Technical Report HCSU-103

HAWAIIAN FOREST BIRD CONSERVATION STRATEGIES FOR MINIMIZING THE RISK OF EXTINCTION: BIOLOGICAL AND BIOCULTURAL CONSIDERATIONS

Eben H. Paxton[1], Megan Laut[2], Stanton Enomoto[3], and Michelle Bogardus[2]

[1] U.S. Geological Survey, Pacific Island Ecosystems Research Center, Kīlauea Field Station, P.O. Box 44, Hawai‘i National Park, HI 96718

[2] U.S. Fish and Wildlife Service, Pacific Island Office, 300 Ala Moana Blvd., Honolulu, HI 96850

[3] U.S. Department of the Interior, Office of Native Hawaiian Relations, 300 Ala Moana Blvd., Honolulu, HI 96850

Hawai‘i Cooperative Studies Unit
University of Hawai‘i at Hilo
200 W. Kawili St.
Hilo, HI 96720

(808) 933-0706

April 2022

Citation: Paxton, E. H., M. Laut, S. Enomoto, and M. Bogardus. 2022. Hawaiian forest bird conservation strategies for minimizing the risk of extinction: Biological and biocultural considerations. Hawaiʽi Cooperative Studies Unit Technical Report HCSU-103. University of Hawaiʽi at Hilo, Hawaii, USA. 125 pages. http://hdl.handle.net/10790/5386

This product was prepared under Cooperative Agreement CAG16AC00281 for the U.S. Geological Survey Pacific Island Ecosystems Research Center.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Hōʻuluʻulu Manaʻo

Ke hālāwai nei nā manu o ka nahele o Hawaiʻi me ka pōpilikia maluō. Ma ka pae ʻāina ʻo Hawaiʻi, ke emi mai nei nō ka nui manu a keu aku ma nā makahiki he 10 a 20 i hala aku nei. I loko nō o ka pā hewa o ka manu no nā makahiki he lōʻihi a he mau haneli i ka nele o kahi e noho ai, ka lāhulu komo hailapu, a me ka poʻiʻa malihini, ʻo ka maʻi malihini, ʻo ia hoʻi ka *avian malaria*, ka mea nui e pau nei ka manu ʻānō. Ua piʻi pū hoʻi ka mehana o ka nahele o nā wao kiʻekiʻe aʻe i ka mehana honua e laha ai ua maʻi nei i nā wahi loaʻa mua ʻole o ua maʻi nei. Ua lilo ka pau ʻemo ʻole ʻana o ka manu he kumu e pau nei ka ʻehā lāhulu manu mūkīkī i ka make loa: ʻo ka ʻakikiki (*Oreomystis bairdi*) lāua me ka ʻakekeʻe (*Loxops caeruleirostris*) ma ka mokupuni ʻo Kauaʻi a me ke kiwikiu (*Pseudonestor xanthophrys*) lāua me ka ʻākohekohe (*Palmeria dolei*) ma ka mokupuni ʻo Maui. Ua lōkahi ka manaʻo o nā akeakamai kālaimeaola nāna e noiʻi ana i kēia poʻe manu, he nui loa ka papaha o ka pau o ua mau lāhulu nei i ka make loa i loko o nā makahiki he ʻumi e hiki mai auaneʻi ke paʻa ʻole ke kiʻina hoʻomaluō e lapaʻau ai. I mea e kālailai ʻia ai nā kaʻakālai hoʻomaluō e emi ai ka pau loa ʻana o ka manu i ka make loa, ua hoʻohui ʻia nā mea mākaukau o nā ʻano like ʻole nona ka ʻike laulā i ka manu o ka nahele a kaiaola o Hawaiʻi a me nā ala hoʻomalu e noʻonoʻo ʻia ana e noiʻi ai i ka papaha o ka puka o ua mau kiʻina hoʻomalu nei. Ma waho o ka noiʻi i ka pōpilikia ma ke kuanaʻike kālaimeaola, ua hoʻohui pū ʻia he hui o nā kānaka Hawaiʻi nona ka pilina ikaika i ka manu o ka nahele, ka nahele, a me ka ʻāwili ʻia o ka moʻomeheu Hawaiʻi ma ka hoʻomalu kumuwaiwai ao kūlohelohe e komo ai ka manaʻo i ka mea nui o ka manu i ke kānaka Hawaiʻi me ka hāpai pū ʻia o ka manaʻo no nā kiʻina hoʻomalu pū kekahi. Ma ka laulā, he ʻekolu kiʻina hoʻomalu e noʻonoʻo ʻia nei he ala e pau ʻole ai ka manu o ka nahele i ka make loa, 1) ke kāohi makika ma o ka *Wolbachia* incompatible insect technique, 2) ka hānai kaʻawale, a me 3) ka hoʻomaluō kaʻawale. ʻO ka manawa a me ka ʻaʻa i ka hana nā kumuloli nui ʻelua o ke pani i ka pau ʻana o kēia mau lāhulu manu ʻehā i ka make loa. No kēlā me kēia lāhulu, kākaʻikahi nō ke koe ʻana mai o kona mau manu a ke hālāwai maoli nei nō me ka pōpilikia o pau i ka make loa. He wā ka mea e pono ai kēlā me kēia kiʻina hoʻomalu e hele ana paha a ma ʻō aku o ka manawa e pau ai ua mau manu nei i ka make loa. He hopena maikaʻi a maikaʻi ʻole nō paha ko kēia mau kiʻina hoʻomalu, a pēlā pū ke kānalua nui i ka puka a me ka puka ʻole nō paha. ʻOkoʻa pū ke kuanaʻike o ke kānaka Hawaiʻi no kēlā me kēia kiʻina hoʻomalu. Hōʻike nā manaʻo o nā mea mākaukau i hōʻuluʻulu ʻia ma kēia moʻolelo he ʻike laulā no nā kiʻina hoʻomaluō e lawelawe ʻia e pani ʻia ai ka pau ʻana o ka ʻakikiki, ka ʻakekeʻe, ke kiwikiu, a me ka ʻākohekoke i ka make loa. I loko nō o ka hāpai ʻole ʻia o nā kiʻina ponoʻī, i mea hoʻi ka ʻike o loko e kākoʻo ʻia ai nā mea nona ka mana hoʻoholo ma ke koho paha i ke kiʻina hoʻomaluō e ʻimi ʻia aku.

ABSTRACT

The iconic forest birds of Hawaiʽi are facing a conservation crisis. Across the Hawaiian Islands, native forest birds have been experiencing population declines that have accelerated in the last one to two decades. While habitat loss, invasive species, and non-native predators have negatively affected forest bird species for hundreds of years, and continue to do so, introduced diseases, particularly avian malaria, are the greatest threat to forest birds today. Further, climate change has increased temperatures in the high-elevation forests, facilitating the spread of disease into areas that were once largely disease-free. Rapid population declines have now (2022) pushed four Hawaiian honeycreeper species to the brink of extinction: the endangered ʽakikiki (*Oreomystis bairdi*) and ʽakekeʽe (*Loxops caeruleirostris*) on Kauaʽi Island, and kiwikiu (*Pseudonestor xanthophrys*) and ʽākohekohe (*Palmeria dolei*) on Maui Island. The biologists that study these birds strongly agree that without a rapid conservation response to the threat of increasing disease mortality there is a high probability these species will go extinct in the coming decade. To help evaluate alternative conservation strategies for minimizing the risk of extinction, we convened diverse groups of experts with broad experience in Hawaiʽi forest birds and ecosystems, as well as the management approaches being considered, to assess the probability of success of alternative management actions. In addition to assessing this crisis from a biological perspective, we convened a group of Native Hawaiian participants that have a strong connection to the forest birds, forests, and the integration of their culture in natural and biocultural resource management. They give voice to the significance of forest birds to Native Hawaiians and provide their perspectives on alternative management actions. Broadly, the three alternative management actions being considered to prevent the extinction of forest birds from the increasing threat of disease are (1) landscape-level mosquito control through the *Wolbachia* incompatible insect technique, (2) captive care, and (3) conservation translocations. The two key components of the problem of preventing extinction in these four bird species is time and risk. For each species, very few individuals remain, and they are all in danger of imminent extinction. Each management action takes time to implement, which might exceed the actual time to extinction. Additionally, each of these conservation actions has potential benefits and inherent risks, as well as substantial uncertainty in terms of being successful. Native Hawaiian perspectives and considerations also vary across the conservation actions. The expert evaluations summarized in this report provide a broad assessment of conservation strategies that could be undertaken to prevent the extinction of ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe. While this report does not recommend specific actions, the information is intended to support decision-makers as they assess which, if any, conservation strategies to pursue.

INTRODUCTION

The Hawaiʽi Forest Bird Conservation Crisis

The iconic forest birds of Hawaiʽi are facing a conservation crisis. Of the more than 50 species once present across the Hawaiian Islands, only 21 remain, and over half of those remaining are listed as Endangered or Threatened species under the U.S. Endangered Species Act (Pratt *et al.* 2009). Across the islands, forest birds have been experiencing sustained population declines, and these declines have accelerated in the last one to two decades (Paxton *et al.* 2018). On Kauaʽi, rapid declines in all six remaining honeycreeper species have occurred despite increasing management efforts, signaling the collapse of the forest bird community (Paxton *et al.* 2016). On Maui, forest bird populations of all three endemic species are also declining rapidly and their ranges have contracted to higher elevation forests (Judge *et al.* 2021). This evidence of rapid declines across islands indicates a new dynamic is underway in high-elevation Hawaiian forests (Liao *et al.* 2015).

While habitat loss, invasive species, and non-native predators have negatively affected forest bird species for hundreds of years and continue to do so, introduced diseases, particularly avian malaria, are the greatest threat to forest birds today. In Hawai'i, avian malaria is spread by the tropical southern house mosquito (*Culex quinquefasciatus*), with both the mosquito and the malaria parasite (*Plasmodium relictum*) requiring warm temperatures for development (LaPointe *et al.* 2010). Historically, this developmental requirement has resulted in cooler high-elevation forests (approximately >1500 m) to remain disease free, and most conservation actions have focused on protecting and restoring these remote forests (Figure 1). However, climate change has increased temperatures in the high-elevation forests (Fortini *et al.* 2020), and mosquitoes and disease are spreading into areas that were once largely disease free (Atkinson *et al.* 2014). This trend of spreading distribution and intensity of disease in the last Hawaiian forest bird sanctuaries is predicted to increase in coming decades (Fortini *et al.* 2015), and we see evidence of increased disease exposure in numerous populations across the Hawaiian Islands (Atkinson *et al.* 2014). Thus, even in forests under active management to protect habitat and reduce threats, forest birds are vulnerable to the increasing range and intensity of disease driven by the rapidly changing climate.

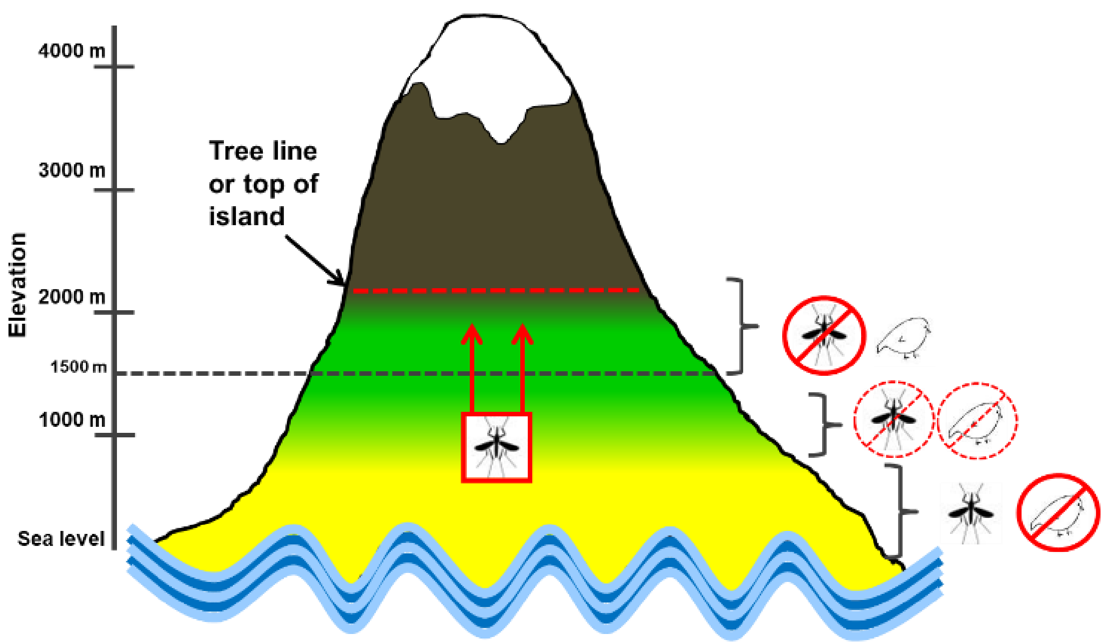


Figure 1. Temperature and elevation affect the distribution and intensity of avian malaria in Hawai'i. Climate change is aiding the rapid movement of disease into disease-free forests. At low elevations, mosquitoes breed year-round, and disease transmission is too intense for most native bird species to persist. At mid-elevations, up to 1500 m, disease is more seasonal, and some native species persist. Only at the highest elevation forests, above 1500 m, are temperatures too cool for mosquitoes and the malaria parasite to develop, resulting in forest habitat with little to no disease transmission. However, climate change is allowing mosquito populations to invade new areas, increasing disease distribution across the Hawaiian Islands.

