restore mesic forest habitat on leeward east Maui.
- Determine feasibility of restoring habitat in windward east Maui, especially high elevation forests dominated by alien trees (e.g., Hosmer's Grove in Haleakalā National Park and Waikamoi Preserve).

5-Year Conservation Goals:
- Continue habitat management, including fence maintenance, in Hanawī NAR, Haleakalā National Park, Waikamoi Preserve, and adjacent areas.
- Complete fencing of about 1,200 ha in the Kahikinui FR and Nakula NAR, remove ungulates, and begin habitat restoration (fencing and ungulate removal are fully funded). Support fencing and restoration on adjacent property owned by the Department of Hawaiian Home Lands.
- Create a second population of Maui Parrotbills by translocating birds into the Kahikinui FR and Nakula NAR.
- Create a third population of Maui Creepers by translocating birds into the Kahikinui FR and Nakula NAR.

Conservation Actions:
- <u>Habitat Management</u>.
    - Maintain existing areas that are fenced and ungulate free, including weed control, fence maintenance, and outplanting of native species as needed.
    - Begin habitat restoration in Kahikinui FR and Nakula NAR. Develop infrastructure to support habitat management and eventually bird translocations.
- <u>Small Population Size and Range.</u>
    - <u>Translocate Maui Parrotbills.</u> Develop protocols and translocate birds into restored habitat in the Kahikinio FR and Naukla NAR. An adaptive approach should be used to collect information and determine how parrotbills use mesic habitats on leeward east Maui.
    - <u>Translocate Maui Creepers.</u> Develop a reintroduction plan and translocation protocols and conduct an experimental translocation to refine protocols and to determine how creepers will use mesic habitats on leeward east Maui. Could be done in advance of Maui Parrotbill translocation to help develop protocols and serve as an experiment, or simultaneously to save money.
- <u>Disease</u>. Translocation of Maui Parrotbill to Kahikinui should result in less exposure to disease. Continued fencing and feral pig control in windward habitat will reduce mosquito breeding habitat.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Manage existing ungulate-free habitat	1 - 5	$400,000	$2,000,000

Habitat restoration in Kahikinui FR+Nakula NAR	1 - 5	$350,000	$1,750,000
Develop (years 1-2) and implement (years 3-5) Maui Parrotbill translocation	1 - 5	$50,000, $200,000	$700,000
Develop (years 1-2) and implement (years 3-5) Maui Creeper translocation	1 - 5	$50,000, $200,000	$700,000
Survey and study Maui Creeper in Poli Poli SP	1-2	$30,000	$60,000

Potential Partners: U.S. Fish and Wildlife Service, National Park Service, Hawai'i Division of Forestry and Wildlife, Department of Hawaiian Homelands, East Maui Watershed Partnership, Leeward Haleakala Watershed Restoration Partnership, The Nature Conservancy, and the American Bird Conservancy.

Ancillary Species: Management that would benefit these species also would benefit all native birds that use forest habitat on Maui, including the 'I'iwi (*Vestiaria coccinea*), 'Apapane (*Himatione sanguinea*), and Hawaii 'Amakihi (*Hemignathus virens*). The Po'o-uli (*Melamprosops phaeosoma*) is probably extinct (USFWS 2006, VanderWerf et al. 2006), but its former range overlapped with these species and any remaining individuals would benefit from management.

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Focal Species: Kaua'i Rain Forest Honeycreepers: ʻAnianiau (*Magumma parva*) ʻAkikiki or Kauaʻi Creeper (*Oreomystis bairdi*) ʻAkekeʻe or Kauaʻi ʻĀkepa (*Loxops caeruleirostris*)

Synopsis: These three species are endemic to Kaua'i and have similar ranges, though the ʻAnianiau is more common and widespread. The ʻAkikiki and ʻAkeke'e have declined dramatically in the past few years and were listed as endangered in 2010. These species had not been closely studied until 2011, and aspects of their biology and threats are being revealed only now. No conservation actions have been directed at these species, but they are expected to benefit from ongoing large-scale habitat management. Climate change and increasing prevalence of mosquito-borne diseases may be a serious threat.


ʻAkikiki. Photo Eric VanderWerf.

Geographic region: Kaua'i, Hawaiian Islands
Group: Forest Birds
Federal Status: ʻAkikiki and ʻAkeke'e Endangered, ʻAnianiau MBTA
State status: ʻAkikiki and ʻAkeke'e Endangered
IUCN status: ʻAkikiki and ʻAkeke'e Critically Endangered, ʻAnianiau Vulnerable
Conservation score: **17/20, 20/20, 20/20, At-risk**
Watch List 2007 Score: **RED**
Climate Change Vulnerability: **HIGH**


ʻAkeke'e male. Photo Eric VanderWerf.


ʻAnianiau male. Photo Jack Jeffrey.

