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REINTRODUCTION AND TRANSLOCATION OF 'ŌMA'O: A COMPARISON OF METHODS

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Abstract. We reintroduced 25 captive-reared 'Ōma'o (*Myadestes obscurus*) and translocated 16 wild-caught 'Ōma'o to former range in the Pu'u Wa'awa'a Wildlife Sanctuary on the island of Hawai'i to develop and refine methods that might be used in the recovery of the closely related and critically endangered Puaiohi (*Myadestes palmeri*) on Kaua'i. Captive-reared 'Ōma'o were soft-released from two hacking towers at 66–57 days of age, whereas wild birds (all adults) were hard-released on the same day as capture or after a 1–9 day holding period. The fate of all birds was monitored daily for two months using radiotelemetry. Only 16 of 76 (21%) wild-caught 'Ōma'o were translocated because of problems with active avian poxlike lesions, an imbalanced sex ratio, or because birds would not eat during holding. Survival to 30 days postrelease was similar for birds released by the two methods: three captive-reared 'Ōma'o were killed by predators, and four wild 'Ōma'o died of handling/transport stress. 'Ōma'o populations are highly male biased, and a sex ratio of captive-hatched eggs of 18 males to 6 females suggests that the sex ratio may not be 1:1 at hatching. Translocation of hatching-year 'Ōma'o would not be practical because of very low capture success for juvenile 'Ōma'o and the skewed sex ratio. Fidelity to the release site was higher for captive-reared birds, and this approach is less expensive for 'Ōma'o and more likely to result in successful establishment of a new population in continuous habitat.

Key Words: captive propagation; Hawai'i; Hawaiian honeycreepers; *Myadestes obscurus*; 'Ōma'o; reintroduction; translocation.

Major management programs have been initiated in recent years by federal, state, and private agencies in Hawai'i to protect and restore portions of native ecosystems deemed critical for the survival of endangered Hawaiian forest birds. In several areas, there has been notable recovery of both the structure and composition of the native vegetation, but reintroductions of captive-reared birds or translocations of wild birds will be needed to speed the recovery of avian populations. The U.S. Fish and Wildlife Service (USFWS) has entered into a long-term agreement with The Peregrine Fund to propagate Hawaiian forest birds in captivity in efforts to restore several species of endangered birds, and captive propagation and release are included in recovery plans for many Hawaiian species. However, considering the relatively poor track record of bird reintroductions on the mainland (Griffith et al. 1989, Snyder et al. 1996, Wolf et al. 1996), the critically low population sizes of some Hawaiian species, and the unique situation where mosquito-borne diseases (Warner 1968, van Riper et al. 1986) and introduced mammalian predators (Atkinson 1977, Scott et al. 1986) have devastated the Hawaiian avifauna, further development and refinement of reintroduction and translocation methods are needed for Hawaiian species before these tools can be used effectively in recovery efforts.

The development of captive propagation and reintroduction methods is recommended in the recovery plan (USFWS 1983a) for two species of critically endangered Hawaiian solitaires on Kaua'i, the Kāma'o (*Myadestes myadestinus*) and Puaiohi (*M. palmeri*). The Kāma'o was once the most common forest bird on Kaua'i but is now extremely rare or extinct (Scott et al. 1986, Reynolds et al. 1997b, *this volume*; Conant et al. 1998), whereas an estimated 300 Puaiohi survive in a 10 km^2 area in the Alaka'i Wilderness Area (T. Snetsinger, unpubl. data). The rear-and-release approach described in this paper has been proposed for establishing new populations of Puaiohi on Kaua'i beginning in 1999. In 1996 and 1997, 14 Puaiohi were hatched by The Peregrine Fund and transported to the Keauhou Bird Conservation Center (KBCC) for captive breeding and subsequent release of offspring to the wild.

