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Source: The Condor, 120(3) : 557-565

Published By: American Ornithological Society

URL: https://doi.org/10.1650/CONDOR-18-25.1

THE CONDOR
Ornithological Applications
AmericanOrnithology.org

Volume 120, 2018, pp. 557–565
DOI: 10.1650/CONDOR-18-25.1

COMMENTARY

Research and management priorities for Hawaiian forest birds

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Submitted February 2, 2018; Accepted April 17, 2018; Published June 27, 2018

ABSTRACT

Hawai'i's forest birds face a number of conservation challenges that, if unaddressed, will likely lead to the extinction of multiple species in the coming decades. Threats include habitat loss, invasive plants, non-native predators, and introduced diseases. Climate change is predicted to increase the geographic extent and intensity of these threats, adding urgency to implementation of tractable conservation strategies. We present a set of actionable research and management approaches, identified by conservation practitioners in Hawai'i, that will be critical for the conservation of Hawaiian forest birds in the coming years. We also summarize recent progress on these conservation priorities. The threats facing Hawai'i's forest birds are not unique to Hawai'i, and successful conservation strategies developed in Hawai'i can serve as a model for other imperiled communities around the world, especially on islands.

Key words: Hawai'i forest birds, island conservation, climate change, disease, non-native species

He mau makakoho noiʻi a hoʻomaluō no nā manu nahele Hawaiʻi

He nui nā pōpilikia pili hoʻomaluō e pōʻino nei nā manu nahele Hawaiʻi. Ke ʻole ka hoʻoponopono i ia mau pōpilikia he halapohe nō paha kekahi mau lāhulu manu ma nā kekeke e hiki koke mai ana. ʻO ka papapau o ko nā manu kaianoho, ka laupaʻi o nā lāhulu naʻi, ka laupaʻi o nā lāhulu poʻi iʻa ʻē, a me ka laha loa o nā maʻi lele ʻē kekahi o ia mau pōpilikia nui e ili nei ma luna o nā manu nahele Hawaiʻi. E ʻoi ʻino a e ʻoi laha nō ia mau pōpilikia i ka loliloli ʻana o ke aniau ma muli o ka Hoʻomehana Honua, a no laila he koʻikoʻi loa ka haku ʻana i mau papahana hoʻomaluō kūpono e ola ai ia mau manu. Ke hōʻike nei mākou ma kēia kōlamu i mau papahana noiʻi a i mau papahana hoʻomaluō i haku ʻia e mau kānaka hoʻomaluō ma Hawaiʻi nei. E koʻikoʻi nui loa ana ia mau papahana no ka hoʻomaluō ʻana i nā manu nahele Hawaiʻi ma nā makahiki e hiki mai ana. Hōʻuluʻulu hoʻi mākou i ka holomua hou o ia mau papahana hoʻomaluō. ʻAʻole ma Hawaiʻi wale nei nō nā pōpilikia e ili nei ma luna o ko Hawaiʻi mau manu nahele. E lilo hoʻi paha ko Hawaiʻi mau kaʻakālai hoʻomaluō i mau laʻana e hoʻohana ai ma nā kaiaola i ʻano pōpilikia like a puni ke ao, keu hoʻi ma nā mokupuni i like me Hawaiʻi.

Ka Papaʻōlelo Koʻikoʻi: nā manu nahele Hawaiʻi, ka hoʻomaluō ma nā mokupuni, Hoʻomehana Honua, maʻi, nā lāhulu ʻē

The forest birds of Hawaii, USA, are famous for their spectacular diversity as well as their conservation plight. Over millions of years, only a few species of terrestrial birds reached the world's most remote archipelago, but those that did radiated into many unique endemic species, best illustrated by the Hawaiian honeycreepers (Amadon 1950, Pratt 2005). However, with the arrival of humans and the many nonnative plants, animals, and diseases they brought with them, Hawaii's birds have experienced multiple waves of extinction. Following the arrival of Polynesians in about 800–1200 C.E., at least 71 species or subspecies went extinct (James and Olson 1991, Olson and James 1991), and another 24 species have gone extinct more recently, since the arrival of Europeans in 1778 (Banko and Banko 2009). Today, 21 species of forest birds on the main Hawaiian Islands are extant, of which 12 (57%) are endangered or threatened species (Table 1). Those that persist, including species classified as non-endangered, are in much-diminished numbers, with greatly contracted ranges mostly confined to high-elevation remnant forests dominated by native plants and out of reach of nonnative disease.