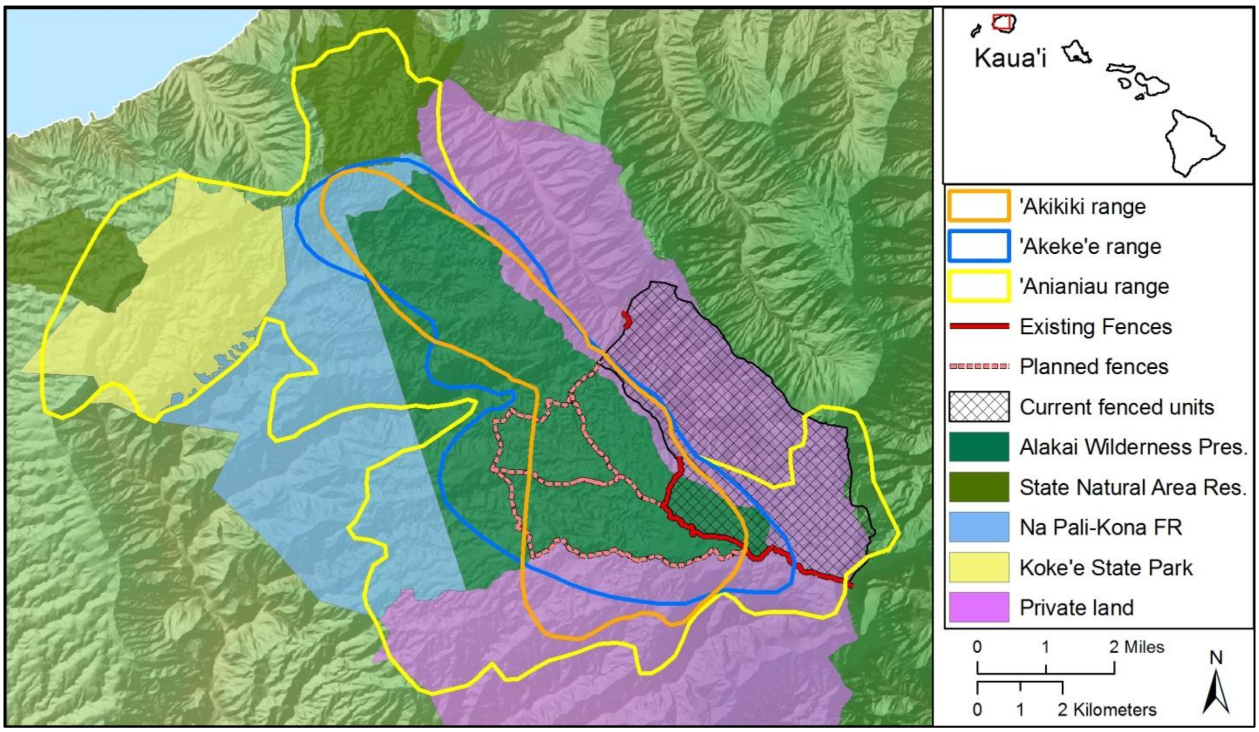
Population Size and Trend:

ʻAnianiau – The population was estimated at 24,230 ± 1,514 birds in the early 1980s (USFWS 1983), but surveys conducted in 2000, 2005, and 2007 indicated that ʻAnianiau densities in the Alaka'i Wilderness Preserve have increased, resulting in a population estimate of about 37,000 birds (Camp et al. 2009, Gorresen et al. 2009). The ʻAnianiau is one of the more common native birds found in high elevation forests on Kaua'i.

ʻAkikiki – Recent population size estimates of the ʻAkikiki have been variable. Estimates based on 2005 and 2007 surveys were 1,364 ± 401 and 1,312 ± 530 birds, respectively (Hawaii

Division of Forestry and Wildlife [DOFAW] and U.S. Geological Survey [USGS], unpubl. data), but based on surveys conducted in 2008 the population was estimated at 3,568 (95% CI 2,369 – 5,011) (Camp et al. 2009, Gorresen et al. 2009). These estimates should be viewed with caution, however, because they are based on a small number of observations, resulting in wide confidence intervals around estimates. Density estimates for the ‘Akikiki have fluctuated more than any other native bird on Kaua‘i, and it is difficult to ascertain whether these fluctuations are real or the result of sampling error.

<u>‘Akeke’e</u> – The current population is estimated to be 3,111 ± 591 (SE) birds, based on surveys conducted in 2008 (DOFAW and USGS, unpubl. data). The estimated population has declined from 7,839 ± 704 birds in 2000 and 5,669 ± 1003 birds in 2005 (DOFAW and USGS, unpubl. data). Camp et al. (2009) reported an estimate of 7,887 birds (95% CI 5,220-10,833), but this number is known to be an over-estimate because it was based on extrapolation of density to an area of 127 km^2, which is larger than the species’ actual range.