The closest relative of these critically endangered solitaires is the 'Ōma'o (*M. obscurus*), a solitary, highly sedentary species (van Riper and Scott 1979, Ralph and Fancy 1994c) that is common in high-elevation, windward forests on the island of Hawai'i. 'Ōma'o now occupy only 30% of their former range on Hawai'i (van Riper and Scott 1979, Scott et al. 1986). The most plausible explanation for the peculiar present day distribution of 'Ōma'o (Fig. 1) is that a virulent strain of avian disease that has since attenuated or disappeared caused the extinction of 'Ōma'o and several other species in leeward Hawai'i and the Kohala Mountains in the late 1800s, followed by the development of resistance and subsequent dispersal by 'Ōma'o in

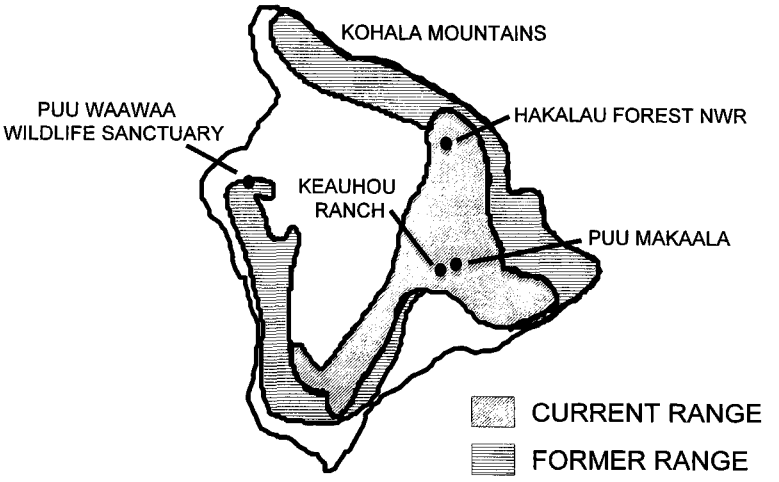

FIGURE 1. Current and former range of ʻŌmaʻo on the island of Hawaiʻi.

windward forests (Scott et al. 1986, Atkinson et al. 1995). Mosquitoes are a vector for avian malaria (*Plasmodium relictum*) and avian pox (*Poxvirus avium*), which have dramatically affected the numbers and distribution of Hawaiian birds (Warner 1968, van Riper et al. 1986, Jarvi et al. *this volume*), and almost all of the ʻŌmaʻo's former range in the Kona and Kohala districts is within the zone of mosquito occurrence (Scott et al. 1986). Breeding populations of ʻŌmaʻo are now found below 1,200 m elevation where mosquitoes occur throughout the year, and the presence of malarial antibodies in ʻŌmaʻo and initial findings for captive ʻŌmaʻo challenged with *Plasmodium relictum* (C. Atkinson, unpubl. data) suggest that some ʻŌmaʻo are resistant to or tolerant of avian malaria.

The main objective of this study was to compare two approaches for reestablishing ʻŌmaʻo in former range based on their practicality and the initial fate of released birds. The reintroduction approach involved collecting eggs from nests in the wild, hatching and raising ʻŌmaʻo in captivity, and releasing them to the wild using soft-release procedures. Translocation involved capturing juvenile and adult ʻŌmaʻo in mist nets, transporting them to the release site after disease screening and a short holding period, and releasing them immediately or after a short holding period. Secondary objectives were to develop captive-rearing and release procedures for Puaiohi using ʻŌmaʻo as a surrogate. The ʻŌmaʻo was an ideal species for this study for several reasons: (1) information obtained from this study will be immediately applicable to recovery of the Puaiohi and possibly the Kāmaʻo, and it has important implications for the recovery of other endangered Hawaiian species; (2) ʻŌmaʻo are locally abundant and nonendangered, thus it is possible to collect eggs and translocate a large number of wild birds without jeopardizing the population; (3) the species is highly sedentary, territorial, vocal, and large enough to carry a transmitter, making it highly tractable for monitoring the fate of individuals following release to the wild; (4) the species has been successfully held in captivity by several zoos, and procedures to hold and feed birds have already been developed; (5) the geographical distribution of ʻŌmaʻo is ideally suited to investigations of distributional anomalies through translocation studies, and careful monitoring of the fate of translocated birds may assist in identifying factors limiting populations of native birds; (6) a detailed study of the life history of the ʻŌmaʻo, including its breeding and foraging ecology, was completed in 1996 (Wakelee 1996); and (7) reintroduction of ʻŌmaʻo to former habitat is an important step, in terms of both research and applied management, in restoring native ecosystems in Hawaiʻi.

