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RESTORATION TECHNIQUES FOR HAWAIIAN FOREST BIRDS: COLLECTION OF EGGS, ARTIFICIAL INCUBATION AND HAND-REARING OF CHICKS, AND RELEASE TO THE WILD

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Abstract. In 1993, The Peregrine Fund (TPF), in cooperation with the U.S. Fish and Wildlife Service, the state of Hawai'i, and the 'Alalā Partnership, began a new restoration program for endangered Hawaiian birds. Through this program, eggs produced in the wild and in captivity are incubated and hatched, the chicks are hand-reared, and the juveniles are subsequently released to the wild. To date, 153 endemic passerine chicks have been artificially hatched, with the wild population of the endangered Hawaiian Crow (*Corvus hawaiiensis*), or 'Alalā, being the first species to benefit from these efforts. Beginning with four nonendangered species in 1995 and 1996—Hawai'i 'Amakihi (*Hemignathus v. virens*), 'Ōma'o (*Myadestes obscurus*), 'I'iwi (*Vestiaria coccinea*), and Hawai'i 'Elepaio (*Chasiempis s. sandwichensis*)—TPF's program has expanded to include construction of a captive propagation facility on the Big Island and the operation of a second facility on Maui. Cooperative projects are underway for the Puaiohi (*Myadestes palmeri*), Palila (*Loxioides bailleui*), Hawai'i Creeper (*Oreomystis mana*), 'Ākohekohe (*Palmeria dolei*), and Maui Parrotbill (*Pseudonestor xanthophrys*), in addition to continuing work with the 'Alalā. Conservation partnerships have been formed with private landowners, government agencies, Kamehameha Schools Bernice Pauahi Bishop Estate, and the Zoological Society of San Diego to implement these restoration activities.

Key Words: captive propagation; conservation; endangered birds; Hawai'i; restoration.

Human modification of the environment in the Hawaiian Islands is causing the steady extinction of endemic bird populations. Loss of secure habitat due to the encroachment of introduced plants, birds, insects, mammals, and disease is contributing to the decline. Long-term, holistic programs involving habitat management and conservation education are required to preserve the remaining natural areas and ensure the survival of Hawai'i's unique avifauna (Ralph and van Riper 1985, Scott et al. 1988, Atkinson et al. 1995).

For some bird species habitat enhancement and protection may not occur quickly enough to guarantee a safe haven for populations on the verge of extinction. In these cases manipulation of wild birds and hands-on intervention can be useful management tools. For example, captive breeding programs to produce birds for reintroduction have proven to be a valuable conservation strategy for endangered Peregrine Falcons (*Falco peregrinus*) and California Condors (*Gymnogyps californianus*; Cade et al. 1988, Kuehler and Witman 1988). However, long-term propagation of birds in captivity is labor-intensive, costly, and not an effective recovery tool for all species (Griffith et al. 1989, Snyder et al. 1996). For some island endemics, such as Ultramarine Lories (*Vini ultramarina*), translocation to secure habitat on another island is a preferable option, if the founder population is large enough to support collection of wild individuals (Kuehler et al. 1997, Lieberman et al. 1997). Cross-fostering is also an intervention technique that has been successfully utilized for the management of Chatham Island Black Robins (*Petroica traversi*). The success of this strategy with robins was partly due to the availability and suitability of using Chatham Island Tits (*Petroica macrocephala chathamensis*) as foster parents (Butler and Merton 1992). However not all endangered birds are as tolerant of intensive nest manipulation as robins, or have accommodating nesting pairs from similar species available to act as foster parents.

An alternative to cross-fostering, translocation, or long-term captive breeding is a short-term intervention strategy termed "rear and release," which involves manipulating wild populations by collecting eggs, artificially hatching and rearing chicks in captivity, and immediately releasing juveniles back to the wild. This conservation management tool increases the reproductive rate through double clutching, and/or providing a protected artificial environment during the incubation and nestling period, normally a period of high mortality in the wild for many bird species. "Rear and release" also decreases the need for long-term maintenance of breeding birds in captivity. Except for the endangered San Clemente Island Loggerhead Shrike (*Lanius ludovicianus mearnsi*), passerine recovery programs have not incorporated "rear and release" techniques into recovery plans due to insufficient technical information relating to the transport and artificial incubation of passerine eggs,

hand-rearing of chicks, and release of juveniles to the wild (Kuehler et al. 1993).

In 1992, legal actions relating to the recovery of the Hawaiian Crow (*Corvus hawaiiensis*), hereafter referred to as the 'Alalā, instigated the formation of a National Academy of Science Committee to evaluate recovery actions for this species (Duckworth et al. 1992). The "rear and release" strategy was recommended for implementation.