Range:

<u>‘Anianiau</u> – The ‘Anianiau is endemic to Kaua’i, where it occurs in native forest above 600 m in elevation on the Alaka’i Plateau, in valleys of the Nā Pali Coast, and in Kōke’e State Park; a small, isolated population also occurs in the Makaleha Mountains (Lepson 1997, Gorresen et al. 2009). In the 1970’s, the species was found in non-native and native forest below 100 m in valleys on the Nā Pali Coast (USFWS 1983). The range of ‘Anianiau was about 200 km^2 in the 1980s, approximately 15% of its original range (Lepson 1997), and it has declined since then.

<u>‘Akikiki</u> – The ‘Akikiki is endemic to Kaua’i, where it is restricted to the Alaka’i Plateau. The species’ range declined from 88 km^2 in 1970 to 40 km^2 in 2008 (USFWS 1983, Scott et al. 1986, Foster et al. 2004, Camp et al. 2009), and appears to be declining farther. Subfossils suggest that

the ‘Akikiki occurred throughout Kaua’i prior to the arrival of humans; now the species occupies less than 10% of its historic range (Foster et al. 2000, Burney et al. 2001).

‘Akeke’e – The ‘Akeke’e is endemic to Kaua’i, where it is restricted to the Alaka’i Plateau. From 1970 to 2000, the geographic range of the Kaua‘i ‘Ākepa was estimated to be approximately 88 km^2 (USFWS 1983, Foster et al. 2004). Surveys in 2008 failed to find the species in many areas where it was previously observed, indicating a range contraction has occurred, and its range is now estimated to be only 50 km^2 in eastern Kōke`e and the upper Alaka`i (Camp et al. 2009).

Essential Biology:

‘Anianiau – The ‘Anianiau is a small (10 g) Hawaiian honeycreeper with a short, thin bill that is slightly curved. Males are bright yellow; females are duller yellow-green. The legs and feet are pink. The song is a high-pitched trill with repeated elements of 2–3 syllables (e.g., *weesee-weesee-weesee-weesee*; Lepson 1997). The most common call is a high-pitched *sweet* or *ps-seet*, given by both sexes, often used as a contact call.

‘Anianiau are most common in mesic and wet native montane forests dominated by ‘ōhi‘a (*Metrosideros polymorpha*), koa (*Acacia koa*), ‘ōlapa (*Cheirodendron trigynum*), ‘ōhi’a ha (*Syzygium sandwicensis*), kāwa‘u (*Ilex anomala*), and kōlea (*Myrsine lessertiana*), with a diverse understory of native plants including ‘ōhelo (*Vaccinium calycinum*) and kanawao (*Broussaisia arguta).* ‘Anianiau are generalist foragers, gleaning a variety of arthropods, particularly caterpillars and spiders (Eddinger 1970), from the outer canopy and smaller twigs and branches. They also take nectar from a variety of native plants (Lepson 1997).

The open cup nest is built by both sexes 3-10 m high in a ‘ōhi‘a tree, either in the crown or on small branches near the trunk. The female incubates the eggs and broods the young, and the male feeds nestlings and provisions the female. Nest construction occurs from February through late May or June. Median clutch size is 3 eggs and young fledge after 18 days. There is no information on post-fledgling behavior, adult or juvenile survival, or movements. Research on nest success and causes of failure is ongoing by the Kauai Forest Bird Recovery Project (KFBRP).

‘Akikiki – The ‘Akikiki is a small (12 g) Hawaiian honeycreeper with a short, pink bill that is slightly curved. Both sexes are olive gray above and off-white below. Juveniles and young birds resemble adults but have white spectacles. The song is a short, descending trill, given infrequently. Males and females give a soft “*whit*” contact call (Foster et al. 2000). They are usually found in pairs or family groups, and may join mixed-species foraging flocks during the non-breeding season.

‘Akikiki are found in wet native montane forests (see ‘Anianiau account for plant species) where they forage on trunks, branches, and twigs of live and dead trees, primarily ‘ōhi’a and koa, and occasionally in subcanopy shrubs (Foster et al. 2000). They feed on insects, insect larvae, and other arthropods taken from bark, crevices, dead wood, and epiphytes by gleaning, probing, and rarely by excavation (Foster et al. 2000, VanderWerf and Roberts 2008).

The nesting season extends primarily from March-June (Foster et al. 2000), but may occur from January to July in some years (VanderWerf and Roberts 2008). The nest is built 4-12.5 m high in the crown of a ‘ōhi’a trees and is composed of moss, pieces of bark and lichen, and fine plant fibers (Eddinger 1972a, Foster et al. 2000, VanderWerf and Roberts 2008). Both sexes help build the nest and feed the nestlings, but only the female has been observed incubating. The male feeds the female during nest construction, incubation, and brooding (Eddinger 1972a, Foster et al. 2000, VanderWerf and Roberts 2008, R. Hammond unpubl. data). Some pairs may attempt to raise two broods in one season (VanderWerf and Roberts 2008). There was no data on nest success, reproductive rates, survival of adults or juveniles, home range size, or movements prior to 2011, but this information is being collected by the KFBRP (L. Behnke and R. Hammond unpubl. data).