Our decision to release ʻŌmaʻo in an area where they had been extinct for almost a century was based on several factors involving avian disease and habitat recovery. ʻŌmaʻo are highly sedentary (van Riper and Scott 1979, Ralph and Fancy 1994c, Wakelee 1996), and much of their former range is separated from the current distribution by heavily grazed, disturbed, or unforested areas, such that natural recolonization would probably occur slowly. The occurrence of breeding populations of ʻŌmaʻo at elevations below 3,000 m in windward Hawaiʻi where mosquitoes and avian disease are common, the rapid recovery from malarial infections by ʻŌmaʻo challenged with *Plasmodium,* and the

occurrence of breeding populations of several native forest bird species at the release site all suggested that avian disease would not preclude the reestablishment of 'Ōma'o in leeward Hawai'i. Also, recent studies of 'Ōma'o habitat requirements (Ralph and Fancy 1994c, Wakelee 1996) and initial surveys of the release site, which is recovering from past cattle grazing, suggested that adequate food, nesting sites, and other requirements were present at the release site.

METHODS

We collected 'Ōma'o eggs and mist-netted wild 'Ōma'o at three study sites in windward forests on the island of Hawai'i, and released all birds at the Pu'u Wa'awa'a Wildlife Sanctuary on the northern slope of Hualālai volcano in leeward Hawai'i (Fig. 1). Subfossil records indicate that 'Ōma'o formerly ranged between 200 and 1800 m elevation on Hualālai (J. Giffin, unpubl. data). The Pu'u Maka'ala study area where 'Ōma'o eggs and adult birds were collected was a closed-canopy forest characterized by 'ōhi'a (*Metrosideros polymorpha*), *Cibotium* tree ferns, 'ōlapa (*Cheirodendron trigynum*), and kōlea (*Myrsine lessertiana*). This study area was at an elevation of 1,000 to 1,150 m where mosquitoes occurred throughout the year, and included portions of the Pu'u Maka'ala Natural Area Reserve and the Upper Waiakea Forest Reserve along the Stainback Highway. The Keauhou Ranch study area, at 1,800 m elevation, had a discontinuous canopy dominated by 'ōhi'a and naio (*Myoporum sandwichense*). The Keauhou Ranch site has had a long history of grazing and koa (*Acacia koa*) logging. The Hakalau study area was located at 1,570 m elevation near Nāuhi Camp, in the Hakalau Forest National Wildlife Refuge, in a 'ōhi'a- and koa-dominated closed forest with a relatively intact native understory. Mosquitoes rarely occur at the Keauhou Ranch and Hakalau study areas because of cooler temperatures at those sites.

The 15.4 km^2 Pu'u Wa'awa'a Wildlife Sanctuary is located between 1,220 and 1,830 m elevation on the northern slope of Hualālai volcano (Fig. 1). The western half of the sanctuary where we released 'Ōma'o has a open- to closed-canopy forest of 'ōhi'a and koa, with an understory of pilo (*Coprosma* spp.), native ferns, and introduced Kikuyu grass (*Pennisetum clandestinum*). The understory has been disturbed by more than 100 years of livestock grazing, and banana poka (*Passiflora mollissima*), a climbing vine from South America, is common in the area (Warshauer et al. 1983).