Species of Immediate Concern

Multiple species of Hawaiian forest birds have experienced population declines in recent decades. The rapid declines of four forest bird species in particular have brought them to the brink of extinction: the endangered honeycreepers ʻakikiki (*Oreomystis bairdi*) and ʻakekeʻe (*Loxops caeruleirostris*) on Kauaʻi, and kiwikiu (*Pseudonestor xanthophrys*) and ʻākohekohe (*Palmeria dolei*) on Maui (Figure 2).

Figure 2. The four Hawaiʻi forest birds most at risk of extinction from climate change driven expansion of avian malaria. From left to right are the ʻakikiki and ʻakekeʻe from Kauaʻi and the kiwikiu and ʻākohekohe from Maui. Photographs provided by Justin Hite for ʻakikiki, Lucas Behnke for ʻakekeʻe, Zach Pezzillo for kiwikiu, and C. Robby Kohley for ʻākohekohe.

Long-term, systematic surveys for forest birds conducted on the islands of Kauaʻi and Maui have documented contracting populations and sharp declines (Table 1, Figure 3; Paxton *et al.* 2020, Judge *et al.* 2021). While other forest birds on the same islands have also experienced concerning declines, their larger population sizes to date puts the risk of extinction farther out on the time horizon.

Table 1. Population abundance estimates (mean with 95% confidence interval) from the most recent survey results (2017 for Maui, 2018 for Kauaʻi), estimated range contraction (%), and annual rate of decline (%) from 2000–2017/2018. Data are from Paxton *et al.* 2020 and Judge *et al.* 2021.

Species	Survey abundance	Estimated range contraction (%)	Annual decline (%)
ʻAkikiki	454 (120–886)	-68	-5
ʻAkekeʻe	1,162 (643–1,698)	-60	-23
Kiwikiu	157 (44–312)	-41	-13
ʻĀkohekohe	1,768 (1,193–2,411)	-61	-16

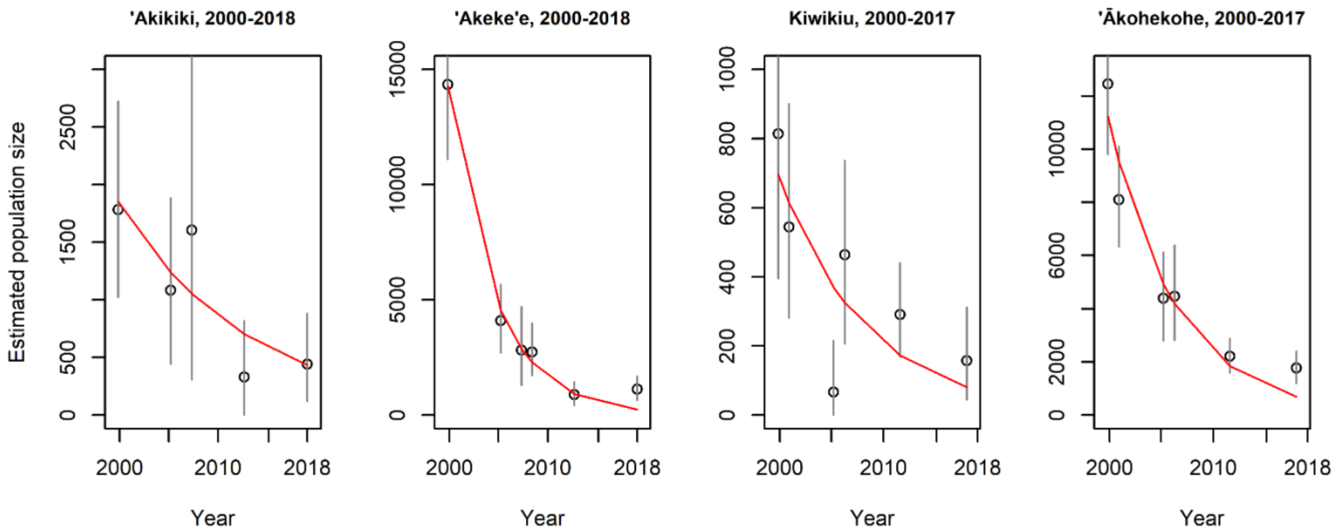


Figure 3. Population sizes and trends for four Hawaiian forest bird species from 2000 to 2017 (Maui) and 2018 (Kauaʽi). Open circles are mean abundance estimates, with bars representing the 95% confidence interval range. Data are from Paxton *et al.* 2020 and Judge *et al.* 2021.

ʽAkikiki and ʽakekeʽe were once fairly common on the Alakaʽi Plateau of Kauaʽi (Scott *et al.* 1986), but in the early 2000s they began to experience rapid population declines (Figure 3) (Paxton *et al.* 2016). The survey results are several years old, and current (2021) results are much lower (see below). Additionally, other methods of population monitoring support rapid declines. For example, recent territory mapping from the core of ʽakikiki's range (Halepaʽakai) has shown a steep decline from 27 pairs in 2018 to one pair and two single males in 2021 (Lisa Crampton, Kauaʽi Forest Bird Recovery Project, written communication, 2021). For ʽakekeʽe, the decline has been very steep, with the population decreasing from over 14,000 individuals in 2000, to approximately 1,000 individuals in 2018 (Paxton *et al.* 2020). Both species are now restricted to areas estimated at 26–43 km^2 within their core historical range. The population declines in Kauaʽi forest birds match studies showing increasing malaria prevalence in birds and increases in climate favorable to mosquitoes (Atkinson *et al.* 2014). Increasing disease prevalence also matches observations by field biologists of increasing mosquito numbers throughout the range of the species based on trapping done by the Kauaʽi Forest Bird Recovery Project. Historically, surveys for mosquitoes on the Alakaʽi Plateau did not detect mosquitoes (Atkinson *et al.* 2014).

The kiwikiu has always been a species existing at low densities, but recently the species has declined rapidly (Figure 3), and its range has contracted 41% from 1980–2017 in the higher elevation portions of its range (Judge *et al.* 2021). ʽĀkohekohe also inhabits a very narrow elevational band in east Maui, with its range having contracted 61% from 1980 to 2017 (Judge *et al.* 2021), restricting it to the very highest portions of the native forest, in a range smaller than the total kiwikiu range. Kiwikiu occupies the windward slopes of east Maui, specifically Waikamoi Preserve, managed by The Nature Conservancy, and Hanawī Natural Area Reserve (NAR) managed by Hawaii State Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW), with a few individuals still present in Haleakalā National Park and on state lands between Waikamoi and Hanawī. High density populations of ʽākohekohe only remain in Waikamoi Preserve, Hanawī NAR, and Manawainui within Haleakalā National Park. While ʻākohekohe has a larger estimated population size (~1,768) than kiwikiu, and therefore longer estimated time to extinction, the two species' ranges overlap, and both species are threatened by increasing disease distribution.

The four species differ in diets, behaviors, and other life history characteristics that have implications for which management actions might be most successful for each species. For example, kiwikiu has a "slow" life history strategy, with only one egg laid per nesting attempt and juveniles depending on their parents for 6–18 months after leaving the nest. Thus, recovery of this species would likely be slow under any management alternative, and population viability assessments indicate the species will decline without increased survival or productivity (Mounce *et al.* 2018). On the other hand, ʻākohekohe does not have a long juvenile dependency period and can produce multiple broods in a year, and therefore could potentially respond quickly to management actions that remove pressures. However, ʻākohekohe is nectarivorous and sustaining it in captivity may be more difficult than with the other species. Alternatively, ʻakekeʻe occupies large areas in the wild and may have complex social interactions, behaviors that would be restricted in captivity. Thus, each management action will need to be considered specifically for each species.

Biologists studying ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe are unanimous that there is a high probability these species will go extinct in the coming decade without rapid conservation actions to address the threat of disease mortality. With already small population sizes, restricted ranges, and increasing prevalence of disease in their habitat, the status quo is not sustainable. Additionally, disease dynamics are influenced by climate, and a year or even a season with favorable weather conditions for mosquitoes could lead to a large disease outbreak that could hasten extinction.

Potential Management Actions to Address the Crisis

Three broad management actions have been identified to minimize the risk of extinction to forest birds from the increasing prevalence of disease.

- *Wolbachia* IIT: *Wolbachia* incompatible insect technique (IIT) is a form of mosquito birth control that suppresses mosquito populations at a landscape level and if successful would effectively break the avian malaria disease cycle (Ross *et al.* 2019). *Wolbachia* IIT would need to be implemented continuously or the effect on mosquito populations would be reversed quickly.
- Captive care: Captive care involves the removal of forest birds from the wild and maintenance in a controlled facility under human care. Long-term conservation rearing can facilitate a breeding program to prevent extinction and supplement wild populations. An alternative approach to long-term captive care is short-term holding of birds until they can be translocated to safer forests (conservation translocation) or released back into the wild once their habitat is disease free following the application of *Wolbachia* IIT mosquito suppression.
- Conservation translocation: Conservation translocation is the deliberate movement of organisms from one location for release in another for the purpose of their conservation or recovery. For forest birds, conservation translocation could occur via (1) direct translocation, the movement of individuals from their current range to a suitable, disease-free site on Hawaiʻi Island; or (2) translocation from captivity, which entails removing individuals from their current range and maintaining them in

a controlled facility under human care for a short period while waiting for translocation planning to be completed. Conservation translocation may have multiple goals, including the establishment of a second population in a new location, or to act as a source population for reintroduction to their historical locations.

Each of these conservation actions has potential benefits, inherent risks, and substantial uncertainty in terms of being successful. Given the small population sizes and the short estimated time until extinction, there may be limited opportunity to try more than one approach for each species. For example, there might not be enough birds to both establish a captive population and translocate individuals to a second separate population. On the other hand, birds could be brought into captivity while waiting for *Wolbachia* IIT to be initiated and then released back into the wild once the disease cycle is broken through mosquito suppression. Native Hawaiian perspectives and considerations also vary among the conservation actions (below and Appendix IV). Below, we describe each of the management alternatives in greater detail, listing general considerations and Native Hawaiian perspectives for each (benefits and risks) and their estimated costs for implementation.

Evaluating Alternative Conservation Strategies

This report summarizes information on the status of the four species at highest risk of extinction from mosquito-borne disease, reviews the possible management options to prevent their extinction, describes specific considerations to be weighed for each option, and uses expert judgement to estimate the probability of success of each management action for each species. The report provides supporting information to decision-makers conserving Hawaiian forest birds.

There are a variety of wildlife agencies, organizations, and landowners that play a role in the conservation of Hawaiian forest birds. To develop this report, we convened specialists with knowledge in various aspects of the problem to provide expert judgment. We first convened groups with expertise in the species of concern and possible management options to gather baseline information on those approaches as feasible conservation strategies. Next, we assembled a diverse group with broad knowledge of Hawaiian forest birds and ecosystems and the management approaches being considered. Opinions were elicited from this group on the probability of success of each alternative management action to reduce extinction risk and ensure viable populations in the coming decade.

In addition to evaluating this crisis from a solely biological perspective, we sought to evaluate it from a cultural standpoint, giving voice to the significance of forest birds to Native Hawaiians. The connections among Native Hawaiians, Hawaiian forests, and forest birds is centuries old. Native Hawaiians are, through the Kumulipo, hula, chants, stories, and other sources, tied to forest birds, their immediate habitat, and their broader island and archipelagic environment.

Native Hawaiians have kuleana (rights and responsibilities) and kaumaha (weight; burden) in the stewardship of their ʻohana (extended family). Consequently, we convened a group of Native Hawaiian participants that have strong connections to the forest birds, forests, and the integration of Hawaiian culture in natural and biocultural resource management. We invited them to provide their views on the ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe and the possible management actions that could be undertaken to prevent their extinction. This dialogue was meant to recognize the familial relationship with these species and to engage the Native Hawaiian community in the meaningful care, decisions, and management actions regarding their family members.

Other forest birds across the Hawaiian Islands are experiencing declines and are of conservation concern (Paxton *et al.* 2018). The approaches developed for the four species in this report can be adapted in efforts to protect other Hawaiian forest birds.

METHODS

This report summarizes the results of expert elicitation from different groups of people to provide decision-makers with guidance on management strategies and actions to help prevent the extinction of Hawaiian forest birds. We conducted three distinct but overlapping components of elicitation in this process, as described below.

The first component involved gathering background information to make informed decisions on conservation planning. We convened groups of experts on Kaua'i forest birds, Maui forest birds, captive care, the application of *Wolbachia* IIT in Hawai'i for conservation purposes, and translocation. First, we asked biologists actively working on the species of concern to provide their expert opinion on current population size (in 2021) and time to functional extinction (defined as <10 breeding pairs), and to estimate what percentage for each species could be captured from the wild, if needed (Appendix III). Second, we gathered experts actively working to bring *Wolbachia* IIT to Hawai'i for conservation purposes. For this group, we both elicited expert judgment on the timing of effective application of *Wolbachia* IIT and the probability of success once implemented (Appendix V). We also requested an outline of the steps that would be needed to fully implement *Wolbachia* IIT in Hawai'i (Appendix VI). Third, we assembled biologists who have experience with translocation in Hawai'i to assess the likelihood of success of translocating each species of concern (Appendix VII). In addition, the group drafted a translocation plan for one of the species ('akeke'e) to illustrate the necessary steps for a successful translocation (Appendix VIII). Fourth, we convened a group of captive care professionals experienced in caring for Hawaiian forest birds, as well as experts with experience in other systems. We asked this group to assess the probability of success in meeting different captive care goals for each of the four species of concern (Appendix IX).