Research over several decades has identified key threats that shape current conservation strategies for Hawaiian forest birds. These threats include feral ungulates that degrade native forest; nonnative plants that can change

TABLE 1. Status and trends of forest birds on the main islands of Hawaii, USA, based on the most current estimates (data for Maui include the islands of Molokai and Lanai when applicable).

Species	Island	Population size (95% confidence interval)	ESA status [a]	IUCN status [b]	Trends	Source
Hawaiian Crow (*Corvus hawaiiensis*)	Hawaii	114 (start of 2016)	EN	EW	Extinct in wild [c]	Zoological Society of San Diego personal communication
Kauai Elepaio (*Chasiempis sclateri*)	Kauai	82,437 (60,973–107,155)		VU	Mixed	Paxton et al. 2016
Oahu Elepaio (*C. ibidis*)	Oahu	1,261 (1,205–1,317)	EN	EN	Declining	VanderWerf et al. 2013
Hawaii Elepaio (*C. sandwichensis*)	Hawaii	207,270 (191,346–223,194)		VU	Stable/declining	Camp et al. 2009
Omao (*Myadestes obscurus*)	Hawaii	170,452 (163,454–177,450)		VU	Stable	Camp et al. 2009
Puaiohi (*M. palmeri*)	Kauai	487 (405–579)	EN	CR	Stable?	Crampton et al. 2017
Akikiki (*Oreomystis bairdi*)	Kauai	468 (231–916)	EN	CR	Declining	Paxton et al. 2016
Alauahio (*Paroreomyza montana*)	Maui	34,839 (32,116–37,562)		EN	Stable/increasing	Camp et al. 2009
Palila (*Loxioides bailleui*)	Hawaii	1,934 (1,494–2,385)	EN	CR	Stable/declining	Camp et al. 2016
Akohekohe (*Palmeria dolei*)	Maui	6,745 (5,199–8,291)	EN	CR	Stable? [d]	Camp et al. 2009
Apapane (*Himatione sanguinea*)	Kauai	98,506 (62,863–117,435)		LC	Declining	Paxton et al. 2016
	Oahu	24,715 (21,730–27,700)		LC	Stable	Camp et al. 2009
	Maui	875,754 (852,230–899,278)		LC	Stable/increasing	Camp et al. 2009
	Hawaii	1,288,515 (1,245,354–1,331,676)		LC	Stable/increasing	Camp et al. 2009
Iiwi [e] (*Drepanis coccinea*)	Kauai	2,603 (1,789–3,520)	TH	VU	Declining	Paxton et al. 2016
	Maui	59,859 (54,569–65,148)		VU	Stable/declining	Paxton et al. 2013
	Hawaii	543,009 (516,312–569,706)		VU	Mixed	Paxton et al. 2013
Maui Parrotbill (*Pseudonestor xanthophrys*)	Maui	590 (382–798)	EN	CR	Stable? [d]	Camp et al. 2009
Akiapolaau (*Hemignathus wilsoni*)	Hawaii	1,496 (1,178–1,814)	EN	EN	Declining	Camp et al. 2009
Anianiau (*Magumma parva*)	Kauai	10,787 (8,396–13,434)		VU	Declining	Paxton et al. 2016
Hawaii Amakihi (*Chlorodrepanis virens*)	Hawaii	869,868 (816,446–923,410)		LC	Stable/increasing	Camp et al. 2009
	Maui	48,526 (64,017–51,035)		LC	Stable/increasing	Camp et al. 2009
Oahu Amakihi (*C. flava*)	Oahu	51,800 (46,500–57,100)		VU	Increasing	Camp et al. 2009
Kauai Amakihi (*C. stejnegeri*)	Kauai	6,519 (4,844–8,495)		VU	Declining	Paxton et al. 2016
Hawaii Creeper (*Loxops mana*)	Hawaii	12,501 (11,061–13,941)	EN	EN	Stable/declining	Camp et al. 2009
Akekee (*L. caeruleirostris*)	Kauai	945 (460–1,547)	EN	CR	Declining	Paxton et al. 2016
Hawaii Akepa (*L. coccineus*)	Hawaii	13,892 (12,067–15,717)	EN	EN	Stable/declining	Camp et al. 2009