‘Akeke’e – The ‘Akeke’e is a small (10-12 g) Hawaiian honeycreeper with an unusual crossed bill. Males are bright yellow below, greenish above, with a yellow forehead and rump and a dark mask. Females are similar but not as bright yellow. The tips of the short, bluish bill are slightly crossed, a characteristic shared with the Hawai’i ‘Ākepa (*L. coccineus*). The tail is notched and longer than in other Hawaiian honeycreepers. The song is a wavering trill that changes in pitch and speed; call notes given by males and females include a soft “*sweet*” (Pratt et al. 1987, Lepson and Pratt 1997). ‘Akeke‘e are most often observed in pairs or family groups.

‘Akeke‘e are found in mesic and wet native montane forests (see ‘Anianiau account for dominant plant species) where they forage for insects, insect larvae, and spiders on the outer branches and leaves of ‘ōhi’a trees, and occasionally in other trees and understory shrubs (Lepson and Pratt 1997). Prey is taken primarily by gleaning, and the crossed bill is used to pry open leaf buds and flower buds, similar to the behavior used by crossbills (*Loxia* spp.).

The nesting season extends from March-June (Lepson and Pratt 1997). The nest is built 9-15 m high in the crown of a ‘ōhi’a tree, and is made of moss and lichen, with a lining of fine grasses and bark strips (Eddinger 1972b, Berger 1981, Lepson and Pratt 1997). Both sexes help build the nest, but the female alone incubates the eggs, and both sexes feed the nestlings (Eddinger 1972, Lepson and Pratt 1997, R. Hammond unpubl. data). There was no data on nest success, reproductive rates, survival of adults or juveniles, home range size, or movements prior to 2011, but this information is being collected by the KFBRP (L. Behnke and R. Hammond unpubl. data).

Primary Threats:

These three species share the same threats, although the ‘Anianiau may be less vulnerable because it is more of a generalist than the other species (Banko and Banko 2009).

- Disease. Diseases carried by the non-native southern house mosquito (*Culex quinquefasciatus*), particularly avian malaria (*Plasmodium relictum*) and avian pox virus (*Poxvirus avium*), limit the distribution of many native Hawaiian forest birds, including the ‘Akikiki and ‘Akeke’e, and to a lesser extent the ‘Anianiau (van Riper et al. 1986, Atkinson et al. 1995, Atkinson and LaPointe 2009). These species are absent from lower elevations where disease is most prevalent (Walther 1995), and are restricted to colder, high elevation areas where disease transmission is lower. Recent declines in the ranges of these species have occurred at the lower edges (Foster et al. 2004), suggesting disease has contributed to these losses.
- Habitat degradation and loss. These species depend on areas of intact native forest for foraging and nesting, and this habitat has been, and continues to be, degraded by invasive alien plants and feral ungulates, particularly feral pigs (*Sus scrofa*) and goats (*Capra hircus*) (Lepson and Pratt 1997, Foster et al. 2004). Feral ungulates degrade native forest by browsing, causing soil erosion, spreading invasive plant seeds, facilitating invasion by

alien plants, and creating breeding habitat for mosquitoes (Cabin et al. 2000, Scott et al. 2001, USFWS 2006). Invasive alien plants such as kahili ginger (*Hedychium gardnerianum*), strawberry guava (*Psidium cattleianum*), blackberry (*Rubus argutus*), and Australian tree fern (*Cyathea cooperi*) displace native plants and prevent forest regeneration. Declines in the ranges of these species have occurred at their edges (Foster et al. 2004), where disturbance and the effects of feral ungulates and invasive alien plants are most severe, suggesting degradation of forest habitat has played a role in the range contraction of the ʻAkikiki and the ʻAkekeʼe, and perhaps to a lesser extent of the ʻAnianiau.

