PUAIOHI FIVE-YEAR RECOVERY WORK PLAN 2010 - 2015
(Updated September 2010)

PURPOSE. The long-term recovery goals, delisting criteria, recovery strategy, and a comprehensive list of recovery tasks for the Puaiohi are provided in the Final Revised Recovery Plan for Hawaiian Forest Birds (USFWS 2006). The purpose of this work plan is to track the progress of previously identified recovery objectives, and to identify additional actions that can be accomplished in the next five years. Identification of recovery objectives and actions will facilitate the efficient use of limited recovery resources and provide milestones that can be used to evaluate progress.

SPECIES SUMMARY. The Puaiohi, or Small Kauaʻi Thrush *(Myadestes palmeri),* is a medium-sized (37 – 43 g), slender, long-legged thrush endemic to Kauaʻi. Adults are olive-brown above, gray below, with a diagnostic white-eye-ring and outer rectrices. Legs are light pink and the bill is black (Snetsinger *et al.* 1999). Males and females are similar. Juveniles have distinctive spots and scalloping on their breast and wings. The song is simple and consists of a preparatory whistle and a prolonged trill, followed by several sharp descending notes; call note is a simple, dry, raspy hiss (Snetsinger *et al.* 1999). Puaiohi are most often observed alone or in pairs.

The species occurs in wet (>6,000 mm rain / year) montane forest in stream valleys and associated ridges above 1,050 m elevation in the southern and central Alakaʼi plateau (Scott *et al.* 1986, Snetsinger *et al.* 1999, USGS and DOFAW unpubl. data). Puaiohi are found in mesic and wet native montane forests dominated by ʻōhiʻa (*Metrosideros polymorpha*), koa (*Acacia koa*), ʻōlapa (*Cheirodendron trigynum*), lapalapa (*C. platyphyllum*), ʻōhia hʻa (*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 hʻa, kanawao, ʻōhelo, paʻiniu *(Astelia* spp.), pūkiawe *(Styphelia tameiameiae),* kāwaʻu, thimbleberry (*Rubus rosifolius*), and pilo *(Coprosma* spp.) (Snetsinger*et al*. 1999). The non-fruit portion of their diet consists of a wide variety of invertebrates (Berger 1981, Snetsinger *et al.* 1999). Puaiohi forge primarily in lower canopy often on terminal fruit or leaf clusters; rarely on the ground. Arthropods are gleaned from terminal leaf clusters, extracted from moss or bark, and removed from ripe fruits (Perkins 1903, Snetsinger *et al*. 1999).

Puaiohi nest in cavities or ledges on cliff faces that are concealed by mosses and ferns, or rarely in trees (Snetsinger *et al.* 2005). Nesting occurs from March to mid-September, with a peak from April to June (Snetsinger *et al.* 2005). Females build nests, and incubate and brood young. Clutch size is almost always two, and eggs hatch after 13 to 15 days of incubation. Both males and females provision nestlings, but males usually feed fledglings while females frequently initiate 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 may be vulnerable to predation. Annual productivity is variable, ranging from 0.4 to 4.9 fledglings / pair / year (Snetsinger et al. 2005, KFBRP, unpubl. data). Juvenile dispersal distance in the Mōhihi Stream was 279 ± 157 (mean ± SD, $n = 5$) and 598 ± 300 m in the Halepāʻākai Stream ($n = 8$, KFBRP, unpubl. data.). Adult survival was estimated at 74% and juvenile survival at 25% in the Mōhihi (Snetsinger *et al.* 2005), and 69% and 19%, respectively, in the Halepāʻākai.