Beginning in the 1970s, propagation of endangered Hawaiian forest birds in captivity was supervised by the U.S. Fish and Wildlife Service (USFWS) and the state of Hawai'i's Division of Forestry and Wildlife (DOFAW) at the Olinda Endangered Species Propagation Facility, Pohakaloa Breeding Facility, and the Patuxent Wildlife Research Center. In 1993, the USFWS and DOFAW requested The Peregrine Fund (TPF) to begin a cooperative restoration program for the 'Alalā. Based on the initial success with this species, in 1995 TPF's Hawaiian Endangered Bird Conservation Program was expanded to include developing techniques for endangered native honeycreepers and thrushes, and construction of a captive propagation facility, the Keauhou Bird Conservation Center (KBCC), on the Big Island. Additionally, in 1996, DOFAW requested that TPF assume the operation of a second facility, the Maui Bird Conservation Facility (MBCC), on Maui (formerly the Olinda Endangered Species Propagation Facility). Cooperative projects are underway for five endangered species: the Puaiohi (*Myadestes palmeri*), Palila *(Loxioides bailleui),* Hawai'i Creeper (*Oreomystis mana*), 'Ākohekohe (*Palmeria dolei*), and Maui Parrotbill (*Pseudonestor xanthophrys*), in addition to continuing work with the 'Alalā.

METHODS

Egg Collection

Nest searching and collection of Hawaiian forest bird eggs is accomplished by biologists from the USFWS, DOFAW and U.S. Geological Survey-Biological Resources Division (BRD), in collaboration with TPF. Eggs are collected and transported, and chicks are hatched at facilities on the island of origin to minimize transport time. Eggs are transported in portable incubators (Dean's Animal Supply, Orlando, FL) and helicopters are used if the terrain is rough or the driving distance long.

Artificial Incubation of Eggs and Hand-Rearing of Chicks

Eggs are incubated in forced-air incubators (Humidaire models 20 and 21; Humidaire Incubator Co., New Madison, OH) under parameters used to hatch similar passerine species: 37.5–38.1° C (dry bulb), 30.0–33.3° C (wet bulb). Mass (water loss) is monitored by weighing eggs throughout incubation and eggs are transferred to hatchers when chicks pip the air cell (Kuehler and Good 1990; Kuehler et al. 1993, 1994, 1996).

Chicks are hand-reared using techniques previously developed for related passerines and subsequently tested on nonendangered surrogate Hawaiian forest birds. Chick mass, vitality, developmental changes and food intakes are recorded. Nutrient analysis of hand-rearing diets is accomplished using the N2 Animal Nutritionist software program which compiles and analyzes the nutrient content of individual food items (Kuehler et al. 1993, 1994, 1996).

Bird Releases

Prior to reintroduction, birds are conditioned in enclosures to (1) develop flight and foraging capabilities, (2) enhance release site tenacity, and (3) provide natural exposure to avian malaria under field conditions where supplemental feeding is available ('Alalā). The length of the acclimation period is species-dependent. For example, 'Alalā spend several months learning to forage prior to release, while 'Ōma'o (*Myadestes obscurus*) require approximately two weeks. Supplemental foods are decreased gradually while the released birds are weaned, and in response to their ability to forage on native foods. The larger, heavier species (e.g., corvids and thrushes) are fitted with transmitters for monitoring, (the smaller size of some species of honeycreepers makes the use of radiotelemetry less practical). Predator control to increase habitat security is undertaken prior to release (Kuehler et al. 1995, 1996; Fancy et al. *this volume*).

RESULTS

Since 1993, 153 endemic passerine chicks have been artificially hatched and the techniques have been developed to hand-rear 11 species of native Hawaiian songbirds, including Hawai'i 'Amakihi (*Hemignathus v. virens*), 'Ōma'o, 'I'iwi (*Vestiaria coccinea*), Hawai'i 'Elepaio (*Chasiempis s. sandwichensis*), 'Apapane (*Himatione sanguinea*), Puaiohi, Palila, Hawai'i Creeper, 'Ākohekohe, Maui Parrotbill, and 'Alalā. Subsequently four species of native passerines have been released: 'Alalā, Hawai'i 'Amakihi, 'Ōma'o, and 'I'iwi. Overall hatchability of viable eggs = 87.4%, survivability of chicks for 30 days = 87.6% (Table 1).