Eight volunteers and one biologist searched for 'Ōma'o nests during April and May 1996 at the Pu'u Maka'ala, Keauhou Ranch, and Hakalau study areas. In addition, two eggs were collected from a single nest at the Hakalau site in August 1995. Nests were located using cues provided by vocalizations and parental behavior (Martin and Geupel 1993), and by carefully following birds to their nest. Eggs were collected by hand, lowered from the tree in a thermos filled with warm millet, and transported to the Keauhou Bird Conservation Center in a portable incubator. Methods for incubation and hatching 'Ōma'o eggs, hand-rearing chicks, and releasing captive-reared birds will be published elsewhere (C. Kuehler, unpubl. data).

Wild 'Ōma'o were captured in 12-m mist nets placed on 6-m poles at the Pu'u Maka'ala and Keauhou Ranch study areas during September–November 1996. 'Ōma'o with an active brood patch or with active lesions characteristic of avian pox were released at the net. Wild 'Ōma'o were initially transported by vehicle to the Biological Resource Division's (BRD) field station in Hawai'i National Park where each bird was weighed and measured, banded with a numbered USFWS band and three colored plastic bands, screened for avian disease (G. Massey, unpubl. data), and fitted with a 1.5-g radio transmitter using an elastic figure-eight harness (Rappole and Tipton 1991, Wakelee 1996). Blood was drawn by jugular venipuncture for disease screening and for DNA analysis to determine sex (Zoogen, Inc.). 'Ōma'o are sexually monochromatic, and wing-chord measurements accurately sexed only 79% of museum specimens (Fancy et al. 1994).

One of the first two 'Ōma'o that was transported by vehicle to Pu'u Wa'awa'a and released the same day died < 24 hours after release, and it was obvious that the 6–8 hour holding time necessary for transport and disease screening before same-day release was too long. We therefore held the next four 'Ōma'o overnight at the BRD field station in 30 × 30 × 60 cm cages provided with perches, water, and native fruits before transporting them by vehicle to Pu'u Wa'awa'a the next morning on 21 September 1996. This approach was also abandoned, as three of the four 'Ōma'o died < 24 hours postrelease. The third strategy used with wild 'Ōma'o was to hold them for 2–5 days in a 4 × 5 × 5 m aviary near the KBCC, transport them to Pu'u Wa'awa'a, and then hold them individually for 1–2 days in 60 × 100 × 122 cm cages suspended 2 m above the forest floor. Six 'Ōma'o were successfully released by this method, but two mortalities occurred before birds were transported. The final strategy was to hold birds in 60 × 122 × 122 cm cages near the mist net where they were captured and to release any birds that would not eat native fruits or fruit cocktail within 4 hours of capture. Four birds were successfully translocated by this approach following a 2–5 day holding period at the capture site or KBCC aviary, and another four were released at the capture site because they would not eat or lost > 10% of their body weight while in captivity.

Captive-reared birds were held and released from two hacking towers at Pu'u Wa'awa'a located 1,200 m apart at 1,640 m elevation, as described by C. Kuehler et al. (unpubl. data). Following a test release of two 'Ōma'o in January 1996, we released four groups of five to seven 'Ōma'o during August–October 1996 after holding them for 6–9 days in the hacking boxes at Pu'u Wa'awa'a. All captive-reared birds were banded with colored leg bands and fitted with transmitters as described for wild 'Ōma'o. Artificial foods and native fruits were provided at the hacking boxes for 2–4 weeks following release (C. Kuehler et al., unpubl. data).

We attempted to locate all 'Ōma'o released at Pu'u Wa'awa'a at least daily using radiotelemetry, and to monitor behavior and social interactions by visual sightings. On 5 November 1996 we used an airplane

TABLE 1. SUMMARY OF REINTRODUCTION AND TRANSLOCATION METHODS FOR 'ŌMA'O AT PU'U WA'AWA'A WILDLIFE SANCTUARY, HAWAI'I, IN 1996