For the second component, we convened a diverse group of biologists with expertise in the species, the management actions, and island conservation in general. This group met remotely multiple times to establish a set of objectives, agree on assumptions, and render expert judgement on the probability of success of the three management actions to meet two stated conservation objectives. The conservation objectives were (1) to prevent the imminent extinction of species, which was meant to prioritize immediate actions within a timeframe of three years from 2021, the mean time for effective implementation of *Wolbachia* IIT based on responses in the first step; and (2) to implement management actions that best ensure one or more viable and stable to increasing wild populations in the long term (beyond 10 years). The purposes of the two objectives were to respond to the immediate need of preventing extinction while balancing the choices that would position species for eventual recovery. Three rounds of meetings were completed to obtain a final expert judgment (Appendix X), using the Delphi method to measure expert judgement (Hemming *et al.* 2017).

The third component of the process involved assembling an interagency hui (group) comprised of representatives from U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), and the Office of Native Hawaiian Relations (ONHR). The hui then brought together a group of Native Hawaiians that were Hawaiian forest and forest bird experts or cultural practitioners and invited them to share their individual experiences, knowledge, and cultural viewpoints on the forest birds, their habitat, and the proposed conservation management actions. Verbal and written comments were sorted into four categories: (1) observations from past conservation actions; (2) Hawaiian forest birds; (3) native forests and habitat; and (4) proposed conservation management actions. A summary of input is provided throughout this report with additional detail and verbatim responses from Native Hawaiian participants in Appendix IV.

RESULTS

Current Status of Hawaiian Forest Birds of Concern

Based on careful review of existing abundance and distribution data for each species, and intimate knowledge of their occurrence across their ranges, Hawaiian forest bird biologists estimated current (2021) population size and time to extinction for each species (Appendix III).

The 2021 population estimates were lower than the most current survey estimates both because time (three to four years) had passed since the surveys, and because the experts took in additional information about changing distributions (Table 2). The time to extinction is based on combining current population sizes and projected declines and represents an unknown (future) event (Table 2). The time to extinction curves (Figure 4) are probability distributions, with the area under each curve summing to 1.0. The peak of the curve indicates when extinction is most likely, based on expert judgement, and the width of the curves indicate the degree of uncertainty. For example, the time to extinction for ʻakikiki is much more certain (higher peak, narrower tails) than for ʻakekeʻe, which has a broad, less peaked probability distribution. While the time to extinction is most likely to occur around 2029 for ʻakekeʻe, there is some probability it could happen as early as 2023 or as late as 2034.

Management Actions

Each management action has uncertainty in the time to implementation, probability of successfully minimizing extinction risk, and Hawaiian cultural considerations. To reduce these uncertainties and articulate the considerations inherent in each management action, we sought information from experts with experience in each of the management approaches (Appendices V–IX). The outcomes are described below along with a description of each of the alternatives.

Native Hawaiian perspectives applicable to all management alternatives

The Native Hawaiian participants expressed several foundational beliefs that helped guide their assessment of the conservation of Hawaiian forest birds. All the Native Hawaiian participants expressed a strong connection with Hawaiian forest birds and reaffirmed their view of them as manifestations of kūpuna (ancestors), ʻaumākua (familial gods), and akua (gods; see Appendix I for the glossary of Hawaiian words). Participants also viewed Hawaiian forest birds as integral to native forests, which in turn, are integral to biocultural, ecological, and ecosystem functions of an ahupuaʻa (land division), moku (district), moku nui (island), and the greater pae ʻāina (group of islands; Hawaiian Islands).

A majority of participants viewed management decisions around ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe akin to making end of life choices for members of their ʻohana. While most participants thought immediate steps should be taken to prevent the extinction of these species, extinction was not always considered the worst-case scenario. Instead, the likelihood of success; welfare of individual birds; and social, biocultural, and cultural connection of the birds to their natural environment were significant considerations when evaluating management options. If these considerations could not be fully realized, some participants considered it more appropriate to allow the birds to go extinct in their natural environment without further

Table 2. Estimated current (2021) population size and time to extinction for the four Hawaiian honeycreepers: ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe. Estimates were based on expert judgement of Hawaiian forest bird biologists with intimate knowledge of each species (Appendix III).

Species	Estimated 2021 population	Estimated time to extinction
ʽAkikiki	45 (min-max: 28–76) + 41 individuals in captivity	2022 to 2025 (2023 most likely)
ʽAkekeʽe	638 (min-max: 208–1,037) + 7 individuals in captivity	2023 to 2034 (2028 most likely)
Kiwikiu	135 (min-max: 108–202) + 2 non-breeding individuals in captivity	2024 to 2032 (2027 most likely)
ʽĀkohekohe	1,657 (min-max: 1,360–1,959). No individuals in captivity	2026 to 2037 (2032 most likely)

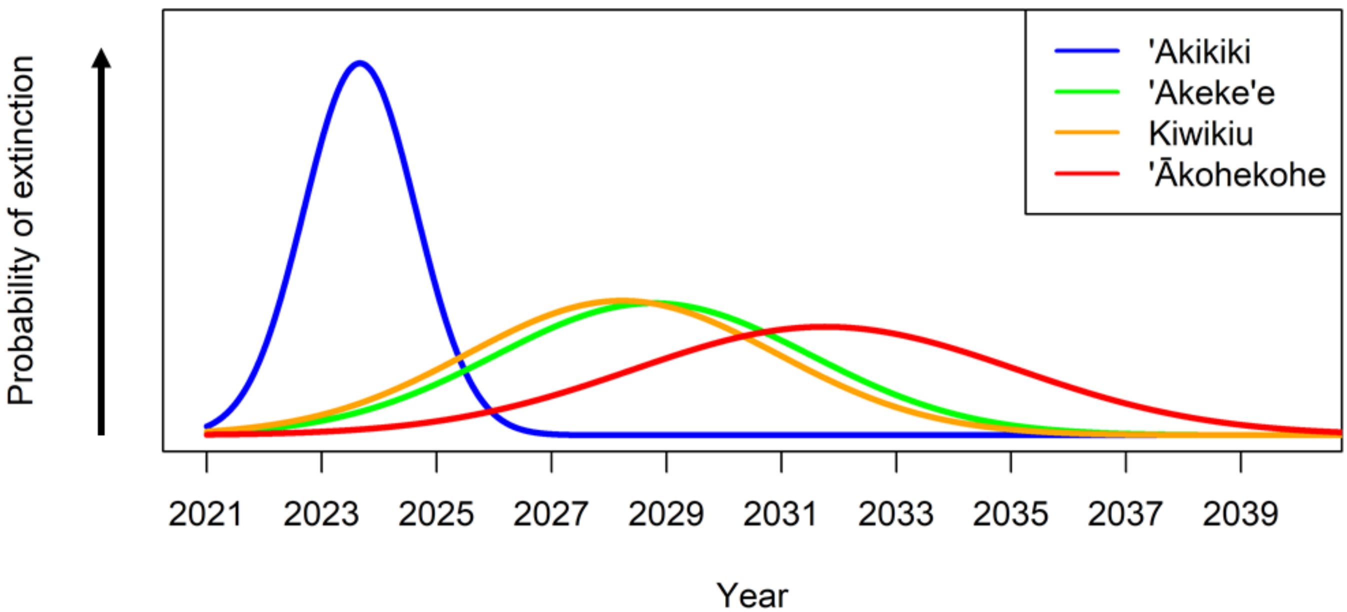


Figure 4. Estimated time to extinction for the four Hawaiian honeycreepers: ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe based on expert judgement of Hawaiian forest bird biologists with intimate knowledge of each species (Appendix III). The curves are probability distributions, with the area under each curve summing to 1.0. The peak of the curve indicates when extinction is most likely, based on expert judgement, and the width of the curves indicates the degree of uncertainty. For example, ʽakekeʽe has a "most likely" time to extinction in 2028, but there is some low probability to species could go extinct as soon as 2023, or may persist to 2034.

intervention, akin to allowing a member of their ʽohana to breathe their last breath in their "one hānau," or birthplace.

***Wolbachia* IIT**

Wolbachia is a naturally occurring symbiotic bacteria that inhabits the majority of invertebrates. When two mosquitoes with different types of *Wolbachia* mate, their eggs can be infertile. *Wolbachia* IIT is a mosquito birth control approach where a population of mosquitoes are identified with or are given a different type of *Wolbachia* than those found in the wild population. Non-biting males from these different mosquito populations are then released into the forests to mate with wild female mosquitoes, resulting in infertile eggs (Ross *et al.* 2019). By releasing large numbers of these incompatible male mosquitoes into forests, the overall mosquito population in the targeted area can be suppressed, thus breaking the disease cycle (Beebe *et al.* 2021).

Implementation of *Wolbachia* IIT is an approach that would require the continuous release of tens to hundreds of thousands of male mosquitoes year after year to suppress mosquito populations in the forest bird habitat. Research on disease dynamics in Hawai'i indicates that >90% of mosquitoes would need to be eliminated to break the disease cycle (Samuel *et al.* 2011), requiring a significant reduction in the existing mosquito population. If the process is paused for even a short period of time, mosquito populations could quickly recover, potentially erasing any benefits from the previous years of suppression. Thus, *Wolbachia* IIT is likely a temporary measure until more long-term sustainable efforts are established.

The use of *Wolbachia* IIT for conservation is adapted from current public health practices employed around the world (Beebe *et al.* 2021). This technique is still being developed for use in Hawai'i, and several inter-related processes would need to be completed prior to its approval here including permitting and public participation procedures. In addition, facilities for raising mass quantities of mosquitoes and techniques for delivering them to rugged, roadless forests would need to be developed or built. Despite the multiple steps that would need to be completed, a group of experts working to bring this tool to Hawai'i thought it could be fully implemented (successfully suppressing mosquitoes) between 2023 and 2026 (Appendix V), but unanticipated delays could extend time to implementation. The group of experts also thought that *Wolbachia* IIT has a 61–93% (82% most likely) chance of successfully suppressing mosquito populations in areas applied (Appendix V). It may not be possible to implement *Wolbachia* IIT on all islands at once, thus the timeline may shift for a given area depending on order of implementation across the islands.

Native Hawaiian perspectives

All Native Hawaiian participants supported efforts to maintain species in the wild through landscape-level mosquito control. Use of *Wolbachia* IIT was viewed as pest control and a means of supporting the health of forest birds and forest habitat. However, a majority of participants raised concerns over broader social acceptance and information accuracy for mosquito control planning and implementation. In particular, many participants expressed concern that lack of social acceptance for *Wolbachia* IIT would forestall implementation and limit this option for forest bird conservation.

Benefits of *Wolbachia* IIT

- Potential to reduce mosquito populations to near zero in treated areas
- Multiple forest bird species at each treatment site would benefit
- Building infrastructure and skills in Hawai'i (would take three to five years)
- Keeps birds in wild, in their historical range

- Birds would retain cultural and familial connections to island/forest of origin and to Native Hawaiian community members, practitioners, and descendants
- Public/community involvement and support through outreach and education campaigns
- Public health benefits if *Culex*-vectored human diseases are introduced to Hawaiʽi

Risks of *Wolbachia* IIT

- Repeated application would be required to maintain low mosquito populations
- Application methods in remote areas have not been developed or tested; success is uncertain
- Very expensive, would need dedicated funding every year
- Research and development hurdles could extend time to implementation
- Uncertainty in mosquito supply source
- High potential for misinformation that affects public/community support
- Additional time and resources needed for extensive community outreach and education campaigns

Costs associated with the implementation of Wolbachia *IIT*

The *Wolbachia* IIT tool is still under development, and additional funds would be needed to complete the process (Table 3). Once it is available, annual costs to use the tool would be an ongoing expense. When mosquitoes are released, funds would also be needed to increase field capacity to ensure adequate monitoring of mosquito and disease prevalence before, during, and after releases. Completing *Wolbachia* IIT tool development for implementation in Hawaiʽi's remote forests is estimated at $2.25 million. Applying the tool at one field site each year is estimated to cost between $5.95 million and $6.15 million.

Table 3. Estimated costs (in U.S. dollars) for implementing *Wolbachia* IIT (incompatible insect technique) on Hawaiian Islands. These costs are general estimates from 2021 to help guide planning decisions, but any factors could change the ultimate cost of the actions detailed.

Item	Startup cost ($)	Annual cost ($)
Complete *Wolbachia* IIT development	2,250,000	
Annual application (per site)		5,750,000
Annual effectiveness monitoring		200,000–400,000
Total startup cost	2,250,000	
Total (per year per site)		5,950,000–6,150,000

Captive Care

The care and breeding of species, generally within a managed (captive) environment, is a conservation tool used worldwide, including in Hawaiʽi. Captive care is a type of insurance against extinction by supplementing or augmenting a wild population or reintroduction to (re)establish populations if a species does become extinct in the wild. Species maintenance under captive care can be part of a larger management program for species, but in the case of these four Hawaiian honeycreepers, it is a means to prevent extinction and buy time until the threat of avian malaria mortality has been addressed.

Past experiences with Hawaiian honeycreepers under captive care have shown mixed success in sustaining or growing captive flocks and producing birds that are suitable for release. Two facilities in Hawaiʻi, which are managed by the San Diego Zoo Wildlife Alliance (SDZWA), have generally been successful in caring for honeycreepers, but less successful in breeding to increase flock size and reintroducing release-suitable individuals. Survival rates of captive honeycreepers after release back into the wild have been low. In some cases, the life history and social systems of the species are complex, which can be hard to mimic in captive situations, thus reducing the success in rearing these birds (such as the ʻakekeʻe). For other species, such as the ʻākohekohe, the numbers of birds in the captive populations have been too few to estimate the probability of success of building an effective program. Globally, species management under captive care and the resulting reintroduction to the wild has had a mixed record, successful in some species but not others, indicating that captive care can be an important tool in conservation but may not work for some species (Snyder *et al.* 1996).