- <u>Non-native Predators</u>. Introduced predators can be a serious threat to Hawaiian forest birds, particularly during nesting (Atkinson 1977, VanderWerf 2009). Black rats (*Rattus rattus*), Polynesian rats (*R. exulans*), Norway rats (*R. norvegicus*), and feral cats (*Felis catus*) are present on the Alakaʻi Plateau and are potential predators on roosting or incubating adults, eggs, and young. Predation by rats on nests of ʻAkikiki and ʻAkekeʼe was documented in 2012 (R. Hammond unpbul. data). Two species of owls, the native Pueo (*Asio flammeus sandwichensis*) and the introduced Barn Owl (*Tyto alba*), also occur on Kauaʻi and are known to prey on forest birds (Snetsinger et al. 1994).
- <u>Hurricanes</u>. Major hurricanes struck Kauaʻi in 1983 and 1992 and degraded native forests by knocking down large trees, creating gaps into which alien plants could expand, and spreading invasive plants. Large numbers of dead trees killed by hurricane Iniki in 1992 are still visible in several areas where ʻAkikiki have declined in abundance or disappeared. (E. VanderWerf pers. obs.).
- <u>Climate Change</u>. Rising temperatures associated with climate change may exacerbate the threat of disease by increasing the elevation at which regular transmission of avian malaria and avian pox virus occurs (Reiter 1998, Benning et al. 2002, Harvell et al. 2002, Loiseau et al. 2012). Malaria transmission already can occur at least periodically across all parts of the island, and GIS simulations have shown that an increase in temperature of 2°C, which is a conservative figure based on recent data (IPCC 2007), would allow regular disease transmission in 85% of the area where it is now only periodic (Benning et al. 2002). The loss of such a large proportion of suitable habitat would likely result in extinction of the ʻAkikiki and ʻAkekeʼe (Pounds et al. 1999, Still et al. 1999). Disease prevalence has been studied in the range of these species and increases in prevalence of malaria in more common species at several locations suggests that exposure to disease is increasing for ʻAkikiki and ʻAkekeʼe (Atkinson and Utzurrum 2010). Climate data on Kauaʻi show a warming pattern at 4,000 ft elevation and a decline in frequency of high water events that could flush mosquito larvae from streams, possibly resulting in an increase in mosquito breeding habitat (T. Giambelluca and C. Atkinson in prep.).
- <u>Other</u>. A number of other factors are likely contributing to the decline of the ʻAkikiki and ʻAkekeʼe. The effects of non-native arthropod predators and competitors are completely unknown. Threats may interact with each other and increase their negative impact. For example, birds with malaria may be more susceptible to predation. Single island endemics with small populations are inherently more vulnerable to extinction than widespread species because of the higher risks posed by random demographic fluctuations and localized catastrophes such as hurricanes, fires, and disease outbreaks (Wiley and Wunderle 1994), and potentially genetic issues. A lack of basic life history information has hampered management decisions, although these data are being collected by the KFBRP.

Conservation Actions to Date:
The ‘Akikiki was a candidate for listing under the Endangered Species Act since 1994; it and the ‘Akeke’e were listed as endangered in March 2010 in response to a listing petition (VanderWerf and American Bird Conservancy 2007). Weed control has been conducted by The Nature Conservancy and Kōke‘e Resource Conservation Program. The Kaua‘i Watershed Alliance (KWA) completed strategic ungulate fence segments in 2010 to protect an 810-ha (2,000-acre) management unit in the southeastern Alaka‘i Wilderness Preserve; ungulates have almost been eradicated from this area. The KWA also has ambitious plans for three more fenced units that would protect an additional 1,215 ha (3,000 acres) in adjacent areas of the ‘Alaka’i that constitute the core of ‘Akikiki and ‘Akeke’e ranges. Fencing in the Hono O Nā Pali Natural Area Reserve also is being planned. Captive propagation has not been attempted for the ‘Akikiki or the ‘Akeke’e, although the Hawai’i Creeper (*O. mana*) and the Hawai’i ‘Ākepa have been bred in captivity by the Zoological Society of San Diego.

Planning/Research Needs:

- Determine if genetic markers or specific phenotypes are associated with disease resistance or tolerance. If disease-tolerant individuals can be identified, they could be used in translocations to establish new populations or to augment existing populations that lack disease tolerance.
- Little is known about these species, and there is an urgent need for natural history information and basic demographic data. Until 2011, these species had not been the focus of any long-term studies or management actions, and life history information was based on anecdotal observations (e.g. VanderWerf and Roberts 2008). In 2011, the KFBRP began intensive studies of occupancy, nesting biology, reproductive output, survival, movements, habitat use, and home range size in all three species. This information will help managers determine which conservation actions are likely to be most effective and will allow the most efficient use of limited resources.
- Investigate the effectiveness of rodent control and weed control as management tools for these species.
- Continue conducting periodic range-wide surveys to monitor status of these species. Larger sample sizes will improve estimates of detection probability, leading to more accurate and precise measures of abundance and improved ability to measure population trends and efficacy of conservation actions.
- Conduct surveys of potential mosquito breeding habitat and continue to monitor prevalence of avian malaria and avian pox virus. Malaria prevalence increased over the past 15 years in the ‘Alaka’i (Atkinson and Utzurrum 2010), but it is not known where the mosquitoes that transmit malaria breed. If mosquito breeding sites can be located, it may be possible to treat or eliminate them.

5-Year Conservation Goals:

- Manage additional forest habitat by fencing, removing ungulates, and controlling invasive alien plants in a larger portion of the ‘Alaka’i Wilderness Preserve, the Na Pali-Kona Forest Reserve, and Hono O Nā Pali Natural Area Reserve.
- Complete life history studies and threat assessments.
- Develop threat abatement strategies based on results from life history studies.