[a] Endangered Species Act (ESA) status: EN = endangered, TH = threatened.
[b] International Union for Conservation of Nature (IUCN) status: EW = extinct in the wild, CR = critically endangered, EN = endangered, VU = vulnerable, and LC = least concern.
[c] Eleven individuals were released into the wild in 2017.
[d] Surveys in 2017 on Maui indicate declining populations of Akohekohe and Maui Parrotbill.
[e] Small numbers of Iiwi may occur on Oahu and Molokai.

forest structure and quality; nonnative predators such as cats, rats, and mongooses; nonnative animals that may compete for resources; and nonnative diseases that are highly lethal to native birds (van Riper and Scott 2001, Pratt et al. 2009; but see Smith et al. 2018). Extensive surveys across the islands (Scott et al. 1986) have identified, for all forest species, key forests that provide habitat. In most cases these are remote, high-elevation forests with largely native plant communities. Many of these important forests are on state and federal land, where they are afforded some level of protection, but most continue to degrade in the absence of active habitat management. Given the pervasive pressure from feral ungulates, invasive plants, and predators, Hawaii's forest birds are conservation-reliant species, requiring continuous management to maintain habitat quality (Scott et al. 2010). Unfortunately, inadequate resources force prioritization of conservation actions to address the many threats faced by Hawaii's forest birds (Leonard 2008).

To identify key conservation issues, a group of more than 60 people concerned with Hawaii forest birds, including researchers, land managers, policy makers, and other stakeholders, met to prioritize a set of actionable research and management items critical for near-term conservation. Here, we summarize priorities identified as necessary to conserve Hawaii's forest birds in light of ongoing threats and a rapidly changing environment. While there have been other efforts to highlight research and management needs, such as the Hawaii Forest Bird Recovery Plan (U.S. Fish and Wildlife Service [USFWS] 2006), a special volume of Studies in Avian Biology (Scott et al. 2001), and a comprehensive book (Pratt et al. 2009), new threats, new research and management tools, and changing priorities require periodic assessments of conservation priorities. Our summary indicates the breadth of actions the Hawaii forest bird conservation community believes are necessary to reverse the historical pattern of declines and extinctions. Conservation challenges facing Hawaiian forest birds are similar to challenges in areas around the world (e.g., invasive species, emerging diseases), and the conservation strategies developed in Hawaii to meet these challenges can serve as a model for other avian communities in peril.

Implement Landscape-Level Mosquito Control Program

Nonnative vector-borne diseases, such as avian malaria and avian pox, likely caused the extinction of multiple species over the past century and remains the greatest threat to forest birds today. There is a strong relationship between temperature and the distribution of the nonnative southern house mosquito (*Culex quinquefasciatus*), which vectors avian malaria and pox in Hawaii (LaPointe et al. 2010). This tropical mosquito and the malaria parasite both require warm temperatures for development, which restricts the distribution of avian malaria in Hawaii such that malaria transmission occurs year-round at low elevations, occurs seasonally at middle elevations (late summer to fall), and is unable to establish in elevations above ~1,500 m, making high-elevation forests largely disease free (LaPointe et al. 2010). However, global warming is expected to increase temperatures 1–2°C by 2100, which should facilitate the movement of mosquito-borne diseases into increasingly higher-elevation forests, where the most disease-sensitive forest birds still persist (Benning et al. 2002, Liao et al. 2015). Climate projection models suggest large-scale changes in climatic conditions for all Hawaii forest bird species by 2100, with some species that reside on low-lying islands (such as Kauai) losing up to 100% of currently suitable climatic space (Fortini et al. 2015). In particular, warming temperatures and changes in precipitation may allow diseases to expand their ranges into currently disease-free areas. Models of the malaria-vector-bird-disease system under future climatic conditions indicate variable response among bird species, depending on sensitivity to disease; but most, if not all, species are likely to experience declines as disease prevalence increases at middle and high elevations (Liao et al. 2015). For highly mobile species, such as the nectarivorous Iiwi, seasonal movements into mid-elevation forests can greatly exacerbate the effects of changing disease distribution (Guillaumet et al. 2017). While there is uncertainty in both the future climate and the consequences for ecological communities, all models strongly agree that diseases will increase in both range and prevalence, which presents an existential threat to most native Hawaiian forest birds.