To identify key elements for successful captive care of Hawaiian forest birds, we brought together a panel of captive care experts from within as well as outside Hawaiʻi to assess potentially successful strategies (Appendix IX). Experts considered multiple options including expanding existing SDZWA facilities, building new facilities that could be managed by other organizations, and using the capacity of zoos outside of Hawaiʻi. We considered short-term holding (<5 years) as well as longer-term breeding (>10 years). Short-term holding would entail bringing in birds and releasing them back to their source site once *Wolbachia* IIT has broken the disease cycle in two to four years or translocating them to the Island of Hawaiʻi once site assessment and regulatory compliance are completed in two to three years. Long-term holding and breeding would be considered if *Wolbachia* IIT implementation is delayed, or if the population is too small to support immediate re-establishment or translocation. For each species, we elicited expert judgement on the success of (1) ensuring wild-caught birds would still be alive in 5 years; (2) developing the techniques for maintaining and growing the captive flock such that we have 1.5 times the founding population within 10 years; and (3) ensuring released birds would have normal wild survival rates after reintroduction and a high likelihood of reproducing.

The group of captive care experts had high confidence that with enough birds, resources, and time they could keep individuals alive (60–80% depending on species), develop techniques to increase the size of the captive flock (50–90% confidence depending on species), and have birds survive and reproduce following release back into the wild (>90% confidence for all but kiwikiu; Appendix IX).

As of February 2022, there is space for 33 additional birds at SDZWA. More capacity would be needed if a decision is made to hold viable populations of multiple species under captive care in Hawaiʻi. Different types of infrastructure are possible depending on how quickly facilities would be needed and the length of time birds are planned to be held. If a decision is made to bring birds in from the wild to protect them from disease mortality until *Wolbachia* IIT breaks the disease cycle, then short-term facilities near the capture locations might allow for holding birds while maintaining a connection to their natural habitat. Such local care facilities may allow for multiple groups to care for birds, facilitating innovation of captive care approaches. Long-term captive propagation would require more extensive facilities, such as those managed by the

SDZWA. International concern about the plight of Hawaiʻi's native forest birds has led to offers from zoos outside of Hawaiʻi to help support long-term conservation flocks. Such facilities could provide extra capacity and skill for minimal additional costs and could be an important part of a multi-tiered conservation strategy.

Native Hawaiian perspectives

All Native Hawaiian participants favored maintaining species in the wild as much as possible. Captive care and breeding were viewed as temporary conservation actions to prevent extinction. Cultural considerations identified by the group for any captive care included:

- Incorporation of cultural protocol into planning of capture and management of the species while in captivity
- Plan designed to maximize the chance of success, minimize pain and suffering of captive individuals, and focus on quality-of-life care

A majority of Native Hawaiian participants indicated a strong preference for captive care facilities located in Hawaiʻi with an understanding that more captive care space may need to be built to accommodate the number of birds. Participants raised concerns regarding moving birds to facilities outside of Hawaiʻi, which would separate the birds from their historical, ecological, cultural, and familial ties. There was discussion around the value of international captive breeding support for nēnē (Hawaiian goose, *Branta sandvicensis*) and the recognition that sometimes movement of birds to facilities outside their native range is necessary for survival when there is hope of success. However, a majority of participants did not consider the movement of birds to facilities outside of the pae ʻāina culturally appropriate under any circumstances.

<u>Benefits of captive care</u>

- Removing birds from the wild immediately reduces risks of disease mortality
- Prevents extinction in the short-term
- Buys time for implementing the other alternative actions
- Currently captive populations exist for three of the species, with historical knowledge of maintaining all four
- Opportunity to retain some cultural and familial connections for captive care at Hawaiʻi-based facilities

<u>Risks of captive care</u>

- Mixed history of success in captive care of Hawaiian forest birds
- Natural behaviors can be lost over generations, reducing success of reintroducing individuals back to the wild
- Genetic diversity can be lost over time
- Space is currently limited in Hawaiʻi
- Lack of social acceptance among the Native Hawaiian community, particularly for captive care in facilities outside of Hawaiʻi
- Potential suffering, mortality, or loss of cultural and familial connection to Native Hawaiian community members, practitioners, and descendants, especially for captive care outside of Hawaiʻi

Costs associated with the implementation of captive care

Temporary holding – As of February 2022, captive care facilities in Hawai‘i do not have the infrastructure to hold the target number of birds for each species if the decision were made to quickly extract birds from the wild. Additionally, if the decision were made that the best option was to hold one or more species temporarily while Wolbachia IIT development was finalized, long-term holding facilities might not be necessary. Costs to build temporary facilities are variable, depending on the durability of materials as well as location. Annual costs would be similar to those for new on-island facilities (Table 4).

Table 4. Estimated costs (in U.S. dollars) for different options of captive care for Hawai‘i forest birds. These costs are general estimates from 2021 to help guide planning decisions. Many factors could change the ultimate cost of the actions detailed. Expanding SDZWA is San Diego Zoo Wildlife Alliance facilities.

Captive care options and cost (per 50 birds)	Startup ($)	Annual ($)
Capture and transport	250,000–500,000	
Species-specific care plan	100,000	
Public outreach	150,000	50,000
Compliance	150,000	
Temporary holding	100,000–750,000	700,000–1,000,000
Expanding SDZWA	4,000,000–8,000,000	150,000–300,000
New Hawai‘i-based facility	4,000,000–8,000,000	700,000–1,000,000
Zoos outside Hawai‘i	75,000–100,000	0–100,000

Expanding SDZWA – As of February 2022, space is available at the current facilities to hold a viable population of one forest bird species (33 founding individuals with room for breeding) with smaller populations of additional species. To hold a viable population (~50 individuals) of a second species, additional facilities would be needed to increase the number of aviary compartments. Infrastructure costs include site preparation and build-out at SDZWA's Maui Bird Conservation Center or Keauhou Bird Conservation Center. Lower figures would be for one additional species while higher numbers would be for expansion of multiple species. Costs of capture and transport are included separately under field extraction.

New facility(ies) in Hawai‘i – Another option would be to build a separate facility in Hawai‘i. This option might decrease the initial infrastructure investment needed, and it would vary widely depending on the option pursued, thus the range is quite wide ($4-8 million). Annual costs would rise as more personnel not already on staff would be needed. Estimates for operating costs are based on the annual operating budget of the two SDZWA facilities as a guide.

Facilities outside of Hawai‘i – Space is available at institutions in the continental United States for lower cost; however, this would increase compliance, outreach, transport costs, and the complexity of management. On the other hand, a potential benefit could be in accessing new expertise in different institutions. Personnel would accompany birds on flights, and this cost is reflected in the startup cost on top of the capture and transport costs included under field extraction.

Capture of birds for collection into captive care is estimated to cost $250–500 thousand. Additional costs with expanding captive care include developing a species-specific care plan ($100 thousand), public outreach ($150 thousand initially and then $50 thousand annually), and compliance with a one-time cost of approximately $150 thousand. The cost of caring for birds in captivity depends on the entity managing the birds. If the current vendor, SDZWA, maintains the birds, expansion of their facilities would cost between $4 and $8 million, with annual costs ranging from $150–300 thousand in addition to their existing costs. If alternative facilities with a different vendor is selected, the cost to build those facilities is likely the same as the SDZWA facilities at $4–8 million. The annual costs for a new vendor are estimated at $700 thousand to $1 million, which is greater than SDZWA. New staff and veterinary professionals would need to be hired. If we select housing birds at zoos on the mainland United States, the initial cost is estimated to be $75–100 thousand with an annual cost of $100 thousand (Table 4).

Conservation Translocation

Translocation is the intentional movement and release of a species, either within or outside its native range, where the primary objective is for a conservation benefit. Neither the Kaua'i nor the Maui species have ever occurred on the Island of Hawai'i, although closely related honeycreepers with similar diets and habitats exist there. Conservation translocations outside the historical range of a species (also known as assisted colonization) are intended for conservation benefits and can help species overcome threats in their historical ranges. However, translocations to novel locations can have unintended consequences, both to the species being moved as well as species that occur in the host location, and guidelines for translocation identify many considerations (IUCN 2013).

The uncertainty around translocation of any of these species to the Island of Hawai'i is high, and various assessments would need to occur prior to translocation to reduce risk to the species as well as the ecological community at the host site (Appendix VII). A translocation outline plan was drafted to identify necessary steps to initiate and complete a translocation including regulatory components (Appendix VIII). From this plan, we estimated it would take a minimum of two years before birds could be moved. Some of the steps that would be required include site identification, suitability assessment, threats assessment and management, pre- and post-release mosquito and malaria monitoring, and regulatory compliance. Translocation could include a short-term captive component while the assessments and plan are completed. If a decision is made to translocate any of these species, a risk assessment and translocation plan would be needed for each species.

If birds are translocated, a group of translocation experts provided probabilities of success for each species ranging from 38% to 51% (Appendix VII). Translocations would be only to sites with little to no disease transmission on Hawai'i Island. These sites would be assessed prior to any translocation. However, it is difficult to predict how long any site would remain disease free given the speed at which climate change is affecting mosquito distributions. Additional study and planning for a species may be able to identify and mitigate threats at any given host site, thus reducing risk.

Native Hawaiian perspectives

A majority of the Native Hawaiian participants expressed support for conservation translocation as a management action to prevent extinction, as long as such translocations incorporated consultation, cultural values, and protocols into planning and implementation. However, a few participants expressed concern about the cultural appropriateness of translocating species to new islands under any conditions. Specific considerations identified by the group included:

- Inclusion of a cultural practitioner or lineal and cultural descendant to conduct appropriate cultural protocol asking permission and communicating intent to both places, kānaka (Native Hawaiian people), birds (those being moved and those existing in the new locations), and all communities involved
- Attempt to ensure the translocated birds do not significantly affect any native forest birds resident in the translocation area
- Plans designed to maximize the chance of success and minimize pain or suffering to translocated individuals

<u>Benefits of translocation</u>

- Birds remain in wild conditions, retaining behaviors and skills needed to survive in wild
- If translocation is successful and populations grow, they could be a source for re-populating source sites
- Techniques have been used in Hawai'i and personnel have the skillset to implement it
- Birds would be able to remain in the wild, in Hawai'i, retaining some cultural and familial connections to Native Hawaiian community members, practitioners, and descendants
- Establishment of a population on a second island would provide insurance against extinction if a catastrophic event affects the first island
- Provision of ecosystems services lost when other species went extinct

<u>Risks of translocation</u>

- May not be enough individuals available for multiple translocations often necessary for successful population establishment
- Unknown how long host sites will remain disease free; deployment of *Wolbachia* IIT on Island of Hawai'i is planned after deployment on Maui and Kaua'i
- Unknown ecosystem impacts, endangered species with similar diet and habitats at host sites
- Potential suffering, mortality, or loss of some cultural and familial connection to Native Hawaiian community members, practitioners, and descendants

Costs associated with conservation translocation

Translocation is a complex process. Because these would be novel introductions, site suitability assessments would likely need to be conducted. In addition, planning and compliance would need to occur prior to the extraction of birds. The release site(s) would also need some preparation to set up release aviaries as well as manage threats. Monitoring of the release populations, ecosystem impacts from the introduction, and threat management would be ongoing costs.

Translocating 50 birds to Hawai'i Island entails approximately $1.4 million in startup costs, inclusive of site selection and evaluation, compliance, planning site preparation and infrastructure, outreach, and capture. Ongoing costs include threat management, species and ecosystem monitoring, and management with an estimated annual cost of $1.5 million (Table 5).

Table 5. Estimated costs (in U.S. dollars) for translocating Hawaiian forest birds from either Kauaʻi or Maui to the Island of Hawaiʻi. Costs are calculated for movement of 50 birds. These costs are general estimates from 2021 to help guide planning decisions, and many factors could change the ultimate cost of the actions detailed.

Translocation item and cost (per 50 birds)	Startup ($)	Annual ($)
Site selection and evaluation	200,000 (one-time cost)	
Compliance	150,000 (per site)	
Translocation plan	100,000	
Site preparation	150,000 (one time)	
Public outreach	150,000	50,000
Release infrastructure	150,000	150,000
Capture and introduction	450,000	
Threat management	200,000	200,000
Species and ecosystem monitoring		450,000
Post-release management		500,000
Habitat management		150,000

Probability of Success of Alternative Management Actions to Minimize Extinction
For each species, a group of experts assessed multiple management actions in terms of probability of success to prevent imminent extinction (Objective 1) and to ensure long-term viability (Objective 2; Appendix X). For Objective 1 (prevent imminent extinction) three actions were assessed: leaving birds in the wild with the hope that *Wolbachia* IIT application would break the disease cycle before effective extinction in the wild; directly translocating birds to Hawaiʻi Island; or bringing birds into captivity. For objective 2, longer-term captive care was divided into: holding for a short time until birds could be released into the wild following successful implementation of *Wolbachia* IIT; holding for a short period until birds could be translocated to Hawaiʻi Island; or keeping in captivity to establish a long-term captive breeding flock (Appendix X).

ʻAkikiki

Given the short timeframe to extinction for ʻakikiki (2022–2025), the group thought bringing birds immediately into captivity (adult and young) was the action most likely to prevent imminent extinction (Objective 1) with a 78% probability of success of achieving Objective 1 (min-max range of individual expert judgments: 50–95%; Figure 5). In contrast, the probability of preventing imminent extinction waiting for the implementation of *Wolbachia* IIT was 11% (min-max: 0–40%), and probability of waiting for a direct translocation was 22% (min-max: 5–50%). Longer term (Objective 2), all options were given less than 53% chance of being successful, reflecting the challenges of establishing stable populations within a 10-year window. Captive care options still had the highest probability of success, with holding and releasing back into the wild as soon as conditions are safe (i.e., the disease cycle broken) being ranked as the strategy mostly likely to be successful.