Reintroduction Method	Translocation Method
31 eggs collected	76 'Ōma'o captured in mist nets
2 eggs dead/inviable	39 probable males released
29 viable eggs	13 with active poxlike lesions released
2 embryo deaths	5 wouldn't eat in captivity and released
27 eggs hatched	2 died during holding prior to translocation
2 chicks died during rearing	1 with active brood patch released
25 chicks fledged	16 'Ōma'o translocated to Pu'u Wa'awa'a
All fledged chicks survived holding/transport/release	4 died within 24 hr of release
25 'Ōma'o released at Pu'u Wa'awa'a	12 'Ōma'o alive 30 d postrelease
3 killed by predators	7 dispersed
22 'Ōma'o alive 30 d postrelease	5 translocated 'Ōma'o at Pu'u Wa'awa'a in mid-December 1996
2 dispersed	
20 reintroduced 'Ōma'o at Pu'u Wa'awa'a in mid-December 1996	

to search for several birds that could not be located from the ground. We found most of those birds 2–5 km south of the release site on Hualālai Ranch or in the Kaloko Mauka subdivision. We determined that a bird had dispersed if we located it by radiotelemetry outside of the Pu'u Wa'awa'a sanctuary, and if changes in the location and amplitude of its signal over one or more days clearly indicated that it was moving.

Prior to and during the release, we controlled rats (*Rattus* spp.) at Pu'u Wa'awa'a using diphacinone rat poison and Victor snap traps, and we trapped feral cats (*Felis catus*) and small Indian mongooses (*Herpestes auropunctatus*) using cage traps. Bait stations with Eaton's molasses and peanut butter-flavored bait blocks were placed at 75 m intervals along twelve 1,950 m long transects between 1,500 and 1,800 m elevation. Seventy-two snap traps baited with coconut were placed near hacking towers to determine rat species composition and relative abundance.

RESULTS

Locating 'Ōma'o nests proved to be difficult, particularly in lower-elevation forests where 'Ōma'o density was low and dense understory vegetation made it difficult to follow 'Ōma'o or observe them from a distance. Many nests were found in the nestling stage, but we did not take nestlings because of the extensive procedures required to prevent the introduction of disease to the captive-breeding facility. Furthermore, removal of eggs instead of chicks is a better conservation strategy for Puaiohi and 'Ōma'o, as it increases the chances of double clutching in wild pairs; for Puaiohi one chick in the typical two-chick clutch usually dies before fledging (T. Snetsinger, unpubl. data). We located 18 nests in the construction or incubation stage and collected 33 eggs after > 360 person-days of searching, for a yield of one egg per 11 person-days of search effort. Four eggs were infertile or dead when collected, and 25 chicks were fledged from the 29 viable eggs and subsequently released at 66–157 days of age (Table 1). The sex ratio for 'Ōma'o hatched from eggs, based on wing-chord measurements and postrelease behavior of the first two 'Ōma'o, and DNA analysis of blood for the remaining birds, was 18 males, 6 females, and 1 unknown, different from the expected 1:1 ratio (Exact binomial test, $P = 0.008$).

Thirty 'Ōma'o were captured in mist nets (N = 4,108 net-hr) at the Pu'u Maka'ala study area during September and October 1996. Twelve (40%) of these were released at the net because they had open lesions characteristic of avian pox, one was released because it would not eat in captivity, and one was released because it had an active brood patch. Twelve of 14 'Ōma'o captured at Pu'u Maka'ala and sexed by DNA analysis (results were not available until after they were translocated) were males. Because of the highly male-biased ratio of 'Ōma'o at Pu'u Maka'ala and the low capture rate of 'Ōma'o at Pu'u Maka'ala, we began capturing 'Ōma'o at the Keauhou Ranch site where 'Ōma'o were more abundant and we only kept those with wing-chord lengths <95 mm that were probably females (Fancy et al. 1994). Forty-six 'Ōma'o were captured at Keauhou Ranch (N = 2,762 net-hr), but only three of these were translocated to Pu'u Wa'awa'a. We released 39 of the 46 'Ōma'o because they were probably males based on wing-chord length; four others were released because they would not eat within 4 hours of capture, and one bird was released because it had active poxlike lesions (Table 1).