Vector control is the most promising pathway to breaking the disease-vector-host cycle. Traditional methods of mosquito control such as widespread application of insecticides (e.g., aerial spraying) is not an option because arthropods are a food resource and conservation of native arthropods is also a priority. However, proven methods such as treatment of larval habitat with *Bacillus thuringiensis israelensis* (*Bti*), a bacterium toxic to mosquitoes, could be implemented for localized control around important bird breeding areas with low nontarget impacts. Recently, new methods have been developed for landscape-level control of mosquitoes, including bacteria (*Wolbachia* spp.) to interfere with reproduction, and genetic engineering to insert a self-limiting gene (Alphey 2014). None of these approaches have been tested at the scale needed in Hawaii, and the rugged, steep, and inaccessible terrain across many Hawaiian forests presents technical difficulties that are not currently being addressed. Implementation in Hawaii would require a number of steps, including significantly increasing mosquito mass rearing capacity, methods for deploying the mosquitoes across the landscape (specifically an aerial deployment capacity), and more robust monitoring tools to inform release efforts. In addition to technical challenges, Hawaii needs more social engagement, as the state does not currently have a robust mosquito-abatement program. Therefore, in parallel with technology development, an effective engagement campaign is needed to link forest bird conservation with mosquito control to gain the support of the public (outreach) and agencies (inreach) to ensure social license for successful landscape-level mosquito control.

As new strategies for vector control advance nationally, several groups have been formed or reconstituted in Hawaii for the purpose of coordinating efforts and developing strategies to control vectors of both human and bird diseases. These include the Hawaii State Mosquito Working Group, the USFWS Avian Malaria Vector Control Working Group, and a 2016 Mosquitoes in Hawaiʻi Workshop (http://www.cpc-foundation.org/uploads/7/6/2/6/76260637/report_on_mosquito_free_workshop.pdf). Additionally, researchers are testing different control approaches, including field trials of *Bti* on Kauai, to study their effectiveness for local mosquito control, and inserting different *Wolbachia* strains into southern house mosquitoes in lab trials to determine the effectiveness of a *Wolbachia*-based control method for use in Hawaii. Any successful vector control campaign, whether for public health or forest bird conservation, will need to incorporate a variety of tools, taking an integrated pest management approach.

Understand the Genetic Basis of Disease Immunity

Vector control may not completely eliminate disease transmission, and ultimately birds will have to evolve immune responses to disease. Encouragingly, some species are developing immunity (resistance or tolerance) to avian malaria, including low-elevation populations of the Hawaii Amakihi (Atkinson et al. 2013) and Oahu Amakihi (Krend 2011) (for scientific names of study species, see Table 1). Other species—such as the Apapane, Oahu Elepaio, Hawaii Elepaio, and Omao—persist at middle to low elevations where disease occurs (Camp et al. 2009), which suggests reduced mortality from disease (Atkinson and LaPointe 2009). Nonetheless, the majority of Hawaiian forest birds are believed to be highly vulnerable to disease (Warner 1968, van Riper et al. 1986), and there is concern over whether they have sufficient genetic variation to evolve disease immunity in the near future, given that they currently exist in small, fragmented populations. Modern genomic approaches hold the prospect of identifying genes that increase resistance and tolerance to diseases, such as avian malaria, which will help identify populations evolving immunity. The National Science Foundation has recently funded research in Hawaiian honeycreepers to (1) identify genes associated with increased immunity, (2) study the genomic basis of the bird-parasite-vector system for avian malaria, and (3) understand how that system might change under future climatic conditions. This will provide valuable information on the evolutionary capability of Hawaiian birds to adapt to changing disease levels. Identification of key genes could lead to strategies for augmenting the evolution of immunity, such as targeted translocations from populations with reduced disease mortality, selective breeding for genes associated with higher immunity, or genetic modification of birds to enhance immunity (Thomas et al. 2013).