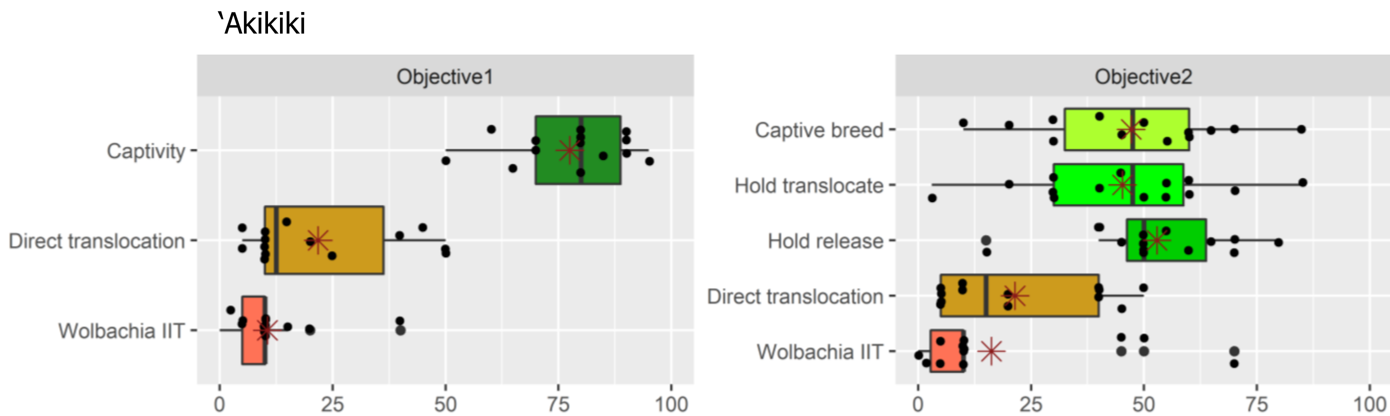


Figure 5. Expert judgement on the probability of achieving either Objective 1 (left panel) or Objective 2 (right panel) goals for ʻakikiki. Objective 1 was concerned with preventing the imminent extinction of species, while Objective 2 was focused on implementing management actions that best ensure one or more viable (stable to increasing) wild populations in the long term (up to and beyond 10 years). For each management action (y-axis), the probability of success (x-axis) was based on the experts' judgement. Each expert's score is represented by a black dot, and the mean value is symbolized by a red asterisk. The boxplots indicate the interquartile range (IQR, 50% of the data distribution, area within the box), with the whiskers extending up to 1.5 x IQR. Median value is represented by the vertical black line in the IQR, which may be difficult to see if the median and upper or lower IQR lines are similar values.

'Akeke'e

The group thought that because 'akeke'e have a larger population size and longer estimated time to extinction compared to 'akikiki, there was less certainty on the need for immediate removal of birds to prevent continuing disease-related mortality. Overall, there was broad overlap in the probability of success of each management action to achieve Objective 1 (Figure 6), with bringing birds into captivity having the highest average probability of success (54%) versus direct translocation (35%) or waiting for *Wolbachia* IIT to be implemented (41%). For longer term stability, holding birds in captivity and then releasing back into the wild when safe was the highest ranked (43%) but closely followed by waiting for *Wolbachia* IIT (41%).

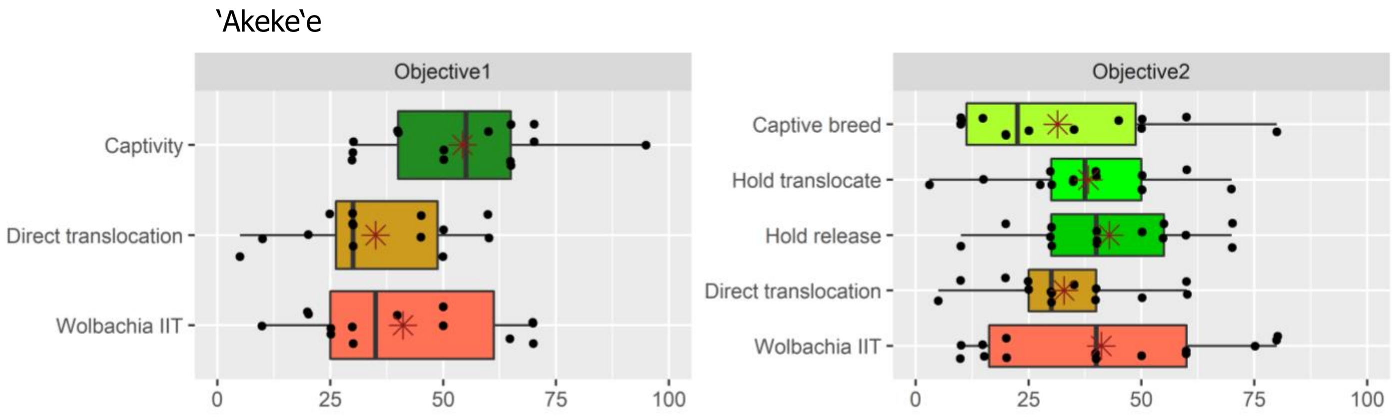


Figure 6. Expert judgement on the probability of achieving either Objective 1 (left panel) or Objective 2 (right panel) goals for 'akeke'e. Objective 1 was concerned with preventing the imminent extinction of species, while Objective 2 was focused on implementing management actions that best ensure one or more viable (stable to increasing) wild populations in the long term (up to and beyond 10 years). For each management action (y-axis), the probability of success (x-axis) was based on the experts' judgement. Each expert's score is represented by a black dot, and the mean value is symbolized by a red asterisk. The boxplots indicate the interquartile range (IQR, 50% of the data distribution, area within the box), with the whiskers extending up to 1.5 x IQR. Median value is represented by the vertical black line in the IQR, which may be difficult to see if the median and upper or lower IQR lines are similar values.

Kiwikiu

Given the small population size and time to extinction in kiwikiu, the group thought that the management action with the highest probability of preventing imminent extinction was to remove birds immediately from the wild to prevent disease-based mortality, giving this action a 75% probability of achieving Objective 1 (min-max range of individual expert judgments: 50–95%; Figure 7). Alternative actions of direct translocation had lower probability of success (43%), while keeping birds in the wild for *Wolbachia* IIT to break the disease cycle was deemed the riskiest strategy (38% probability of preventing extinction). Longer term (Objective 2), all options were deemed having less than 51% chance of being successful, on average, reflecting the challenges of establishing stable populations within a 10-year window. Captive care options still had the highest probability of success, with holding and releasing back into the wild as soon as it was safe ranked as the conservation strategy most likely to be successful. However, there was large overlap in expert judgement for all options when considering Objective 2 goals.

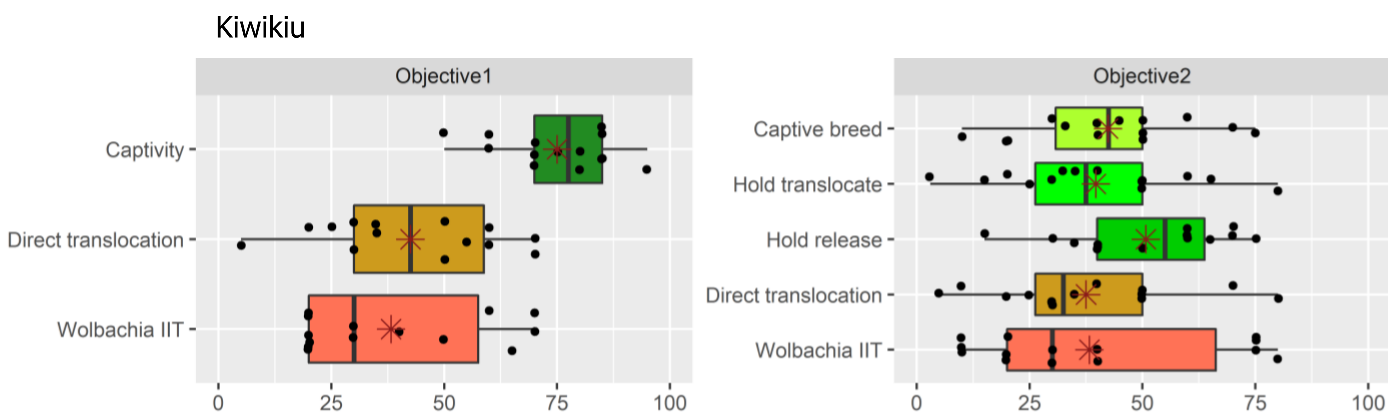


Figure 7. Expert judgement on the probability of achieving either Objective 1 (left panel) or Objective 2 (right panel) goals for kiwikiu. Objective 1 was concerned with preventing the imminent extinction of species, while Objective 2 was focused on implementing management actions that best ensure one or more viable (stable to increasing) wild populations in the long term (up to and beyond 10 years). For each management action (y-axis), the probability of success (x-axis) was based on the experts' judgement. Each expert's score is represented by a black dot, and the mean value is symbolized by a red asterisk. The boxplots indicate the interquartile range (IQR, 50% of the data distribution, area within the box), with the whiskers extending up to 1.5 x IQR. Median value is represented by the vertical black line in the IQR, which may be difficult to see if the median and upper or lower IQR lines are similar values.

'Ākohekohe
Given the larger number of individuals remaining, and the longer estimated time to extinction, experts thought that keeping birds in the wild and waiting for *Wolbachia* IIT to break the disease cycle had the highest probability of achieving both Objective 1 and Objective 2 (both 61% probability of success on average; Figure 8). However, there was broad overlap in assessments of the different management actions, and probability of success for Objective 1 on direct translocation (55%) and bringing into captivity (51%) were similar. Longer term (Objective 2), the median probability of success for *Wolbachia* IIT and direct translocation were almost the same, indicating that multiple management actions for this species are deemed to have similar probabilities of success.

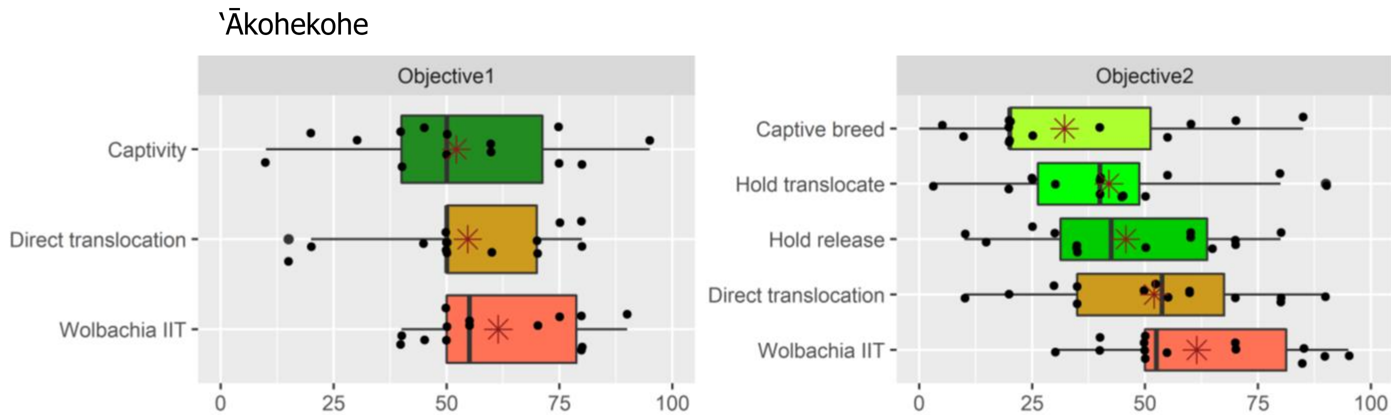


Figure 8. Expert judgement on the probability of achieving either Objective 1 (left panel) or Objective 2 (right panel) goals for 'ākohekohe. Objective 1 was concerned with preventing the imminent extinction of species, while Objective 2 was focused on implementing management actions that best ensure one or more viable (stable to increasing) wild populations in the long term (up to and beyond 10 years). For each management action (y-axis), the probability of success (x-axis) was based on the experts' judgement. Each expert's score is represented by a black dot, and the mean value is symbolized by a red asterisk. The boxplots indicate the interquartile range (IQR, 50% of the data distribution, area within the box), with the whiskers extending up to 1.5 x IQR. Median value is represented by the vertical black line in the IQR, which may be difficult to see if the median and upper or lower IQR lines are similar values.

DISCUSSION

The two key components for preventing extinction in ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe are time and risk. For each species, very few individuals remain, and they are all in danger of imminent extinction. Each management action takes some time to plan, initiate, and become fully implemented, which might exceed the time-to-extinction. Even for species with longer time to extinction horizons, each successive year that it takes to implement a management action would result in fewer and fewer individuals remaining to help prevent extinction, thus reducing the likelihood of success of that action. Likewise, for a decision to bring birds into captivity, which is the management action with the quickest implementation time frame, it would likely take several years to catch enough individuals for a viable captive population, with fewer birds remaining available for capture each successive year. Thus, questions of how long it would take to implement a specific action, and the probability that it would be successful, are important considerations when deciding among alternative management actions.