'Alalā (1993–June 1998)

Five, seven, four, and eight hand-reared 'Alalā were released into historical habitat in the South Kona District on the island of Hawai'i in 1993, 1994, 1996, and 1997, respectively. All 24 birds survived 180 days post-release and 12 birds survive to date (50% survivability to June 1998). First-year survivability of wild passerine populations (parent-rearing) has been reported to range between 2% and 63% (Sullivan and Roper 1996). Known mortality of reintroduced 'Alalā has largely been due to 'Io (*Buteo solitarius*) predation in areas of high 'Io population densi-

TABLE 1. SUMMARY OF HAWAIIAN FOREST BIRD EGGS ARTIFICIALLY INCUBATED AND CHICKS HAND-REARED BY THE PEREGRINE FUND 1993-JUNE 1998

Species	Viable eggs collected	Hatched (%)	Survive (%) (30 days)
Hawai'i 'Amakihi	26	21 (80.8)	19 (90.5)
'I'iwi	2	2 (100)	2 (100)
'Ōma'o	29	27 (93.1)	25 (92.6)
'Elepaio	2	1 (50.0)	1 (100)
Palila	22	21 (95.5)	11 (52.4)
Puaiohi	32	30 (93.8)	29 (96.7)
	6	6 (100)	5 (83.3)
'Ākohekohe	9	9 (100)	9 (100)
Hawai'i Creeper	1	1 (100)	1 (100)
Maui Parrotbill	2	2 (100)	2 (100)
'Apapane	44	33 (75.0)	30 (90.9)
'Alalā	175	153 (87.4)	134 (87.6)

ties (D. Ball, pers. comm.). In 1997 the USFWS began translocation and removal of predatory 'Io in 'Alalā release areas.

Eighteen 'Alalā currently reside in captivity in two facilities on Maui and the Big Island (MBCC and KBCC). Thirty-three 'Alalā have been hatched in TPF facilities from 1993 to June 1998.

HAWAI'I 'AMAKIHI (1995)

In 1995, 16 nonendangered Hawai'i 'Amakihi were artificially incubated and hatched, hand-reared, and experimentally released in low-elevation forest (1,212 m) containing predators and mosquito-transmitted avian disease. This surrogate project required the development of egg transport, artificial incubation, and hand-rearing procedures for honeycreepers and tested the efficacy of releasing birds in compromised habitat. Eleven of the released birds were known to have died due to avian malaria and pox. This experiment showed that, although it was possible to artificially incubate and hand-rear honeycreepers, the release techniques developed for juvenile 'Alalā, which are capable of surviving avian malaria and pox infection, would not be applicable to honeycreepers even under conditions of supplemental feeding. Restoration of endangered honeycreepers may be possible only in mosquito-free and predator controlled release sites in Hawai'i (Kuehler et al. 1996).

'ŌMA'O (1995–JUNE 1998)

In 1995 and 1996, the first restoration attempt of a small Hawaiian passerine to predator controlled habitat with a low incidence of disease was made with the release of captive-reared 'Ōma'o into Pu'u Wa'awa'a Forest Reserve (PWW); where this species has been absent for nearly 100 years. In 1995, two birds were reintroduced as a preliminary test release, and in 1996, 23 birds were released in cohorts numbering from two to seven birds. Of the 25 released birds, the two birds released in 1995 were observed one year later, and 22 of the 1996-hatched birds were monitored and known to have survived for at least 30 days post-release (duration of transmitters). In December 1996 the two captive-reared 'Ōma'o released in 1995 were observed copulating and carrying nesting material. An unbanded juvenile was observed in the same area six months later.

Additionally, during fall 1996, an experimental translocation of 'Ōma'o was undertaken by BRD biologists in the same area to compare the fate of captive-reared release birds and translocated wild 'Ōma'o (Fancy et al. *this volume*). This evaluation of techniques for nonendangered 'Ōma'o provides information for the development of conservation strategies for the endangered Puaiohi. A follow-up survey was conducted during the week of May 18, 1997, by BRD and TPF biologists. Fifteen 'Ōma'o were estimated to remain within 2 km of the release aviaries. Eight birds were identified by bands (seven captive-reared and one translocated), although most birds had moved to higher elevation areas where fruit was more abundant. Additional 'Ōma'o are known to have dispersed elsewhere, and recent reports of sightings have been made by residents of a subdivision about 5 km away from the release site. The results of the 'Ōma'o study suggests that using founder release cohorts of captive-reared birds may enhance reestablishment of wild populations in secure/managed areas, due to their greater site fidelity after release. An additional 'Ōma'o survey will be conducted by BRD and TPF biologists in summer 1998 (Fancy et. al. *this volume*).