The 25 captive-reared 'Ōma'o all survived the transport and holding period in hacking boxes and were released at Pu'u Wa'awa'a. Twenty-two of these 'Ōma'o survived more than 30 days

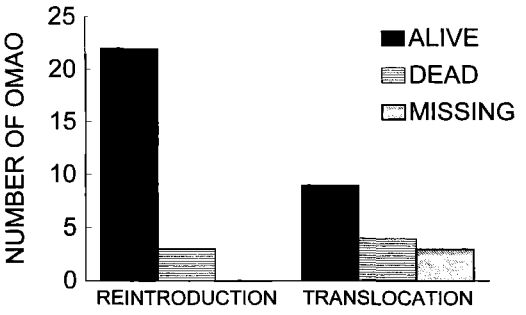

FIGURE 2. Comparison of survival > 30 days postrelease of reintroduced and translocated 'Ōma'o.

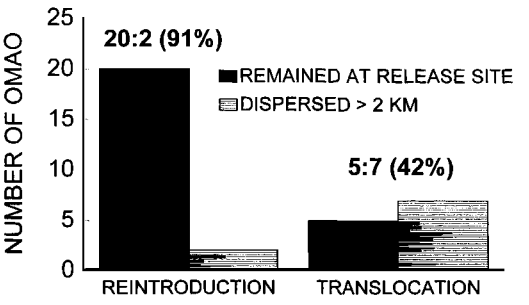

FIGURE 3. Comparison of fidelity to release site of reintroduced and translocated 'Ōma'o within 60 days postrelease.

postrelease (Fig. 2). The remaining three 'Ōma'o were killed by predators: one by an Hawaiian Hawk (*Buteo solitarius*), one by a pet cat after the 'Ōma'o dispersed to a housing subdivision 5 km west of the release site, and one by a rat. Two of the three depredated 'Ōma'o were females. Five captive-reared birds left the study area 1–2 days after release: two of these returned 30–40 days later after dispersing 1.5–2.5 km west of Pu'u Wa'awa'a, one was observed near the hacking tower in June 1997, one was depredated, and one had not returned by mid-December when its transmitter's batteries expired. In mid-December when intensive monitoring ended, 20 of the 22 surviving captive-reared 'Ōma'o remained at the Pu'u Wa'awa'a study area (Fig. 3).

Sixteen wild 'Ōma'o were translocated to Pu'u Wa'awa'a, but four of these died within 48 hours of release, probably because of the stresses of handling and transport. Including these four mortalities, survival to 30-days postrelease of wild 'Ōma'o (12/16) did not differ from that of captive-reared 'Ōma'o (22/25, $\chi^2 = 2.0$, 1 df, $P = 0.20$). Eight of the remaining 12 'Ōma'o dispersed 2–5 km west of Pu'u Wa'awa'a to Hualālai Ranch and the Kaloko Mauka subdivision within 3 days of release. Three wild 'Ōma'o that dispersed > 2 km from Pu'u Wa'awa'a returned after a 1–8 week absence, and by mid-December, five wild-caught 'Ōma'o remained at Pu'u Wa'awa'a. Fidelity of wild 'Ōma'o to the release site was lower than that for captive-reared 'Ōma'o ($\chi^2 = 9.67$, 1 df, $P = 0.0037$). It is interesting that three of four wild 'Ōma'o that were held in a hacking box at Pu'u Wa'awa'a for 7–9 days before release remained there (one dispersed but returned after 6–8 days), suggesting that holding translocated birds in hacking boxes may increase site fidelity.