For each management action and for each species, there is a range of minimum and maximum time to implementation or extinction, based on expert judgement. Management actions could be delayed for any number of unforeseeable reasons, extending the time to effective implementation. Likewise, species could decline faster than anticipated, making time to extinction sooner than predicted. Understanding how the timelines for specific management actions line up with time to extinction estimates can help optimize conservation strategies for each species (Figure 9).

Alternative Management Actions

All participants agreed that the preferred outcome for ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe was to have them remain in the wild in their current, historical range, allowing them to retain their wild behaviors and connection to Native Hawaiian community members, practitioners, and descendants. However, the climate change driven increase in distribution and intensity of avian malaria threatens these species in their historical range. To leave them in the forest would require managing disease at the landscape level, and the only tool being pursued that could achieve this at this time is the *Wolbachia* IIT approach for landscape-level mosquito suppression. The effort to use *Wolbachia* IIT to conserve Hawaiian forest birds is moving forward regardless of any additional management actions that are being considered. However, *Wolbachia* IIT will take an additional two to four years to effectively implement (assuming no unforeseen delays), and there is some uncertainty that it would successfully suppress mosquitoes in the remote forest bird habitat. Thus, to wait for *Wolbachia* IIT to be implemented risks species going extinct before it can be implemented, or species continuing to dwindle only to eventually determine that *Wolbachia* IIT is not effective to break the avian malaria disease cycle but leaving too few birds to exercise any other options.

Therefore, for all species except ʽākohekohe, the action that had the highest probability of preventing extinction (based on biologists' average expert judgement) was bringing birds quickly into captivity, holding them until *Wolbachia* IIT breaks the disease cycle, and then returning them to the wild where captured. However, captive care has inherent risks and costs, and it is unknown whether species could be easily released into the wild after two to six years in captivity. Additionally, many of the Native Hawaiian participants expressed strong concern regarding the cultural appropriateness of holding species in captivity for long-term conservation breeding, particularly if using facilities outside of Hawaiʽi. The third option considered, translocation to Hawaiʽi Island, was ranked low for all species in terms of probability of

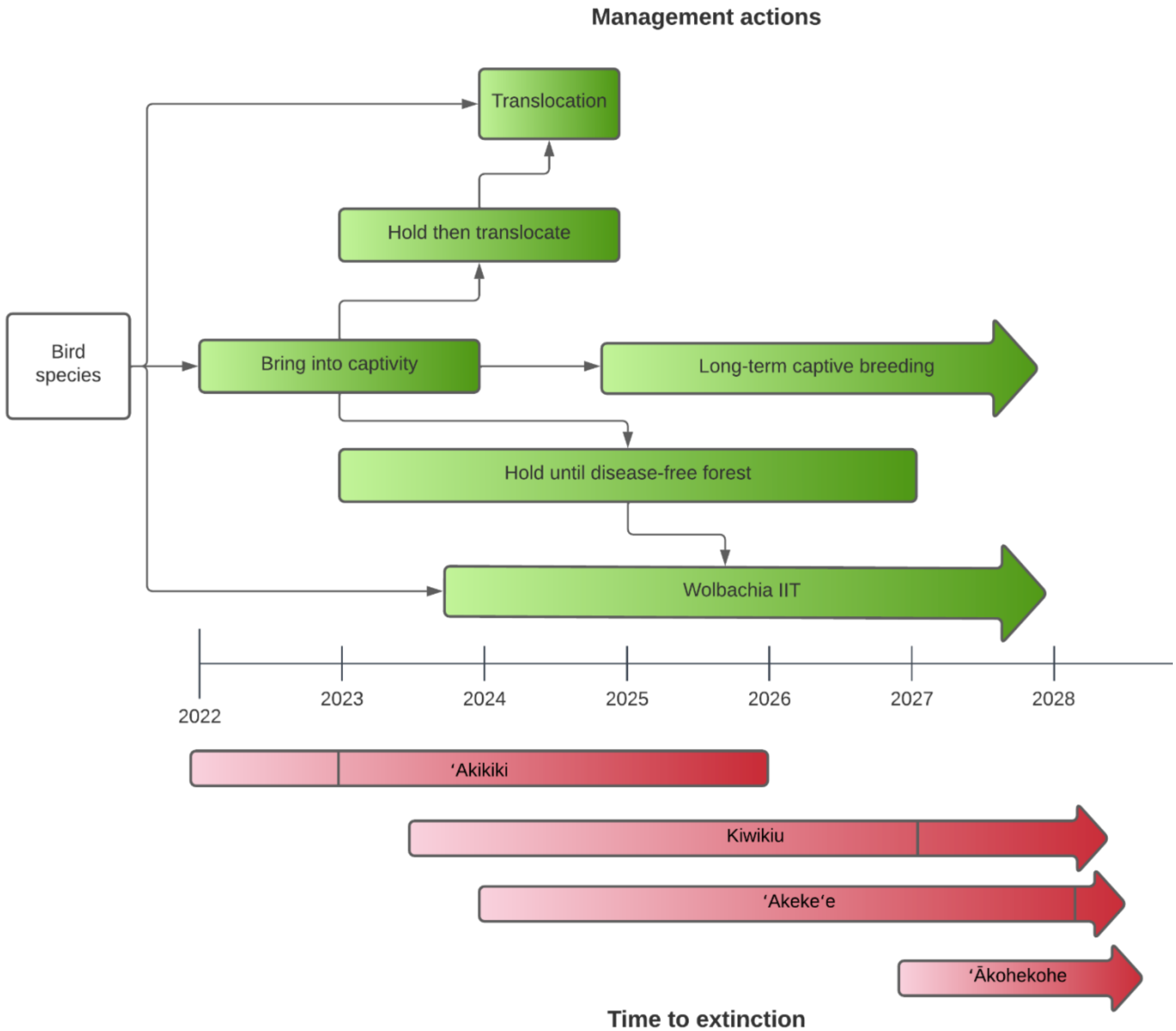


Figure 9. Alternative management actions and approximate timelines for implementation (green bars) and time to extinction for the four Hawaiʽi forest birds (red bars). The length of the bars indicates the timespan an event can occur, from the earliest (left side, lighter shade) to the latest (right side, darker shade) based on the judgement of experts with knowledge of the techniques and species (Appendices V–IX). The black vertical lines in the red species bars indicate the time most likely for extinction to occur, but extinction could occur over any of the time represented by the red bars (based on expert judgement). For example, kiwikiu and ʽakekeʽe may persist through the earliest time that *Wolbachia* IIT could be implemented, but they could go extinct before *Wolbachia* IIT is implemented if they decline at the fastest rate or *Wolbachia* IIT takes the longest time to implement.

successfully achieving the stated objectives. The lower rankings on translocation indicate considerable uncertainty among experts on the probability of success, especially when there are so few individuals to form a founder population. Thus, both time and uncertainty are key factors in choosing among management actions to minimize extinction risk.

Each species has different population sizes, time to extinction estimates, and unique life history traits, which may require different sets of management actions to optimize conservation strategies.

ʻAkikiki

ʻAkikiki has the smallest estimated population size (~45) and the closest time to extinction in the wild (~2023) estimate. The experts were concerned there was very little time to respond to the declining population of ʻakikiki and thought that removing birds as rapidly as possible from the wild where they were subject to disease mortality was the management action most likely to prevent imminent extinction. However, what to do with those birds once in captivity was less certain, with broad overlap in whether to hold until they could be released following successful *Wolbachia* IIT control, translocate to Hawaiʻi Island, or keep for the long-term breeding program. In 2013, a structured decision making (SDM) workshop was convened to assess strategies needed to prevent the extinction of both ʻakikiki and ʻakekeʻe (Paxton *et al.* 2022), which yielded three key recommendations: institute an emergency captive flock at SDZWA's Hawaiʻi and Maui facilities, assess sites on Maui for translocation, and continue habitat management. As a result of these earlier conservation planning efforts, egg harvesting from 2015–2018 has resulted in a captive flock of 41 individuals being established (as of February 2022). This flock represents a significant effort to prevent complete extinction, but most of these birds are five to eight years old, and breeding within the captive flock has been sporadic with only seven ʻakikiki chicks produced in captivity over a five-year period. The low level of reproduction is partly due to protocols that have emphasized parent rearing to produce more behaviorally fit birds for release but at a cost of lower productivity. The SDZWA has indicated that future efforts will focus on hand-rearing again to improve hatching and survival. However, breeding has been sporadic with difficulties at all stages (pair formation, incubation, chicks, and fledging), indicating hand rearing is only part of the solution.

Short-term holding of ʻakikiki also brings risks. Time for implementation of *Wolbachia* IIT is later than the estimated time to extinction for ʻakikiki. Temporary holding facilities constructed on state land in the Alakaʻi Plateau of Kauaʻi may provide a solution to remove birds from the threat of disease and be able to quickly release them back to the wild when disease levels are reduced. Translocation of ʻakikiki to Hawaiʻi Island was overall considered to have a low probability of success (<25%). Additionally, there is an ecologically similar endangered forest bird species on Hawaiʻi Island (ʻalawī or Hawaiʻi creeper; *Loxops mana*) with the potential for direct competition for resources and habitat. However, some of the experts discounted the threat of competition from a small, translocated population, particularly given that all the islands once supported much larger bird communities and populations.

ʻAkekeʻe

ʻAkekeʻe has a larger population size (~638) and a longer time to extinction estimate (~2028) than ʻakikiki, but it has been declining at a faster rate (-23% per year). Overall, there was no strong consensus among experts on the best management action for ʻakekeʻe. To prevent imminent extinction, bringing birds into captivity was considered more likely to be successful than direct translocation or waiting for *Wolbachia* IIT, but there was broad overlap in estimates of success for all actions. The 2013 SDM workshop conducted for ʻakikiki and ʻakekeʻe (Paxton *et al.* 2022) also resulted in an effort to start a captive flock of ʻakekeʻe, but was far less successful than it was with ʻakikiki. Despite extensive field efforts from 2015 to 2018, few nests were found; of eggs collected seven did not hatch; and the current captive flock (February 2022) of seven individuals at the SDZWA's Hawaiʻi facilities has not successfully bred to date and has suffered some mortality. Aviculturists caring for ʻakekeʻe think the species is very stress-prone in captivity, potentially due to changes in social dynamics and small spaces for this wandering species.

Translocation of ʻakekeʻe to Hawaiʻi Island is an alternative to keeping in captivity for long periods but was considered a risky action with a 35% estimated probability of success. Complications include catching enough individuals to translocate and their non-territorial behavior may result in individuals wandering from the release area, limiting the ability to evaluate success, and preventing a critical mass of individuals from finding one another to breed. There is also an endangered honeycreeper on Hawaiʻi Island, the Hawaiʻi ʻākepa (*Loxops coccineus*), which would likely overlap in diet and habitat use. These two species do show different breeding behavior (cavities versus open cup nests), which may indicate that any hybridization concerns would be unwarranted. Moving the species to an area without Hawaiʻi ʻākepa could also mitigate those concerns, but such a decision might complicate future reintroductions of Hawaiʻi ʻākepa to those areas and would be a matter for consideration within a larger long-term conservation plan. While leaving birds in the wild until *Wolbachia* IIT could be implemented to break the disease cycle was considered a riskier strategy to prevent imminent extinction, from a longer-term perspective it was a more competitive action given the concerns about the success of captive care and translocation.

Kiwikiu

Kiwikiu was the second highest species of concern after ʻakikiki, with a small population size (~135), rapid population declines (-13% annual), but with a slightly longer time to extinction horizon (~2027). Experts were worried that kiwikiu could go extinct in the wild before management actions could be fully enacted and thought bringing birds as quickly as possible into captivity would be the action most likely to prevent imminent extinction. Waiting to directly translocate kiwikiu to Hawaiʻi Island or until *Wolbachia* IIT was implemented received similar scores, both of which were lower than bringing birds into captivity. There was broad overlap in expert judgement on which actions would best ensure viable populations of kiwikiu over the longer term, indicating considerable uncertainty in how to best manage the species into the future. However, the management action with the highest average score was to bring birds into captivity and hold them for just long enough for *Wolbachia* IIT to break the disease cycle, then release back to their capture locations.

Although translocation for kiwikiu was estimated to have less than a 43% chance of success, past efforts to translocate kiwikiu to another location on Maui demonstrated that initial translocation steps could be successfully achieved. A conservation translocation in 2019 of kiwikiu from Hanawī NAR to Nakula NAR successfully moved birds, but nearly all birds rapidly succumbed to malaria either shortly after release, or while they were still in the release aviaries (Warren *et al.* 2021). Later it was determined that the translocated wild individuals tested positive for the malaria parasite prior to the move to Nakula (Warren *et al.* 2021), although they may have been re-infected at the release site as seven captive birds also brought to the site for release quickly succumbed to avian malaria too. The presence of malaria at the high elevation translocation site highlighted the difficulty in finding safe places to move birds to on Maui.

The experience of translocating kiwikiu makes a translocation to Hawaiʻi Island more likely to be successful, but the slow reproductive rate of kiwikiu and potential negative impacts on endangered species at host sites could be barriers to success. Kiwikiu also have a long (20-year) history of being held in captive care. The captive program was started in the 1990s through egg collection, but four adult kiwikiu have also been brought into captivity. All adult birds brought into captivity survived over a year with multiple individuals breeding successfully, although the flock size was always small, and the low reproductive rate did not maintain or grow the captive flock size. Following the failed 2019 translocation, a plan was developed to bring kiwikiu into captivity to prevent extinction (MFBWG 2020), including sending birds outside of Hawaiʻi to zoos that were committed to helping recover the species. However, these recommendations were never implemented.