- Develop captive propagation programs, if deemed necessary based on results of life history studies and monitoring, potentially focusing on individuals with disease tolerance.
- Increase public support for forest bird conservation through outreach.

Conservation Actions, 2013-2017:

- Disease. Fencing and feral pig removal will reduce disease prevalence by reducing breeding habitat for mosquitoes.
- Habitat Management.
  - Complete ungulate removal within the KWA fence in the eastern ʻAlakaʼi.
  - Support efforts by the KWA to fence and remove ungulates from three management units encompassing 1,215 ha (3,000 acres) in the Alakaʼi Wilderness Preserve.
  - Fence and remove ungulates from the Hono O Nā Pali Natural Area Reserve and select parts of the Na Pali-Kona Forest Reserve.
  - Continue to control invasive alien plants in the Kokeʼe/ʼAlakaʼi area.
- Non-native Predators. Predation on ʻAkikiki and ʻAkekeʼe nests by rats has been documented by the KFBRP, and rat control around known nests could benefit these species. Additional information about frequency of predation and ability to control rats would allow assessment of whether this threat can be managed.

Summary and Estimated Costs of Conservation Actions, 2013-2017:

Conservation Action	Years	Annual Cost	Total Cost
Mosquito surveys	1-2	$125,000	$250,000
Disease monitoring	1,5	$100,000	$200,000
Regulatory compliance for additional KWA fencing in the Alakaʼi Wilderness Preserve	1	$80,000	$80,000
Build KWA fence and remove ungulates from 3,000 acres in the Alakaʼi Wilderness Preserve	2-5	$900,000	$3,600,000
Invasive alien plant control	1-5	$300,000	$1,500,000
Continue life history research	1-2	$150,000	$300,000
Investigate nest predation and predator control	1-3	$100,000	$300,000
Range-wide surveys of ʻAkikiki and ʻAkekeʼe	1,5	$40,000	$80,000

Potential Partners: Hawaiʼi Division of Forestry and Wildlife, U.S. Fish and Wildlife Service, Kauaʼi Watershed Alliance, University of Hawaiʼi, Kokeʼe Resource Conservation Program, U.S. Geological Survey Pacific Island Ecosystems Research Center, Zoological Society of San Diego, Pacific Rim Conservation, American Bird Conservancy, Long Foundation, Alexander & Baldwin Foundation.

Ancillary Species: Management that would benefit these species also would benefit all other native bird species that use forest habitat on the island, including the Pueo or Hawaiian Short-eared Owl (*Asio flammeus sandwichensis*), Kauaʼi ʻElepaio (*Chasiempis sclateri*), Puaiohi (*Myadestes palmeri*), Kauaʼi ʻAmakihi (*Hemignathus kauaiensis*), ʻIʻiwi (*Vestiaria coccinea*), and ʻApapane (*Himatione sanguinea*).

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Focal Species: Hawaiian Hoary Bat or Ōpea'ape'a. (*Lasiurus cinereus semotus*)

Synopsis: The Hawaiian Hoary Bat is the only land mammal native to Hawai'i. It is considered a subspecies of the North American hoary bat, but additional research would help to confirm this status. Unlike many bats, it roosts solitarily in large trees rather than in caves. Recent research has begun to shed light on its ecology, behavior, and movements, but it still relatively little-known and more information is needed. It is found on most of the larger islands, but its population size and trend are unknown because of the difficulty in detecting this nocturnal species. Important conservation actions are to minimize lethal collisions with wind turbines, barbed wire fences, and other structures.

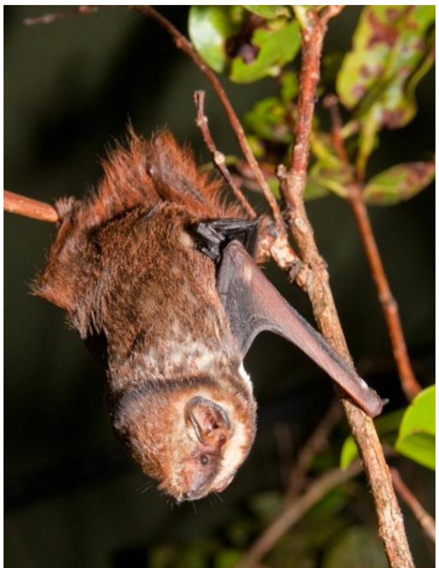

Photo David Leonard

Geographic region: Island of Hawai'i
Group: Bats
Federal Status: Endangered
State status: Endangered
Watch List 2007 Score: NA
Climate Change Vulnerability: High

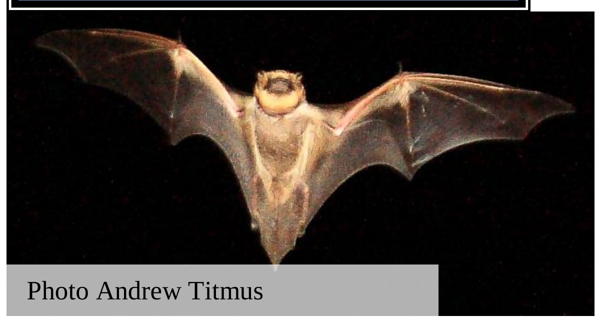

Photo Andrew Titmus

Population Size and Trend: Unknown, however there are substantial populations on Hawai'i Island, Maui, and Kaua'i (Bonaccorso 2010). Infrequent sightings occur on Oahu, Moloka'i, Lana'i, and Kaho'olawe (Tomich 1986), and bats have been detected on O'ahu using ultrasonic "bat detectors" to record their vocalizations.