In December 1996, we observed two of the captive-reared 'Ōma'o copulating, and another 'Ōma'o was observed carrying nesting material. In June 1997, we searched an area of 150 ha surrounding the hacking towers and found nine 'Ōma'o, including one unbanded juvenile that was observed near the site where an 'Ōma'o was seen with nesting material 6 months earlier. Seven of the eight adult 'Ōma'o that were identified were captive-reared birds and one was a wild, translocated bird. We estimated, based on a variable circular-plot count, that 15 'Ōma'o remained within the 150 ha area, compared to 25 'Ōma'o in the same area in mid-December (Nelson and Fancy 1999). In May 1998, one person spent three days at Pu'u Wa'awa'a and sighted four 'Ōma'o, two of which appeared to be a breeding pair. The two individual 'Ōma'o that were identified by their colored leg bands were both captive-reared males. An additional search for 'Ōma'o at Pu'u Wa'awa'a will be made during summer 1998.

DISCUSSION

With one exception, all of the birds that dispersed from Pu'u Wa'awa'a flew to the west, to Hualālai Ranch and the Kaloko Mauka subdivision, along a gradient of increasing moisture. The Pu'u Wa'awa'a Wildlife Sanctuary is bordered on the north by heavily grazed and arid ranchlands, and to the south and east by shorter, dry 'ōhi'a forest and shrublands dominated by pūkiawe (*Styphelia tameiameiae*). Ōlapa, a preferred food of 'Ōma'o (van Riper and Scott 1979; C. J. Ralph, unpubl. data) that was abundant at the Pu'u Maka'ala and Keauhou Ranch study sites, is mostly absent from Pu'u Wa'awa'a because of livestock grazing, but it is common in the Kaloko Mauka subdivision. A fire burned the eastern third of Pu'u Wa'awa'a Wildlife Sanctuary in March 1995 and the more open, drier forest to the east may have limited the dispersal of 'Ōma'o in that direction.

Our initial results suggest that the rear-and-release approach, where birds are soft-released in the same year that eggs are collected, is more

likely to result in establishment of a self-sustaining population at the release site, primarily because of greater site fidelity. Assuming that a captive propagation facility is already available, reintroduction was more practical and less costly than translocation, although both methods were labor-intensive and expensive. The reintroduction method required 11 person-days of search effort for each egg found, after which one or two persons were needed to hatch, raise, and release the birds. For the translocation method using a nine person field crew, our capture rate was 0.73 ʻŌmaʻo/100 net-hours at the lower-elevation site and 1.67 ʻŌmaʻo/100 net-hours at Keauhou Ranch where ʻŌmaʻo density is high (Ralph and Fancy 1994c). Furthermore, we had to release 60 of 76 (79%) ʻŌmaʻo because of problems with active poxlike lesions, the excess of males, or because some individuals would not eat in captivity. Only two hatch-year ʻŌmaʻo were kept, but both died during their first night in captivity before they could be translocated. In 1992, a group of biologists from several mainland zoos also found that the majority of wild-caught ʻŌmaʻo would not eat in captivity, and they released 8 of 11 (73%) adult ʻŌmaʻo (S. Derrickson, pers. comm.). At our higher rate of capture and retention, it would require > 2,500 net-hours of effort to obtain 20 adult ʻŌmaʻo for translocation, and > 22,600 net-hours (ca. 161 days using 20 nets for 7 hr/d) for 20 hatch-year ʻŌmaʻo, and even then there would be a shortage of females.

ʻŌmaʻo are the most sedentary of any closely studied Hawaiian forest bird species (van Riper and Scott 1979, Ralph and Fancy 1994c), and yet most of the wild ʻŌmaʻo released at Puʻu Waʻawaʻa quickly dispersed from the study area. Similar results were found during two translocations of second-year and adult Palila (*Loxioides bailleui*; Fancy et al. 1997; L. Johnson, unpubl. data), as more than half of the birds returned to the source population. Because of the difficulty and high cost involved in reintroduction and translocation efforts, high fidelity to the release site is critical to the successful establishment of a new population, and the reintroduction approach offers better chances for success.

Age is a confounding variable in our comparisons of survival and site fidelity between hatch-year, captive-reared ʻŌmaʻo and adult, wild-caught ʻŌmaʻo, but our objective was to develop a practical management tool, not to compare survival and fidelity between hatch-year and adult ʻŌmaʻo. For efficiency and cost purposes, the reintroduction approach requires that ʻŌmaʻo be released as juveniles, whereas translocation of juvenile ʻŌmaʻo is impractical because of the difficulty in capturing enough juveniles of each sex that will survive the translocation.