ʻĀkohekohe

ʻĀkohekohe is the species with the largest population size (~1,657) and longest time to extinction estimate (~2032) compared to the other species, but they have been declining at a steep rate (-16%), have contracted to just 61% of their historical range, and are vulnerable to disease moving up into the narrow band of high elevation forest where they still persist. There was broad overlap in experts' judgement on the success across alternative management actions, indicating considerable uncertainty on the best approach to minimize extinction in ʻākohekohe. However, unlike the other species considered, waiting for *Wolbachia* IIT to break the disease cycle was considered the action to have the highest probability of success, reflecting the longer time horizon ʻākohekohe has to wait for successful implementation. Captive care for ʻākohekohe was considered the management action least likely to be successful, given their specialized diet (nectar) and aggressive behavior, along with less experience caring for this species. There was an effort in the early 2000s to rear ʻākohekohe from wild sourced eggs at the SDZWA facilities. However, the program was short-lived, and the few birds that they had were aggressive with other individuals. Translocation is another viable option and considered more tractable than captive care for this species. ʻĀkohekohe have high reproductive potential and inhabit ʻōhiʻa lehua (*Metrosideros polymorpha*) forests with well-developed understory, which are similar to forests existing on Hawaiʻi Island. ʻĀkohekohe are aggressive and at the top of the nectarivore food chain, so they may affect other honeycreepers, particularly ʻiʻiwi (*Drepanis coccinea*). However, given the small numbers that would be translocated compared to the large numbers of ʻiʻiwi on the Island of Hawaiʻi, this is likely to have a small localized effect on a few ʻiʻiwi.

Logistical and Economic Considerations

In addition to time to implementation and uncertainty of success, each approach has several logistic and cost considerations. While bringing birds into captivity may be the quickest and most certain approach to pausing the rapid declines of these species, there is currently not enough space in existing facilities to house all the birds with viable population sizes for all four species. Additional facilities may need to be constructed, which may delay the speed that birds could be brought in, although it is possible that existing space could be filled while new facilities were being built. *Wolbachia* IIT has several components that still need to be constructed and developed. For example, mosquito rearing facilities that can produce tens to hundreds of thousands of mosquitoes a year are needed to implement *Wolbachia* IIT control on multiple islands. Further, there is no developed, reliable approach to release mosquitoes across these roadless remote forests. All approaches require startup costs and dedicated annual funding to implement and ensure the programs continue for as long as they are needed.

All management actions have significant costs associated with them, both startup and annual costs for implementation. Applying *Wolbachia* IIT in Hawai'i to control mosquitoes and break the avian malaria disease cycle is estimated to require $2.3 million to have all the components in place for implementation, and then ~$6 million per year per field site. Thus, application of *Wolbachia* IIT on the islands of Kaua'i, Maui, and Hawai'i would cost ~$18 million per year based on current cost estimations (Table 3). Translocation also has startup and annual costs, with an estimated $1.5 million per species to initiate a translocation, and ~$1 million a year for monitoring (Table 5). If multiple species were translocated to the same area(s), then there may be savings on overall costs. The cost of captive care depends on the type of facilities needed (Table 4). All four options would have initial costs (e.g., capture efforts, species specific plans) that would apply to all options ($650,000–900,000), although capture costs may be less per species if multiple species from the same locations are targeted. For facilities, costs could be as low as $100,000 to $8 million, and annual costs may range from $150,000 to $1 million per year, although partnering with zoos from outside Hawai'i may greatly reduce facility and annual costs.

Every successive year that a species decreases in numbers and moves closer to extinction, the more difficult and expensive each management action would be and the lower the probability of success. This is because with fewer individual birds, there are fewer to catch, fewer to found a new population (either through translocation or conservation breeding), and fewer to respond to *in situ* actions such as *Wolbachia* IIT. Declines from disease are difficult to predict, as annual variation in weather can play large roles in the intensity of disease outbreaks from year to year. A bad year with the perfect conditions for a mosquito outbreak could greatly accelerate the decline of species, just as more favorable weather could slow rates of mortality.

Cultural Considerations

Native Hawaiian participants, through the expert elicitation process, reaffirmed deep kinship with Hawaiian forest birds and their reverence of them as family, ancestors, guardians, spirits, and gods, connected through the realms of Wao Kānaka, Wao Lani, and Wao Akua. Further, they reflected on the importance of Hawaiian forest birds as integral components of native forests, which in turn are essential to the ecology and ecosystem functions of an ahupua'a, moku, moku nui, and the greater pae 'āina. This centuries-long relationship between Native Hawaiians and forest birds and their reverence for forest birds' connections inform the way in which Native Hawaiians perceive the extinction risk of these species and the possible strategies that could be undertaken.

The integrated values of relationships, kuleana, respect, and quality of life distinguish the Native Hawaiian cultural perspective; from their perspective, preserving biodiversity and preventing the extinction of species is less important than the treatment of each forest bird with the respect of a family member. While there was some variation among individual Native Hawaiian participants on specific strategies for 'akikiki, 'akeke'e, kiwikiu, and 'ākohekohe, most people expressed strong support for strategies that preserved the species in the wild, preferably on their island of origin, where they could retain their integral connections to the land and people. Conservation actions that removed forest birds from the wild, particularly captive care outside of Hawai'i, evoked strong concerns regarding the loss of familial and ecological connection and the well-being of each bird at an individual level.

With the understanding that Native Hawaiians share a familial relationship with native species in Hawai'i as 'ohana, medical and human health care analogies helped inform their understanding of values for species that are in ill health. Regarding 'akikiki, 'akeke'e, kiwikiu, and 'ākohekohe, all of which are at risk of extinction, a palliative care model was raised as a useful frame for viewing the extinction plight of the birds. The World Health Organization defined palliative care as "the active total care of patients whose disease is not responsive to curative treatment…" The goal of palliative care is "achievement of the best quality of life for patients and their families who are facing problems associated with life-threatening illness." Various models and examples exist regarding the interface of palliative care with clinical or medical treatment of a life-threatening illness. One such example is a "bow tie" model (Hawley 2014) or overlapping integration of disease management and palliative care that would lead to one of two outcomes—rehabilitation and survivorship or hospice, death, and bereavement.

The "bow tie" model, when adapted to the four Hawaiian forest birds at risk of extinction, serves as a useful image and analogy (Figure 10). Considering species on a conservation gradient, they can be healthy and resilient populations to declining and stressed populations to species at the brink of extinction. The management practices and cultural relationships will change as species move across this conservation gradient, leading to shifting strategies and interactions. Biocultural care, as expressed and exercised by natural resource managers and Native Hawaiian practitioners in coordination with each other, serves as a means of palliative care for the Hawaiian forest birds that complements proposed conservation management actions.

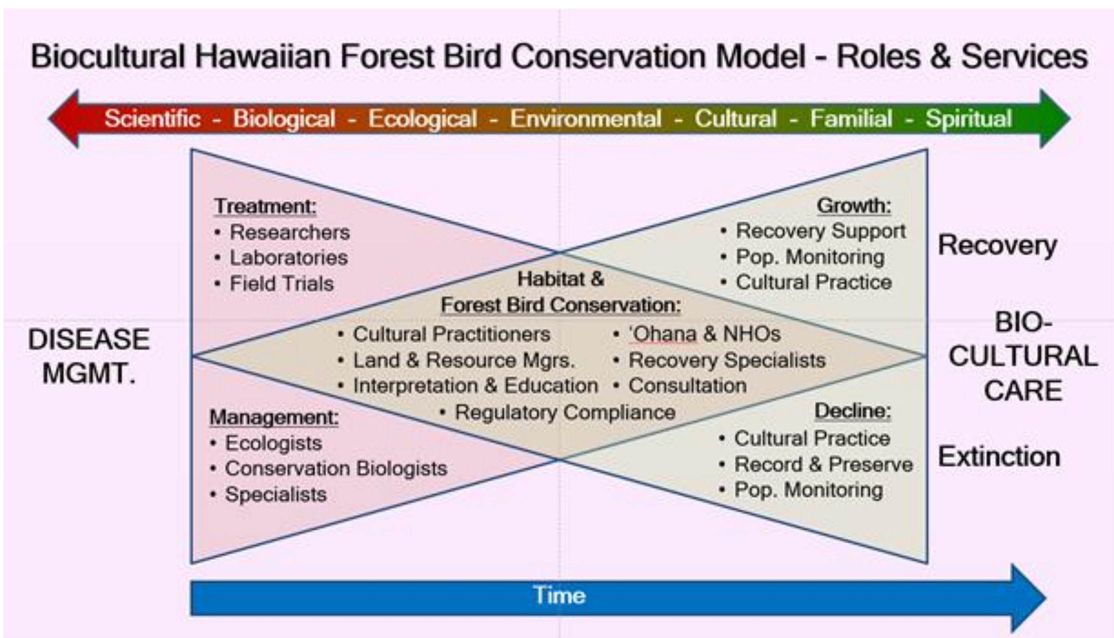


Figure 10. The palliative care bow-tie or pewa model represents the spectrum of care from active treatment to recovery or death. As species move across the conservation spectrum from healthy to near extinction, the responsibilities, actions, and practices of natural resource managers and biocultural practitioners will change. Adapted from Hawley's (2014) bow tie model.

In imagery, the bow tie also resembles a pewa (Figure 11), a wooden wedge used to repair cracks in Hawaiian bowls and wooden instruments. In this context, the pewa/bow tie, and its representation of the bringing together of conservation management actions and cultural care, serves as a metaphor for the piece that repairs and sustains the usefulness and integrity of Hawaiian forests (the bowl) and by extension, the Native Hawaiian community.

Figure 11. A Koa bowl with multiple pewa (bow-tie wedges) that are used to repair cracks. The palliative care bow tie model is analogous to the pewa, a wooden wedge used to repair cracks in wooden implements and to "make whole" damaged vessels.

CONCLUSION

This report details several alternative management actions to reduce the risk of extinction in ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe from increasing disease risks. Each management action has strengths and weaknesses, and a conservation strategy for all four species may include all the management actions. Additionally, some species may benefit from trying multiple approaches (e.g., captive care and translocation), although some species may have enough individuals left for only one attempt at a specific action. While this report does not make definite recommendations, the information presented is intended to support entities that have decision responsibility for these species as they assess which, if any, conservation strategies to pursue. Although each entity will weigh these actions in accordance with their own roles, legal authority, and values, thoughtful discussion about these considerations among entities supports the overarching conservation and recovery of the four forest bird species.

The bow tie or pewa model (Figure 10) is illustrative of how the summation of considerations—whether they be biological, logistical, financial, or cultural—work together to inform thoughtful analysis of each conservation strategy and species. The center of the model represents the shared space in which resource managers, agencies, and Native Hawaiian community members, practitioners, and descendants can collaborate to identify and implement appropriate conservation actions that best support the recovery of the bird species. The model symbolizes the pewa, which illustrates the equal involvement of biocultural care with conservation management actions and serves as a metaphor for the piece that repairs and sustains the usefulness and integrity of Hawaiian forests (the bowl) and, by extension, the Native Hawaiian community.

Once species reach a point of near extinction, with very small population sizes that are continuing to decline, the conservation options and effectiveness of those options are limited. In addition to ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe, seven additional Hawaiian forest bird species are considered vulnerable to extinction from increasing disease prevalence in the coming decades: Kauaʻi ʻamakihi (*Chlorodrepanis stejnegeri*), ʻanianiau (*Magumma parva*), Maui ʻalauahio (*Paroreomyza montana*), ʻakiapōlāʻau (*Hemignathus wilsoni*), Hawaiʻi ʻākepa (*Loxops coccineus*), ʻalawī or Hawaiʻi creeper (*Loxops mana*), and ʻiʻiwi (*Drepanis coccinea*). Conservation strategies developed to save ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe could also benefit these bird species and others from reaching the brink of extinction in the next several decades. A more deliberative process that accounts for changing conditions within an adaptive framework would allow for more proactive management approaches and provide opportunities for input from the diverse communities interested in Hawaiian forest birds.