Protect Key Habitat for Forest Birds

Even with a reduction in the threat of disease, there still would be considerable conservation challenges for Hawaii's forest birds. The distribution and quality of forest habitat, following large-scale deforestation and degradation, remains a central concern for the long-term persistence of forest birds. New threats are constantly emerging, and the value of strengthened biosecurity in Hawaii is a key component of habitat protection. For example, a recently introduced wilt pathogen (*Ceratocystis* sp.), commonly referred to as "rapid ʻohiʻa death" or ROD, has been responsible for extensive mortality of ʻohiʻa lehua (*Metrosideros polymorpha*; Keith et al. 2015), a keystone tree species in Hawaiian forests and an important resource for some Hawaiian birds. Recent conservation actions have focused on protecting high-elevation, native-dominated forests. This should continue to be a key conservation strategy, as those forests continue to support the rarest species in Hawaii and are predicted to do so into the future as climate change threatens lower-elevation habitats (Benning et al. 2002). Protecting existing habitat continues to be a major conservation strategy for conserving forest birds and their habitat, with $>$30,000 ha receiving additional protection in 2015–2017 through new acquisitions, fencing and removal of nonnative ungulates, and nonnative plant control. In addition, restoration of deforested areas is beginning to pay dividends through the colonization of forest birds into previously deforested pasture lands (Paxton et al. 2018, Pejchar et al. 2018). However, there is also potential value in mid- and low-elevation forests that, although not currently considered high-priority habitats, could support some species of native birds. For example, areas on native–nonnative forest edges and diseased–disease-free boundaries may be areas critical for the future of the forest birds as "evolution preserves," where evolution of traits adapted to nonnative conditions would be encouraged through direct management (Kilpatrick 2006). Additionally, with anticipated changes brought on by climate change, models of future bird distributions (Fortini et al. 2015) and habitat changes (Vorsino et al. 2014) could be combined strategically to designate areas for restoration efforts that will become critical several decades in the future. The continuing development and refinement of climate change models under plausible emission scenarios will help with planning for future challenges.

Assess the Efficacy of Predator Control

Nonnative predators pose additional threats to Hawaiian forest birds. Black rats (*Rattus rattus*) are likely the most significant nest predator, preying on nests and possibly on incubating females (Moors et al. 1992), although feral cats (*Felis catus*) and Javan mongooses (*Herpestes javanicus*) may be important predators for some species (Hess et al. 2009). There is widespread agreement that rats can be harmful, even at low levels, and that rat control also would benefit endemic plant, snail, and arthropod communities (Moors et al. 1992). For some species, such as the Oahu Elepaio and the Puaiohi, rat control may be essential for population persistence (Tweed et al. 2006, VanderWerf 2009), whereas other species have apparently low nest predation rates and may not be as strongly affected by predators (Cummins et al. 2014, Hammond et al. 2015). Currently, a number of rat-trapping programs are underway to protect specific species, including the Akekee and Akikiki on Kauai, the Oahu Elepaio on Oahu, the Maui Parrotbill on Maui, and the Hawaiian Crow on Hawaii Island, but none of these programs are specifically evaluating the effect of the treatment on the bird populations. Historical efforts to control rats for the purpose of improving forest bird demographics have produced mixed results—positive outcomes for the Oahu Elepaio (VanderWerf and Smith 2002), but ambiguous or no discernible benefits for other species (Tweed et al. 2006, Sparklin et al. 2010). Given the cost of control efforts and limited resources for management actions, more research is needed on the efficacy of rat control to understand which species would benefit, what levels of effort would be needed to discern a benefit response for those species, and whether other management could have greater benefits (Armstrong et al. 2006).