POPULATION STATUS. First collected in 1891 by Henry Palmer, the Puaiohi was the last bird endemic to Kauaʻi to be discovered. Bryan and Seale (1901) failed to detect the species during a three week collecting trip in 1900. Perkins (1903) considered the species rare and in 1895, the Kāmaʻo (*M. myadestinus*) outnumbered the Puaiohi 100 to 1 in mesic forests of Halemanu Valley (Perkins 1903). Puaiohi went unreported for 45 years until two birds were observed in 1940 in the southern Alakaʻi (Donaghho 1941). In 1960, Richardson and Bowles (1964) found at least 17 individuals. The first

quantitative data on the population and distribution was based on 866 half-hour counts conducted from 1968-1973. These surveys estimated an island-wide population of 177 ± 96 birds and identified isolated populations on Lāʻau Ridge and above Nuʻalolo west of Kōkeʻe (USFWS 1983, Snetsinger *et al.* 1999). Most individuals were found in Alakaʻi Plateau north of Koaiʻe Valley at elevations ranging from 1,100-1,250 m, and smaller numbers were found between 900 and 1,100 m elevation on Kohua Ridge and between 1,370 and 1,450 m elevation near the USGS cabin at Waiʻaleʻale. In 1981, the number of Puaiohi estimated to occur in a 25 km^2 area of the southeastern Alakaʻi Wilderness Preserve was 20 ± 17 (Scott *et al.* 1986). Comparing these surveys to those conducted by the USFWS is problematic because of a lack of overlap in sampling locations and differing survey methods. Rare bird surveys conducted on Kauaʻi in the spring of 1996 yielded 55 to 70 individuals and found birds widely distributed across the plateau between 1,060 and 1,280 m elevation. These surveys and demographic research suggested a population exceeding 200 birds (Reynolds and Snetsinger 2001).

The current population of the Puaiohi is estimated at about 500 birds (range: 200 – 1,000) (KFBRP unpubl. data). The breeding population is restricted to an area of < 20 km^2 and 75% occurs in 10 km^2 (Fig. 1). Puaiohi occur in high densities (up to 11 pairs / km of stream) in three adjacent drainages: the Upper Mōhihi, Upper Waiakoali, and the northeastern upper Kawaikōī, but density declines with elevation (Snetsinger *et al.* 1999). The upper reaches of the Halehaha and Halepāʻākai drainages support a medium-density population of about 5 pairs / km of stream and low-density populations occur in the lower Waiaʻalae / unnamed drainage (1.25 pairs / km; Pratt *et al.* 2002) and lower Kawaikōī / Kauaikinana (0.5 pair / km). In 1994, two small, low-density populations were detected on private lands along the Halekua and Waiau streams at the southern edge of the species' range, but neither population was detected during surveys in March 2000 (Telfer pers. comm.). Surveys in March 2000 confirmed the existence of a small population along an upper tributary of the Koaiʻe Stream, although its size and extent are unknown (Foster, unpubl. data).

MANAGEMENT / PROTECTION TO DATE. The Puaiohi was federally listed as endangered in March of 1967 (USFWS 2006). Studies to determine life history and demography of the Puaiohi were conducted between 1996 and 1998 by USGS and have been ongoing since 2006 by the Kauaʻi Forest Bird Recovery Project (KFBRP). Weed control is being conducted by The Nature Conservancy and Kōkeʻe Resource Conservation Program. The Kauaʻi Watershed Alliance is currently (2010) constructing a fence to protect the southeastern Alakaʻi Wilderness Preserve from ungulates and fencing in the Hono O Na Pali Natural Area Reserve is currently being planned.

A captive propagation and release program has been implemented for the Puaiohi by the Zoological Society of San Diego (ZSSD). Between 1999 and 2010, 200 birds have been released at three sites (Kuehler *et al*. 2000, Woodworth *et al.* 2009, Lieberman and Kuehler 2009, ZSSD 2009). Despite this effort, no known new subpopulations have been permanently established. Captive-bred released Puaiohi have fledged young with both wild and captive-bred mates, this may indicate that suitable habitat is saturated. Of the birds that have been released, about 24% died between four and ten weeks post release and another 36% disappeared over this same period; only 16 have been detected as breeders (KFBRP, unpubl. data). Recruitment of captive birds into the breeding population appears to be related to the local density of the wild birds. In the low density Kawaikōī drainage 13.8% of captive birds have bred, while in the higher density Halepāʻākai drainage only 1.4% have bred (KFBRP, unpubl. data). Thus while released birds have survived and reproduced, the efficacy of captive releases is difficult to assess but seems low. Some birds, however, may be recruiting into the breeding population after dispersing and go undetected.