PUAIOHI (1996–JUNE 1998)

In 1995, BRD, DOFAW, USFWS, and TPF began a cooperative project to establish additional breeding populations of the critically endangered Puaiohi in the Alaka'i Wilderness Area on Kaua'i. The total wild population of this species is estimated to be approximately 300 individuals (T. Snetsinger, pers. comm.).

In 1996 and 1997, wild eggs were collected to provide breeding stock for propagation and release; 14 chicks were hatched. Four females hatched in 1996 subsequently laid a total of 15 infertile eggs in captivity during the 1997 breeding season (there were no males in the flock).

As of June 1998, 15 second generation Puaiohi chicks were produced via captive-breeding at the KBCC on the Big Island. These birds will comprise the first release cohort of Puaiohi

scheduled for reintroduction in the Alaka'i Wilderness Area in February 1999.

'Ākohekohe (1997)

Historically, 'Ākohekohe populations were found in the wet forests of Moloka'i and in eastern and western Maui (Perkins 1903). Currently one population of approximately 3,500 birds remains on the windward side of Haleakalā (T. Pratt, pers. comm.).

In 1997, six 'Ākohekohe eggs were collected in cooperation with BRD and DOFAW in Maui; six chicks hatched, and five were hand-reared. 'Ākohekohe are being maintained in captivity to develop the breeding and release techniques for future re-introduction into managed habitat.

Maui Parrotbill (1997–June 1998)

The estimated wild population of Maui Parrotbill is about 500 birds and is restricted to the remaining high-elevation rain forests of East Maui (T. Pratt, pers. comm.). This species has a low reproductive rate and lays a single egg clutch (Simon et al. 1997).

In cooperation with BRD, one nest of this species was located in 1997 and one chick was reared from the single egg collected. No wild nests were located by DOFAW biologists in 1998 to provide a mate for this single bird. If possible, in 1999, additional wild eggs will be collected to establish a captive breeding flock. Given the low reproductive rate and scarcity of nests, "rear and release" is not a practical strategy for this species.

Hawai'i Creeper (1997–June 1998)

Hawai'i Creepers are found in several disjunct populations; approximately 12,500 birds existed in the wild in the late 1970s (Scott et al. 1986). In order to develop the restoration techniques for Hawai'i Creepers and to serve as a model for other rare insectivorous species, four eggs were collected from Hakalau Forest National Wildlife Refuge with BRD assistance in 1997 and five eggs were collected in 1998. Hawai'i Creepers will be bred in captivity to produce birds for future release into secure habitat.

Palila (1996–Present)

Historically Palila occurred on the slopes of Mauna Kea, Mauna Loa, and Hualālai. Today a few thousand birds are restricted to the montane māmane forests of Mauna Kea (Jacobi et al. 1996).

Eleven Palila were reared in 1996, with ten surviving for more than one year. Because of the identification of possible disease infection (*Mycoplasma* spp.) in the wild and captive flocks in 1996, these birds are being held for captive propagation and research. Offspring will be candidates for captive breeding and/or release in 1999 (B. Rideout, pers. comm.).

Currently, BRD researchers are translocating wild juvenile Palila to determine the feasibility of introducing young Palila to new habitat. This study will determine the advisability of using either translocation, or captive-breeding and reintroduction as a restoration strategy for Palila (P. Banko, pers. comm.).

DISCUSSION

Recovery techniques involving birds in captivity are costly strategies which have been the subject of considerable debate in the conservation arena. "Better dead than captive-bred" is a familiar refrain. Although hands-on manipulation of wild birds has helped endangered California Condors and Peregrine Falcons, lack of thoughtful planning has also resulted in inappropriate efforts for some species (Griffith et al. 1989, Hutchins and Conway 1995, Hutchins et al. 1995, Snyder et al. 1996). Captive propagation techniques, in concert with habitat management, can only be effective conservation tools when (1) thorough knowledge of species biology exists, (2) the causes of decline are understood and ongoing programs to reverse the trend are being implemented, (3) captive propagation technology and expertise is available, (4) release techniques exist which result in behaviorally competent birds, (5) adequate funding and facilities are available, (6) recovery objectives and goals are clear, and (7) acceptable, secure release sites are available in the wild.

Unique management techniques for artificially incubating eggs and subsequently rearing and releasing passerines are currently being developed as restoration tools for endangered Hawaiian birds. These strategies are being used as stopgap measures to increase reproductive output in rare bird populations during this period of environmental crisis. Intervention techniques provide a means to preserve options until the habitat is secure and wild populations are stabilized. However, without commensurate action to protect and enhance the habitat, these hands-on restoration efforts cannot establish viable self-sustaining wild populations.

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