Conduct Reintroductions and Translocations to Achieve Conservation Goals

Conservation of Hawaii's forest birds will increasingly require more direct actions, such as reintroductions of captive species back into former portions of their range, and translocations to either historical or new areas to increase geographic distributions and decrease the risk of extinction. Translocation of bird species has a long history in Hawaii, where past translocations of the Palila (Fancy et al. 1997), Omao (Fancy et al. 2001), Poo-uli (*Melamprosops phaeosoma*) (Groombridge et al. 2004), and Iiwi (Becker et al. 2010) had initial success but did not establish long-term self-sustaining populations. Currently, 3 projects are underway or planned for the next several years: (1) reintroduction of Hawaiian Crows, extinct in the wild since 2002, to a historical portion of its range in Puʻu Makaʻala Natural Area Reserve (NAR), Hawaii Island; (2) introduction of Maui Parrotbills to restored habitat on the southern slopes of East Maui to provide a new, geographically distinct population; and (3) translocation of the frugivorous Omao from occupied forests on the eastern side of Hawaii Island to forests on the western side of the island. In addition to serving as a model for future translocation, the Omao translocation also aims to return seed-dispersal services. The release of Hawaiian Crows into the wild in 2016 and 2017 began the process of reestablishing wild populations, with the most recent effort (fall 2017) resulting in a population of 11 reintroduced individuals. Additional releases are planned for 2018. On Maui, plans are moving forward for an early 2019 introduction of Maui Parrotbills in the Nakula NAR, which will include a mix of captive and wild birds. Increasingly serious discussions have considered introductions to novel locations—particularly for endangered Kauai birds (e.g., Akikiki and Akekee), which may not be able to persist in their historical range in the near future (Fortini et al. 2015, Paxton et al. 2016)—on neighboring islands that have forest habitat at elevations with low disease prevalence but similar climatic conditions (Fortini et al. 2017). A first step could be translocating the Akekee (i.e. the Kauai Akepa) to Maui, where its sister species the Maui Akepa (*Loxops ochraceus*) is presumed extinct. Such a translocation could restore historical ecological function and reduce the extinction risk for the Kauai endemic, although identifying and rectifying the causes of extinction for the Maui Akepa would need to be evaluated and possibly rectified.

Strengthen Captive Breeding Capacity

Captive breeding has a long history as part of Hawaii's conservation efforts to prevent extinctions (Lieberman and Kuehler 2009). Two facilities are currently managed by the Hawaii Endangered Bird Conservation Program—a partnership between the Zoological Society of San Diego, Hawaii State Division of Forestry and Wildlife, and USFWS—to support forest bird species, including the Hawaiian Crow, Puaiohi, Maui Parrotbill, Palila, and, most recently, the Akikiki and Akekee. With their resources increasingly limited, these facilities have ended their program for the Puaiohi and will end the Maui Parrotbill program within the next 2 yr as part of the planned Maui Parrotbill introduction to Nakula NAR (see above). However, the needs for the program remain, and a new focus of the captive program from 2015 to present has been the harvesting of eggs from Akikiki and Akekee on Kauai to establish a robust captive population to prevent extinction. As of fall 2017, the captive population consisted of 39 Akikiki and 6 Akekee, with one pair of Akikiki attempting to breed in captivity in 2017. Although captive breeding is an important tool to prevent extinction, it is only a stopgap measure. The ultimate goal is to be able to return birds to the wild, introduce them to a new area, or augment small population sizes. Unfortunately, this overall goal has not been achieved for any of the Hawaiian forest bird captivity programs to date. Captive breeding efforts for the Palila and Maui Parrotbill were unable to increase captive population sizes and are now being phased out. Captive breeding efforts for the Puaiohi, by contrast, were successful, but captive-bred individuals released into the wild had low survival (VanderWerf et al. 2014), and this program has also been phased out. A reintroduction effort for the Hawaiian Crow in the 1990s was ultimately unsuccessful, and while the most recent effort to reestablish this species in the wild has gone well so far, there are still many steps left before it can be considered reestablished in the wild. Challenges moving forward include increasing capacity in the captive breeding program to manage both current populations and the likely establishment of new species and ensuring that captive populations are large enough to maintain genetic diversity over potentially long periods until repatriation into the wild (Lacy 1987). At the same time, future captive propagation efforts should have clear plans and success benchmarks for bringing captive individuals back into the wild, including how long it may take to reach those goals and size requirements of captive populations.