Range: Hawaiian hoary bats occur throughout the main Hawaiian Islands and are found from sea level to the highest volcanic peaks (approaching 4,270 m [14,000 ft]). While prime habitats include native moist and rain forests up to at least 1,830 m (6,000 ft), bats also use native xeric and disturbed habitats as well as wet to moist non-native habitats and urban areas (Bonaccorso 2010).

Essential Biology:
The Hawaiian hoary bat is Hawaii's only native terrestrial mammal, although fossil evidence indicates that at least one other bat species formerly occurred in Hawai'i. Males and females have a wingspan of approximately 4.7 cm (12 in) and weigh between 12.4-20 g (0.4-0.7 oz); females are typically larger than males. Hawaiian individuals are about 30% smaller than their North American relatives (Jacobs 1996). Both sexes have a coat of brown to gray fur and individual hairs are tipped or frosted with white; "hoary" means frosted. The Hawaiian name refers to a half taro leaf or canoe sail shape which is somewhat similar to the bat's shape in

flight. Hawaiian hoary bats roost in native and non-native vegetation and rarely in lava tubes, cracks in rocks, or man-made structures. While roosting during the day, bats are solitary, although mothers and their pups roost together. On Hawai'i, bats appear to move to higher elevations during January through April, potentially because the cooler temperatures allow them to achieve a lower metabolic rate while roosting.

Individuals begin foraging either just before or after sunset depending on the time of year; altitude also may affect activity patterns. Similar to other insectivorous bats, echolocation is used to locate a variety of native and non-native night-flying insects, including moths, beetles, crickets, mosquitoes, and termites (Belwood and Fullard 1984, Bernard 2011, Bonaccorso et al. 2012, Jacobs 1999, Whitaker and Tomich 1983). Water courses and edges (e.g., coastlines and forest/pasture boundaries) are important foraging areas and the species also is attracted to insects that congregate near artificial lights.

Breeding has been documented only on Hawai'i and Kaua'i. Mating most likely occurs during the late fall and females are suspected of storing sperm until they return to warmer, coastal areas (i.e., April). Females give birth to twins during late June or early July and pups remain with their mothers for about two months. While the timing of gestation, birth, and fledging is somewhat understood, the species' requirements during the winter/spring, when most of the population moves to elevations above 1,525 m (5,000 ft), is little known. Nothing is known about annual survival or longevity.

Primary Threats:

- <u>Collisions</u>. Hawaiian hoary bats are injured and killed from collisions with man-made structures including barbed wire fences, wind turbines, and communication towers. Snagging on barbed wire is the most significant source of reported mortality (Zimpfer and Bonaccorso 2010). Most individuals are snagged at the tail membrane probably while maneuvering to catch insects or when prey is transferred to the mouth; echolocation is shut down for a few seconds while prey is eaten.

  To date, relatively few instances of bat striking wind turbines have been reported in Hawai'i. However, methods used to evaluate bat mortality associated with wind turbines are inadequate. The State of Hawai'i has mandated that renewable energy will provide 70% of the state's energy by 2030 and there are strong incentives to fast-track alternative energy projects. Given the high rate of bat mortality associated with wind turbines on the mainland, expansion of wind energy production in Hawai'i is a cause for concern. Currently, proposals are in place to double the number of facilities in the state.
- <u>Lack of information</u>. The primary criterion for delisting the Hawaiian hoary bat (USFWS 1998) is that populations on Hawai'i, Kaua'i, and Maui must be well distributed, naturally reproducing, and stable or increasing for at least five consecutive years. This information is currently being collected. The recovery plan further states that the majority of the species' genetic diversity should be maintained. Currently, the Hawaiian hoary bat is recognized as an endemic subspecies of the hoary bat found throughout North America, however genetic analyses of Hawaiian individuals has not been conducted. Some experts have suggested that the Hawaiian hoary bat is a distinct species (N. Simmons, pers. comm.) or that multiple subspecies or species occur across the main Hawaiian archipelago. Genetic data would provide information needed to manage potentially distinct populations, however a lack of funding has prevented genetic analyses to date. Finally, because relatively little is known about the species'

life history and threats, designing effective recovery and mitigation actions is difficult.