PRIMARY THREATS. Non-native disease appears to limit the distribution of many native Hawaiian forest birds, including the Puaiohi (van Riper *et al.* 1986, Atkinson *et al.* 1995, Atkinson and LaPointe 2009), and global climate change may exacerbate this threat by allowing an increase in 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). Currently, there are no forested areas on Kauaʻi where the mean ambient temperature prevents the seasonal incursion of malaria; mosquitoes and malaria can survive across all parts of the island, at least periodically (Benning *et al.* 2002). Benning *et al.* (2002) used GIS simulation to show that an increase in temperature of 2° C, which is a conservative figure based on recent data (IPCC 2007), would result in an 85 % decrease in the land area on Kauaʻi where malaria transmission currently is only periodic. Without translocation to higher islands or the development of disease resistance, the loss of such a large proportion of suitable habitat would likely result in extinction of the Puaiohi (although see below) (Pounds *et al.* 1999, Still *et al.* 1999). Prior to 2000, seven wild Puaiohi were tested for malaria. One individual had malaria antibodies but none had active infections, suggesting that at least some Puaiohi may survive the disease (Atkinson *et al*. 2001). Between 2007 and 2009, 56 wild Puaiohi were tested for malaria and 11 (19.6) were determined to be infected (Atkinson and Utzurrum 2010). This is an increase from sampling conducted between 1994 and 1997, although only seven birds were included in this sample (1 of 7; 14.3%) (Atkinson and Utzurrum 2010). At least three captive birds that died soon after release were determined to be infected with malaria. Thus, disease may limit Puaiohi from inhabiting low elevation areas with suitable nesting habitat.

The habitat of the Puaiohi has been, and continues to be, negatively affected 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). Puaiohi depend on areas of intact native forest for foraging and nesting. Feral ungulates negatively affect native forest by browsing , causing soil erosion, disrupting regeneration, spreading of invasive plant seeds, facilitating the invasion of alien plants, and creating breeding habitat for mosquitoes (Cabin *et al.* 2000, Scott *et al.* 2001, USFWS 2006). Degradation of forest habitat has likely played an important role in the range contraction of the Puaiohi. 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*) suppress native food plants. Daisy fleabane (*Erigeron karvinskianus*) will cover nesting walls, reducing their suitability for nest sites (Woodworth *et al.* 2009).

Introduced predators are one of the most serious threats to Hawaiian forest birds, particularly during nesting (Atkinson 1977; Scott *et al.* 1986; VanderWerf and Smith 2002). Predation by rats *(Rattus* spp.) is likely a serious threat to Puaiohi. Although their habit of nesting on steep cliff faces 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. The difference between these two studies could be related to annual 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. 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). Feral cats (*Felis catus*) also are present on the Alakaʻi Plateau.

Major hurricanes struck Kauaʻi in 1983 and 1992 and significantly affected native habitats by destroying native habitat, creating gaps into which alien plants could expand, and spreading invasive plants. Because Puaiohi occupy stream drainages, which presumably offer some protection, it is difficult to assess the population level affects of hurricanes. However, the populations identified on Lāʻau Ridge and above Nuʻalolo west of Kōkeʻe (USFWS 1983) did not persist after these hurricanes.

A number of other factors are likely contributing to the decline of this species. The effects of non-native arthropod predators and competitors are completely unknown. Threats or stressors may interact with each other and increase their negative impact on Puaiohi. For example, birds experiencing malarial symptoms may be more susceptible to predation. Finally, single island endemics like the Puaiohi are inherently

more vulnerable to extinction than widespread species because of the higher risks posed to a single population 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, although see Brodie 2007). As populations and ranges of island birds decline due to other threats, the extinction risk from catastrophic events also increases.