Reassess Monitoring Strategies

The Hawaii Forest Bird Surveys (Scott et al. 1986), which surveyed forest birds across the Hawaiian Islands in the 1970s and ’80s, set a standard for survey methods and have been the baseline for most subsequent monitoring in Hawaii (Camp et al. 2009). While the current monitoring scheme provides long-term trend information over large areas, it is largely inadequate for measuring rapid changes in population sizes, detecting small to moderate density changes in rare species, or detecting distributional shifts along elevational gradients. Recently, a working group has been formed to address the inadequacy of current survey methodology, identify improvements, and help organize a multi-agency, multi-NGO partnership that could allow large-scale monitoring objectives to be met with limited resources. Adoption of new monitoring protocols may entail abandoning some long-term surveys, potentially losing decades of valuable trend information, but may increase precision (e.g., Gorresen et al. 2016). However, a mixed approach of continued long-term surveys at key locations—coupled with surveys along elevational gradients to detect range contraction, demographic studies to monitor survival and productivity in 2 or 3 key locations, and targeted surveys for endangered species—may be possible with existing financial resources, especially if efforts are coordinated across different landowners and combined for analysis at the landscape level. Tools like eBird (Sullivan et al. 2009) may allow citizen science to contribute to monitoring needs, which could help defray costs, increase the geographic scope of survey areas, encourage public participation, and promote public support for conservation issues, but with a trade-off in quality control and potential for analysis.

Establish a Hawaii Forest Bird Leadership Group

Leadership on Hawaii forest bird conservation is currently decentralized, with island-specific groups of researchers and managers focused on high-profile endangered species. Yet there is a strong need for a group with a geographic scope that covers all the islands and all species of forest birds (not just endangered species) that can help prioritize conservation strategies, coordinate responses to emerging threats, establish lines of communication (e.g., list servers, forums), and coordinate periodic meetings. A unified message on the conservation needs of Hawaii’s forest birds is also essential for educating and preparing the public, policy makers, and legislators for the costs and difficult decisions that will be needed to address challenges for Hawaii forest birds. This could include articulating the ecological and cultural importance of native Hawaiian species, promoting education on vector control methods, and providing information on endangered species management to landowners. Further, given the discrepancy between conservation needs and current funding levels, it will be necessary to identify new sources of funding beyond traditional government sources. A leadership group could help coordinate the mix of funding from government, private foundations, NGOs, crowdsourcing campaigns, and private citizens that will be needed to ensure sufficient and consistent funding levels.

The framework for a Hawaii forest bird leadership group has recently been established to fill this void. The overall organization consists of a Steering Committee and a number of subgroups focused on specific topics. The Steering Committee’s role is to ensure communication across the subgroups and the overall conservation community, as well as advise agencies on major issues. The subgroups are organized with a group leader and set of members who are active in, or interested in, the respective topic. The number of subgroups is likely to change over time, but the founding ones are (1) Kauai Forest Bird Recovery Project, (2) Maui Forest Bird Recovery Project, (3) Alala Working Group, (4) Mauna Kea Forest Restoration Project, (5) Big Island Forest Bird Conservation Group, (6) Translocation and Reintroduction, (7) Hawaii Forest Bird Monitoring Group, (8) Disease and Vectors Impacting Hawaii Forest Birds Group, and (9) Hawaii Forest Bird Outreach Group.