There was no indication that avian disease was involved in any of the mortalities that occurred by mid-December when intensive monitoring ended. For the 16 wild ʻŌmaʻo translocated to Puʻu Waʻawaʻa, all of the deaths occurred within 48 hours of their release and seemed to be a direct result of capture stress and handling. Predators were responsible for the three deaths among 25 captive-reared ʻŌmaʻo (six from low-elevation populations where mosquitoes are present and 19 from high-elevation populations).

Mosquitoes were observed at Puʻu Waʻawaʻa during the time that birds were being released, and avian malaria and avian pox have been documented there. G. Massey (unpubl. data) found that 4.9% of 209 Hawaiʻi ʻAmakihi (*Hemignathus virens*) captured at Puʻu Waʻawaʻa in 1994 had poxlike lesions and two Hawaiʻi ʻAmakihi had active malarial infections. Additionally, H. Baker (unpubl. data) in 1995 found that 11.5% of Hawaiʻi ʻAmakihi had poxlike lesions. Disease related mortalities of native birds are greatest in the warmer months of August–November because of increased abundance of cold-intolerant mosquitoes at higher elevations where native birds are more common (C. Atkinson, unpubl. data). Although avian disease has been documented at Puʻu Waʻawaʻa, and our study was conducted during the warmer months when disease transmission would be expected to be highest, our data are too limited to determine whether avian disease prevents the recolonization of Puʻu Waʻawaʻa by native birds such as ʻŌmaʻo and ʻAkiapōlāʻau (*Hemignathus munroi*). However, our results and findings from challenge experiments that ʻŌmaʻo quickly recover from avian malaria infections (C. Atkinson, unpubl. data) suggest that avian disease would not preclude the establishment of ʻŌmaʻo in lower-elevation forests such as Puʻu Waʻawaʻa or the Kohala Mountains.

The highly male-biased sex ratio was a problem, and we were surprised that 18 of the 24 known-sex young from captive-hatched eggs were males. Additional validation of the DNA sexing method for Hawaiian solitaires is needed, but blood samples from three ʻŌmaʻo that died and were necropsied were all correctly sexed as males by Zoogen. Two field studies of banded ʻŌmaʻo populations found male-biased sex ratios (Wakelee 1996; C. J. Ralph, unpubl. data). It is usually assumed that a skewed adult sex ratio results from differential mortality between sexes (Breitwisch 1989, Lindsey et al. 1995a), but the excess of male ʻŌmaʻo in our sample of eggs is unexplained. It is interesting that Wake-

lee (1996) found a 2:1 male : female ratio among hatch-year and second-year 'Ōma'o, which could mean either that juvenile females have higher mortality than males, or that the sex ratio of 'Ōma'o is not 1:1 at hatching as our data suggest.

Most translocations and reintroductions require multiple releases of birds before a self-sustaining population is established (Griffith et al. 1989, Wolf et al. 1996). We observed breeding activity by captive-reared 'Ōma'o in December 1996 and found a juvenile 'Ōma'o at the release site in June 1997, but it is unlikely that a viable 'Ōma'o population will become established on Hualālai since the founding population contained only eight females by December 1996. Our results from the comparison of the two methods indicate that the reintroduction approach is more likely to result in successful establishment of Puaiohi and other endangered birds because reintroduced birds had greater fidelity to the release site. However, additional translocation experiments should be conducted to determine whether holding wild birds in hacking towers for > 7 days or translocating juvenile birds will increase fidelity to the release site. We support the recommendation, made more than 20 years ago by J. M. Scott and C. van Riper (pers. comm.), to reestablish 'Ōma'o in the Kohala Mountains and forests of leeward Hawai'i as part of the restoration of native Hawaiian ecosystems.

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