RECOVERY STRATEGY. Several tools can potentially be used to manage Puaiohi, including captive propagation and release, which may include the breeding of disease resistant individuals; controlling predators or deploying rat-resistant artificial nest boxes, which may facilitate the evolution of disease resistance (Kilpatrick 2006); controlling alien plants; fencing and ungulate eradication; and translocating the species to other islands. The most appropriate strategy depends on the size, distribution, and trend of the population. The best evidence indicates that the population is approximately 500 individuals, little suitable unoccupied habitat exists, and there is no evidence of a declining trend. This suggests that management directed at wild birds, and not captive propagation, may be most appropriate.

Interim Recovery Objectives [2005 - 2010]. To meet the long-term recovery goals for the Puaiohi the following objectives were developed in 2005 (italicized font indicates status as of 2010, with main conclusion in bold font):

- Investigate management tools for stabilizing / increasing the Puaiohi population and determine which is most effective.
    - Predator control.. *Traditional ground based rodent control is difficult because of the terrain of the Alaka'i Wilderness Preserve, and because of large fluctuations in rodent populations (see Tweed et al. 2006). Being able to predict periods of high rodent abundance would be an important step in refining a protocol to protect nests, but any ground- based control method would be limited in scope.* **Aerial broadcast of rodenticide would likely contribute to Puaiohi recovery and should be pursued.**
    - Nest boxes. *To date, Puaiohi have not used boxes designed to be predator proof.* **Because of the low cost, developing and installing alternative designs and installing boxes in areas lacking nest sites is a worthwhile investment.**
    - Weed control. *Evidence suggests that landscape scale weed control would benefit Puaiohi, especially in areas such as the Kawaikōī, however most weed control is now focused on the interior of the Alaka'i.*
    - Releasing captive birds. *See above (Management / Protection To Date). The captive propagation program was initiated when the population was estimated to be much lower than recent data suggests. Based on this, if there was not a program in place now, it is unclear if one would be initiated.* **Additional effort should be invested in searching for released birds.**
    - Determining disease prevalence. *Analysis is complicated by temporal variation and differences in protocol, but it seems that prevalence is highest in Kawaikōī, moderate at Halepa'akai, and lowest in Mōhihi.*
- Determine the current population distribution, and size, population trend.
    - Population distribution and size. *Spot-mapping surveys were completed in 2005, but are problematic in terms of survey design.*
    - Population trend. *Annual surveys at the Halepā'ākai do not indicate area-wide declines.*

Five-year Recovery Actions (2005 - 2010) - Status as of July 2010. To realize the recovery objectives described above, the following actions were developed in 2005:

- Compile and summarize existing population survey data (KFBRP / USGS). *Surveys completed.* **Full analysis still lacking.**

- Identify a new release site that has high quality habitat, zero or low density of wild Puaiohi, sites for the erection of release towers, and helicopter access (KFBRP / ZSSD). **A new release site with low Puaiohi density was identified (Kawaikōī Drainage), but the habitat quality is questionable.**
- If a release site is identified, relocate the release infrastructure (towers, cages, weatherport, etc.) to new release site (ZSSD / USFWS / DOFAW). *Completed.*
- Use landsat images and geographic and biological data to model Puaiohi habitat with GIS and identify additional potential habitat (USGS). *Not completed because of a lack of funds.*
- Conduct large-scale rodent control by aerial broadcast of rodenticide. Possible treatment sites include upper Mōhihi and Halepāʻākai. Treatment of both a high-density and a medium-density site might provide valuable comparison (USFWS). *Not completed.* **Aerial broadcast is likely not a viable option in the short-term because of sociopolitical resistance.**
    - In order to implement and fully evaluate the efficacy of an aerial broadcast additional actions are required
        - Collect baseline data on survival and reproduction of Puaiohi to compare to post-eradication data (KFBRP). **Baseline data have been collected from two sites.**
        - Begin public outreach about importance and benefits of controlling rodents and the safety of diphacinone (USFWS). **Outreach efforts were initiated in 2009.**
        - Collect before and after data on water quality and possible contamination of game species if these are deemed necessary to obtain public support (USFWS). *Not completed.*
- Evaluate efficacy of rat-resistant artificial nest boxes at reducing predation of wild and captive birds (USDA, KFBRP, Eric VanderWerf). **Rat-proof boxes were designed and deployed, but have not been used by wild Puaiohi.**
- Compare nest success and female survival in natural nests vs. artificial nest boxes (KFBRP). *Not completed.* **Impossible to determine if birds are not using artificial nest boxes.**
- Fledge captive birds from artificial nest boxes so they recognize and use artificial nest boxes after release (ZSSD). *Not completed because most nestlings are hand-reared.*
- Measure survival and dispersal of adult and juvenile Puaiohi, through mist-netting, banding, resighting, and radiotracking (KFBRP). **Data have been collected and are being analyzed.**
- Model Puaiohi population to determine trend and the effect of management (KFBRP). **Data have been collected to determine lambda and are being analyzed. Determining the latter will be difficult since little management specific to Puaiohi is being conducted.**

