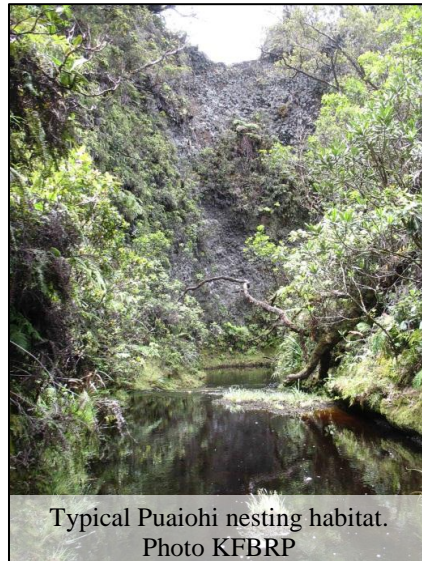


Focal Species: Puaiohi or Small Kaua'i Thrush (*Myadestes palmeri*)

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



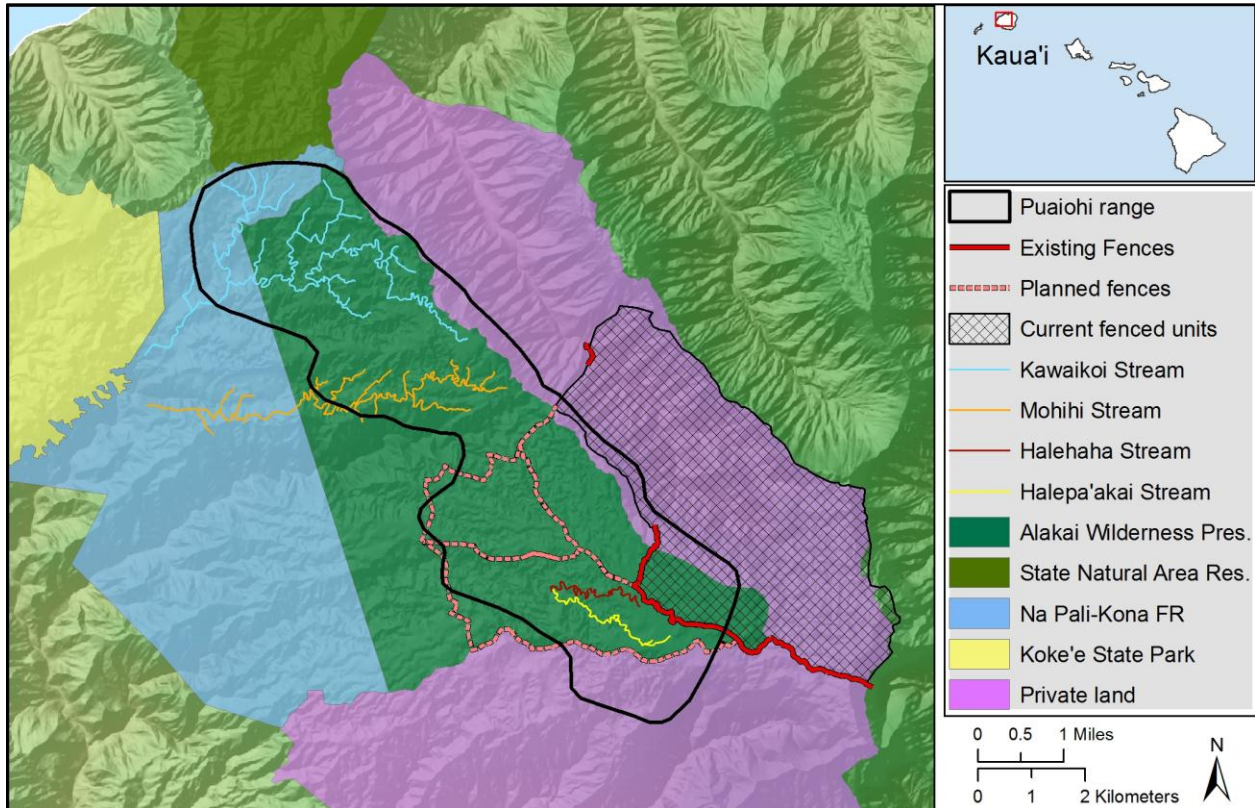
Juvenile Puaiohi. Photo Eric VanderWerf

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 km² on the 'Alaka'i Plateau, and 75% of the population is estimated to occur in just 10 km² (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 Kaua‘i. 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 ‘ōhi‘a (*Metrosideros polymorpha*), ‘ōlapa (*Cheirodendron trigynum*), lapalapa (*C. platyphyllum*), ‘ōhia 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*). Puaiohi feed on insects and fruits of native plants, particularly ‘ōlapa, lapalapa, ‘ōhia ha, kanawao, ‘ōhelo, pa‘iniu (*Astelia* spp.), pūkiawe (*Styphelia tameiameia*), kāwa‘u, 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 reneest 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 Uzzurum 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



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

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.

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 Puaiohi 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.

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- 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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