Conservation Focus on Kauai

Conservation concern in Hawaii is particularly focused on Kauai Island, where the native forest bird community is experiencing rapid declines (Paxton et al. 2016). Analysis of survey data indicates that 6 of 8 native species are rapidly declining across their range; the other 2 are the Kauai Elepaio, which is declining on the periphery of its range, and the Puaiohi, which is already so rare that long-term trends are difficult to determine. The crisis on Kauai represents an immediate challenge, to which we can apply the approaches described above. Threats include loss of disease-free habitat, continued degradation of habitat, and introduced predators, although there is uncertainty about the relative importance of these threats. Eight specific conservation steps have been identified that could be undertaken in the near term:

1. Immediately implement a phased vector control program.
2. Continue ongoing efforts to protect and restore core forest habitats.
3. Implement a demographic study to understand key drivers of the ongoing declines (low adult survival, low recruitment, or low productivity).
4. Quantify movement patterns of Akikiki and Akekee to understand the spatial extent required for vector control.
5. Estimate mosquito population size and immigration rates to accurately scale future vector control efforts.
6. Identify numerical thresholds of declining populations of species not currently listed as threatened or endangered to determine at what point listing is possibly warranted.
7. Survey low-elevation forests for native species before and after vector control to assess distributional responses to the vector control.
8. Expand outreach to increase conservation attention and funds to the Kauai conservation crisis.

Currently, tests are underway using *Bti* for localized mosquito control, and local outreach by the Kauai Forest Bird Recovery Project has been ongoing. However, many of the identified research needs and landscape-level vector control efforts have gone unfunded, while bird populations continue to decline precipitously.

ACKNOWLEDGMENTS

The prioritization of research and management needs came out of a Hawaii Forest Bird Conservation Forum held in Honolulu in 2015. Christine Ogura was our superb facilitator, and Tracy Borneman did a tremendous job helping organize the forum. The Hawaii Department of Land and Natural Resources provided facilities for the forum. Mahalo to Noah Gomes for the Hawaiian language abstract. Our thanks to the participants who helped develop the priorities presented in this paper: K. Asing (DOFAW–MKFRP), C. Atkinson (USGS–PIERC), D. Ball (USFWS–ES), P. Banko (USGS–PIERC), M. Bogardus (USFWS–ES), T. Borneman (HCSU), J. Burgett (USFWS–Pacific Islands Climate Change Cooperative [PICCC]), K. Burnett (UH Hilo), E. Campbell (USFWS), M. Clark (USFWS), C. Cole (Three Mountain Alliance), S. Conant (UH Manoa, retired), M. Costantini (Kauai Forest Bird Recovery Project), C. Crampton (Kauai Forest Bird Recovery Project), D. Duffy (PCSU–UH), F. Duvall (DOFAW), S. Evans-Peters (Pacific Birds Habitat Joint Venture), J. Fisher (USFWS), R. Fleischer (Smithsonian Institution), L. Fortini (USGS–PIERC, PICCC), B. Gagne (DLNR–DOFAW–NARSC), J. Gaudioso-Levita (USGS–PIERC), M. Hagemann (Bishop Museum), S. Hall (NFWF), D. Helweg (USGS), J. Hite (Kauai Forest Birds), J. Hoskins (USFWS–Migratory Birds), D. Hu (National Park Service), J. Jacobi (USGS–PIERC), L. Kaiser (UH), G. Koob (USFWS, coordinator for Conservation and Restoration Program), J. Kraus (USFWS–Hakalau Forest NWR), D. LaPointe (USGS–PIERC), B. Masuda (Hawaii Endangered Bird Conservation Program, San Diego Zoo), S. Miller (USFWS), R. Monello (National Park Service–HAVO–I&M Program), H. Mounce (Maui Forest Bird Recovery Project), A. Nadig (USFWS–ES), J. Nelson (USFWS), C. Ogura (USFWS), W. Peterson (PICCC), T. Pratt (USGS–PIERC), J. Price (UH Hilo), F. Reed (UH Manoa), S. Robertson (National Park Service–Hakeakala NP), R. Rounds (USFWS), T. Rubenstein (DOFAW), J. Rubey (Pacific Birds Habitat Joint Venture), J. Sutton (UH Hilo), J. Tamayose (National Park Service–Hakeakala NP), D. Tessler (USFWS), G. Tribble (USGS–PIERC), J. Underwood (USFWS), E. VanderWerf (Pacific Rim Conservation), A. Vorsino (USFWS), G. Wallace (American Bird Conservancy), C. Warren (Maui Forest Bird Recovery Project), M. Wilson (Bishop Museum), and K. Young (USFWS).

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