The following actions from 2005 – 2010 will be continued during the next five-year period:
- Analysis of past survey data.
- Collection of demographic data.
- Investigate more designs and continue monitoring current boxes.
- Investigate allowing second broods to fledge from nest boxes.

Interim Recovery Objectives [2010 - 2015]
- Develop a Puaiohi specific survey method and resurvey the entire population.
    - Search for captive released birds
    - Search for areas of suitable unoccupied habitat.
- Determine habitat occupancy / preferences.
- Determine limiting life stages. Low juvenile survival suggests that this maybe the limiting stage, however apparent survival is likely higher because of dispersal out of the study area.
- Determine disease prevalence and factors promoting transmission of avian pox and malaria. Disease prevalence in Puaiohi has remained stable over the past 10 years (Atkinson and Utzurrum 2010), but there is variation in prevalence across the Alakaʻi Wilderness Preserve.
    - Explore disease management options
        - Rodent control to facilitate evolution of disease resistance

    - Breed disease resistant birds
- Investigate feasibility of translocating birds to higher Hawaiian Islands (e.g., Maui).

If these objectives are met within five years, then new recovery objectives will be identified to continue to guide progress toward recovery. If these objectives are not met, then the causes for failure should be identified and rectified if possible. If it is not possible to correct the causes for failure and the current strategy is deemed ineffective, then a new strategy will be developed.

Five year Recovery Actions 2010-2015

- Develop a method to analyze historic survey data.
- Develop a rigorous survey method, with the caveat that data must be comparable to data collected during previous range-wide survey (KFBRP / BRD).
- Resurvey the entire range of the Puaiohi to document current distribution and abundance, determine if changes have occurred since the 2005 surveys, and document the presence of released birds (KFBRP).
    - Determine if areas of suitable habitat exist that are not occupied by Puaiohi (Moaalele Peak in Hono o Na Pali NAR, Namolokama, and Lāʻau Ridge).
- Couple these surveys with analysis of imagery to look at gross scale vegetation, topography etc. and with data from vegetation, food plant, rat, and mosquito surveys at a subsample of plots at survey stations, and / or in both territories and areas not supporting Puaiohi (KFBRP / TNC / Greg Asner).
    - Develop protocols.
    - Determine availability of imagery.
- Continue reproductive and survival monitoring at the Halepāʻākai and at an additional site for spatial comparison with a temporal control.
    - Focus on pairing rates, territory turnover, territory occupancy, number of territories with fledglings, and resighting banded birds.
    - Attempt to attach radio transmitters to fledglings
    - Deploy nest cameras to identify predators.
- Conduct overwinter radiotelemetry of fledglings / juveniles (released or wild birds), followed by assessment of winter habitat.
- Continue to monitor and experiment with nest boxes.
- Experiment with playback to promote retention of released birds.
- Complete population model.
- Begin the process of phasing out the captive release program.
- Develop a translocation document.
- Continue and expand outreach.

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