- Pesticides. The effect of pesticides on bats in Hawai'i is poorly understood and the use of pesticides by agro-industry should be investigated.
- Disease. A disease called "white-nose syndrome" that is caused by the fungus *Geomyces destructans* has resulted in serious declines in populations of multiple species of bats in North America (Blehert et al. 2009, 2011). Although this disease has not been detected in Hawaii and appears to primarily affect cave-dwelling bats that roost in groups, the arrival of this or a similar disease could affect the Hawaiian hoary bat.
- Habitat changes. Past clearing of forested lands for pastures, pineapple, and sugar cane likely reduced foraging and roosting habitat, however, coffee, macadamia nuts, and fruit orchards provide important habitat. The replacement of native trees with alien horticultural species in rural, suburban, and smaller urban areas is not detrimental as the Hawaiian hoary bat is a habitat generalist.
- Predation. Introduced mammalian and avian predators appear to take few bats. The species' low population density as well as its solitary and cryptic roosting behavior likely contributes to low predation rates.

Conservation Actions to Date:
The Hawaiian hoary bat was listed as endangered under the Endangered Species Act in 1970. In 2003 the Hawaiian Hoary Bat Research Cooperative (HHBRC) was formed to prioritize and fund research, members include the Hawai'i Division of Forestry and Wildlife, U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service, U.S. Forest Service, Research Corporation University of Hawai'i at Hilo, non-government organizations, and private businesses. Since 2003, HHBRC partners have provided more than $1,000,000 to collect life history information and to evaluate the species' status. Ongoing studies on Hawai'i by USGS have documented daily movement patterns, home range size, roost tree selection, foraging patterns, insect prey, seasonal use of habitats, and population trends. These data have been collected using a variety of methods including automated bat detectors, mist-netting, and radio-telemetry. Acoustic monitoring on western Kaua'i was completed in 2011 and indicated that bats had a widespread distribution. The HHBRC and its technical committees meet at least once a year to plan and evaluate progress.

Planning/Research Needs:

- Determine genetic diversity and population structure.
- Develop effective monitoring protocols of bat activity near wind turbines as well as mortality associated with wind turbines. An effective, replicable, economical, comparative, and quantitative methodology is urgently needed.
- Determine the risk of the fungus that causes White-nose Syndrome being transported to lava tubes by mainland spelunkers.
- Determine the effects of pesticides on Hawaiian hoary bats.

5-Year Conservation Goal:

- Develop guidelines to minimize mortality risk associated with barbed wire.
- Refine monitoring methods to evaluate bat activity near, and take associated with, wind energy facilities to guide mitigation and minimize risks.
- Continue research on Kaua'i and Oahu and initiate work on Maui.

- Analyze tissue samples to determine the genetic diversity of the Hawaiian hoary bat across their range.

Conservation Actions:

- Collisions. Wherever possible smooth wire should be used instead of barbed wire. If having barbed wire is critical, using or replacing the top strand of barbed wire with smooth wire is beneficial. Investigate the use of visual and noise generating materials hung from fences to reduce the chances of bats getting snagged on barbed wire. Use infra-red videography to monitor bat behavior near fences to develop strategies to minimize strikes. Develop automated near infra-red videography to monitor behavior near wind turbines and to evaluate strikes and near-strikes.
- Lack of information. Continue life history studies to determine winter/spring habitat requirements as well as survival rates. Conduct genetic analyses of the species using samples that have already been collected. Determine the feasibility of testing for White-nose Syndrome.

Summary of 5-year Actions, 2013-2017:

Conservation Action	Year(s)	Annual cost	Total Cost
Monitor barbed wire for take	1-2	$50,000	$100,000
Develop methods to reduce barbed wire mortality	1-3	$100,000	$300,000
Develop methods to monitor turbine mortality	1-3	$200,000	$600,000
Conduct genetic analysis	1	$50,000	$50,000
Continue life history monitoring	1-4	$250,000	$1,000,000
TOTAL		$650,000	$2,050,000

Potential Partners: U. S. Geological Survey, U. S. Fish & Wildlife Service, U. S. Forest Service, U. S. Department of Agriculture, Hawai'i Department Forestry & Wildlife, Research Corporation University of Hawai'i at Hilo, First Wind (wind energy production company), The Nature Conservancy, Three Mountain Alliance, Kamehameha Schools.

Ancillary Species: Wind energy facilities in Hawai'i are a threat to seabirds that travel to their nesting colonies at night, including the Hawaiian Petrel, (*Pterodroma sandwichensis*), Newell's Shearwater, (*Puffinus newelli*), and Band-rumped Storm-petrel, (*Oceanodroma castro).* The videographic tools and methods required to monitor bats likely will have the ability to document nocturnal seabird activity. Habitat improvements for bats (e.g., riparian forest buffers, integrated pest management) are likely to benefit the Hawaiian hawk (*Buteo solitarius*) and other native forest and open-country birds.

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