ACKNOWLEDGEMENTS

We dedicate this report to Fern Duvall (1953–2022) who dedicated his life to the conservation of Hawaiʻi forests and the birds that depend on them. This report summarizes the expert judgement of many professionals dedicated to the conservation of Hawaiʻi forest birds and their native forests. These experts committed considerable time to provide the information and judgements summarized in this report. This assessment would not be possible without their dedication and generous contributions. For their contribution, we thank: William Ailā, Jr., Department of Hawaiian Homelands; Hannah Bailey, San Diego Zoo Wildlife Alliance; Paulokaleiokū Timmy Bailey, National Park Service; Paul Banko, U.S. Geological Survey; Lucas Behnke, The Nature Conservancy; Lainie Berry, Hawaii Department of Land and Natural Resources; Laura Berthold, Maui Forest Bird Recovery Project; Keahi Bustamente, State of Hawaii Division of Forestry and Wildlife; Joseph Kualiʻi Camara, Office of Hawaiian Affairs; Lisa Cali Crampton, Kauaʻi Forest Bird Recovery Project; John Ewen, London Zoological Society; Chris Farmer, American Bird Conservancy; Kamakana Ferreira, Department of Hawaiian Homelands; Josh Fisher, U.S. Fish and Wildlife Service; Noah Gomes, Kamehameha Schools; Sam ʻOhu Gon III, The Nature Conservancy; Justin Hite, Kauaʻi Forest Bird Recovery Project; Nick Holmes, The Nature Conservancy; Brad Kaʻaleleo Wong, Office of Hawaiian Affairs; Pōmaikaʻi Kaniʻaupiʻo-Crozier, Maui Land and Pineapple Co.; Brad Keitt, American Bird Conservancy; Cynthia King, Hawaii Department of Land and Natural Resources; Robby Kohley, Pacific Rim Conservation; Melia Lane-Kamahele, National Park Service; Dennis LaPointe, U.S. Geological Survey; Dave Leonard, U.S. Fish and Wildlife Service; Peter Luscomb, Pacific Bird Conservation; Keahi Manea, Kauaʻi hula practitioner; Kai Markell, Office of Hawaiian Affairs;

Bryce Masuda, San Diego Zoo Wildlife Alliance; Wendy Miles, U.S. Fish and Wildlife Service; Ryan Monello, National Park Service; Bret Nainoa Mossman, State of Hawaii Division of Forestry and Wildlife; Hanna Mounce, Maui Forest Bird Recovery Project; Megan Nagel, U.S. Fish and Wildlife Service; Scott Newland, Sedgwick County Zoo; Benton Keali'i Pang, U.S. Fish and Wildlife Service; Teya Penniman, American Bird Conservancy; Zach Pezzillo, Maui Forest Bird Recovery Project; Sheldon Plentovitch, U.S. Fish and Wildlife Service; Dave Rimlinger, San Diego Zoo Wildlife Alliance; Rachel Rounds, U.S. Fish and Wildlife Service; Monique Van Sluys, Taronga Conservation Society, Australia; Lisa Oshiro Suganuma, Office of Native Hawaiian Relations; Nanea Valeros, U.S. Fish and Wildlife Service; Eric VanderWerf, Pacific Rim Conservation; John Vetter, U.S. Fish and Wildlife Service; Adam Vorsino, U.S. Fish and Wildlife Service; Alex Wang, Hawaii Natural Area Reserve System; Chris Warren, National Park Service; Nāmaka Whitehead, Kamehameha Schools; and Tyler Winter, Kaua'i Forest Bird Recovery Project. Kamalani Johnson (Nanaikamalama LLC) provided Hawaiian translations.

This report was greatly improved through comments by Lainie Berry, Lisa Crampton, Jessie D'Elia, Jim Jacobi, Hanna Mounce, and John Vetter. Sarah Nash provided editorial and online publishing support through the Hawai'i Cooperative Studies Unit. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

LITERATURE CITED

Atkinson, C. T., R. B. Utzurrum, D. A. LaPointe, R. J. Camp, L. H. Crampton, J. T. Foster, and T. W. Giambelluca. 2014. Changing climate and the altitudinal range of avian malaria in the Hawaiian Islands—an ongoing conservation crisis on the island of Kaua'i. Global Change Biology 20:2426–2436.

Beebe, N. W., D. Pagendam, B. J. Trewin, A. Boomer, M. Bradford, A. T. Ford, C. Liddington, A. Bondarenco, P. J. De Barro, and J. Gilchrist. 2021. Releasing incompatible males drives strong suppression across populations of wild and Wolbachia-carrying Aedes aegypti in Australia. Proceedings of the National Academy of Sciences 118:e2106828118.

Fortini, L. B., A. E. Vorsino, F. A. Amidon, E. H. Paxton, and J. D. Jacobi. 2015. Large-scale range collapse of Hawaiian forest birds under climate change and the need for 21st century conservation options. PLoS ONE 10:e0140389.

Fortini, L. B., L. R. Kaiser, and D. A. LaPointe. 2020. Fostering real-time climate adaptation: Analyzing past, current, and forecast temperature to understand the dynamic risk to Hawaiian honeycreepers from avian malaria. Global Ecology and Conservation 23:1–10.

Hawley, P. H. 2014. The bow tie model of 21st century palliative care. Journal of Pain and Symptom Management 471:e2-e5.

Hemming, V., M. A. Burgman, A. M. Hanea, M. F. McBride, B. C. Wintle, and B. Anderson. 2017. A practical guide to structured expert elicitation using the IDEA protocol. Methods in Ecology and Evolution 9:169–180.

IUCN (International Union for Conservation of Nature). 2013. Guidelines for Reintroductions and Other Conservation Translocations. IUCN/SSC, Gland, Switzerland.

Judge, S. W., C. C. Warren, R. J. Camp, L. K. Berthold, H. L. Mounce, P. J. Hart, and R. J. Monello. 2021. Population estimates and trends of three Maui Island-endemic Hawaiian honeycreepers. Journal of Field Ornithology 92:115–126.

LaPointe, D. A., M. L. Goff, and C. T. Atkinson. 2010. Thermal constraints to the sporogonic development and altitudinal distribution of avian malaria *Plasmodium relictum* in Hawai . Journal of Parasitology 96:318–324.

Liao, W., O. E. Timm, C. Zhang, C. T. Atkinson, D. A. LaPointe, and M. D. Samuel. 2015. Will a warmer and wetter future cause extinction of native Hawaiian forest birds? Global Change Biology 21:4342–4352.

MFBWG (Maui Forest Bird Working Group). 2020. Kiwikiu emergency capture and care management plan: establishment, need, and goals of a captive population to ensure species persistence. Maui Forest Bird Working Group. 54 pp. https://dlnr.hawaii.gov/wp-content/uploads/2021/03/C-3.pdf

Mounce, H. L., C. C. Warren, C. P. McGowan, E. H. Paxton, and J. J. Groombridge. 2018. Extinction risk and conservation options for Maui parrotbill, an endangered Hawaiian honeycreeper. Journal of Fish and Wildlife Management 9:367–382.

Paxton, E. H., K. Brink, L. H. Crampton, J. Hite, and M. Constantini. 2020. 2018 Kauai forest bird population estimates and trends. Hawaiʻi Cooperative Studies Unit Technical Report HCSU-098. University of Hawaiʻi at Hilo, Hawaiʻi, USA. 31 pages. http://hdl.handle.net/10790/5507

Paxton, E. H., L. H. Crampton, J. P. Vetter, M. Laut, L. Berry, and S. Morey. 2022. Conservation strategies for two rapidly declining forest bird species on Kauaʻi Island. Wildlife Society Bulletin. wsb.1254.

Paxton, E. H., M. Laut, J. P. Vetter, and S. J. Kendall. 2018. Research and management priorities for Hawaiian forest birds. The Condor 120:557–565.

Paxton, E. H., R. J. Camp, P. M. Gorresen, L. H. Crampton, D. L. Leonard, and E. A. VanderWerf. 2016. Collapsing avian community on a Hawaiian island. Science Advances 2:e1600029.

Pratt, T. K., C. T. Atkinson, P. C. Banko, J. D. Jacobi, and B. L. Woodworth. 2009. Hawaiian Forest Birds: Their Biology and Conservation. Yale University Press, New Haven, Connecticut, USA.

Ross, P. A., M. Turelli, and A. A. Hoffmann. 2019. Evolutionary ecology of *Wolbachia* releases for disease control. Annual Review of Genetics 53:93–116.

Samuel, M. D., P. H. F. Hobbelen, F. DeCastro, J. A. Ahumada, D. A. LaPointe, C. T. Atkinson, B. L. Woodworth, P. J. Hart, and D. C. Duffy. 2011. The dynamics, transmission, and population impacts of avian malaria in native Hawaiian birds: a modeling approach. Ecological Applications 21:2960–2973.

Scott, J. M., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology 9:1–431.

Snyder, N. F. R., S. R. Derrickson, S. R. Beissinger, J. W. Wiley, T. B. Smith, W. D. Toone, and B. R. Miller. 1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10:338–348.

Warren, C. C., L. K. Berthold, H. L. Mounce, P. Luscomb, B. Masuda, and L. Berry. 2021. 2019 kiwikiu conservation translocation report. Pacific Cooperative Studies Unit, University of Hawaiʽi at Mānoa, Honolulu, Hawaiʽi, USA. 227 pp. http://hdl.handle.net/10125/75447

APPENDIX I. GLOSSARY OF THE HAWAIIAN VOCABULARY USED IN THE HAWAIIAN FOREST BIRD BIOCULTURAL ASSESSMENT

Hawaiian word	English meaning
ʻAha	Meeting, assembly, gathering
ʻAha moku	An indigenous resource management practice that incorporates land, water, and ocean system best practices and defined by regional boundaries.
Ahupuaʻa	Land division usually extending from the uplands to the sea. A watershed.
ʻahuʻula	Feathered cloak
ʻAkekeʻe	Hawaiian honeycreeper, *Loxops caeruleirostris*
ʻAki	Nibble
ʻAkikiki	Kauaʻi creeper, *Oreomystis bairdi*
ʻĀkohekohe	Hawaiian crested honeycreeper, *Palmeria dolei*
Akua	God, goddess
ʻAlalā	Hawaiian crow, *Corvus hawaiiensis*
Aliʻi	Chief, chiefess, noble, royal, aristocratic
ʻAumākua	Family or personal gods (unique plural form)
Hānau	To give birth, born
Hapa	Part, half, referring to those of mixed ancestry
He Hawaiʻi au	A saying, "I am Hawaiian."
Hoʻomana	Empower
Hui	Association, group, team
Hula	The dance of Hawaiʻi
ʻike kuʻuna	Traditional or inherited knowledge
ʻIke papālua	To see double; to have the gift of second sight and commune with the spiritual world
ʻIo	Hawaiian hawk, *Buteo soltarius*
Iwi	Bones, remains
Kaʻao	A traditional tale
Kaʻiulani	Heir apparent to the throne of the Hawaiian Kingdom (1875–1899)
kākoʻo	To uphold, support, assist
Kalākaua	The last king of the Kingdom of Hawaiʻi (1836–1891)

Kānaka	Native Hawaiian people (unique plural form)
Kapu	Something sacred, taboo, or prohibited
Kaumaha	Weight, burden
Kiki	Swiftly
Kinolau	A form taken by a supernatural body
Kiwikiu	Maui parrotbill, *Pseudonestor xanthophrys*
Kōkua aku, kōkua mai	A Hawaiian saying, "to give and receive"
Kuleana	Responsibility
Kumulipo	A Hawaiian creation chant reciting birth order and relatedness of all life
Kupua	A group of supernatural entities
Kūpuna	Grandparents, ancestors (unique plural form)
Lani	A place of heavenly nature
laupaʽi hou	Continued reproduction and abundance
Liliʽu	See Queen Liliʽuokalani
Mālama ʽāina	To care for the land and natural resources
Māmaki	Native plant (*Pipturus albidus*)
Manaʽo	Thought, thinking, advice
Manu	Bird
Manu ʽōiwi	Native birds
Mauna	Mountain
Moku	A district of an island; a small offshore island; also, poetic reference to large islands
Moku nui	Large island (also mokupuni)
Moʽolelo	Story, legend
Nānā i ke kumu	A Hawaiian saying that translates to "look to the source." It encourages us to look to our ancestors and to nature for guidance.
Nēnē	Hawaiian goose, *Branta sandvicensis*
ʽOhana	Family, kin group, relative
ʽŌiwi	Native
ʽŌlelo	Words, language
Oli	Chant; especially with prolonged phrases chanted in one breath
ʽŌʽō	A genus of extinct birds in the Hawaiian bird family Mohoidae

ʻŌʻūholowai	Type of Hawaiian cloth (kapa) made of the māmaki (*Pipturus albidus*) plant
Pae ʻāina	Island archipelago
Papahānaumokuākea	Name of the marine national monument containing the Northwestern Hawaiian Islands.
Pewa	A wooden wedge used to repair cracks in Hawaiian bowls and other wooden instruments.
Pilina	Relationship, connection
Pono	Right, correct
Pule	Prayer, incantation, blessing
Queen Liliʻuokalani	Last queen of the Hawaiian Kingdom (1838–1917), also known as Liliʻu.
ʻUaʻu	Hawaiian petrel (*Pterodroma sandwichensis*)
Wahi pana	Sacred and celebrated places
Wai	Freshwater
Wao Akua	Place of gods
Wao Lani	Place of chiefs, heavenly nature
Wao Kānaka	Place of people

APPENDIX II. LIST OF ACRONYMS USED IN THIS REPORT

CI	Cytoplasmic incompatibility
DHHL	Department of Hawaiian Home Lands
DLNR	Hawaiʽi State Department of Land and Natural Resources
DOFAW	Division of Forestry and Wildlife
EA	Environmental assessment
EPA	Environmental Protection Agency
EUP	Experimental Use Permit (granted by the EPA)
FWS	Fish and Wildlife Service
HDOA	Hawaiʽi Department of Agriculture
HDOH	Hawaiʽi Department of Health
HEPA	Hawaii Environmental Policy Act
IIT	Incompatible insect technique
IUCN	International Union for Conservation of Nature
MFBWG	Maui Forest Bird Working Group
MM	MosquitoMate
MSU	Michigan State University
NAR	Hawaiʽi State Natural Area Reserve
NEPA	National Environmental Policy Act
NPS	National Park Service
ONHR	Office of Native Hawaiian Relations
PMNM	Papahānaumokuākea Marine National Monument
pgSIT	Precision-guided sterile insect technique
SDM	Structured decision-making
SDZWA	San Diego Zoo Wildlife Alliance
UAV	Unmanned aerial vehicle
UCSD	University of California San Diego
UH	University of Hawaiʽi

APPENDIX III. STATUS ASSESSMENTS FOR EACH SPECIES OF CONCERN

We asked island biologists actively working on the species of concern to provide expert assessments on current population size and time to extinction (Appendix III, Table 1). For each island group, we spent one hour on a video conferencing meeting to discuss all available information on distribution, detections, current and past surveys, and assessments of trends. At the end of the one hour, each participant was queried on two questions per species:

1) Please estimate population size in wild. Using your knowledge of all available data and personal experience working with the birds in their natural habitat:
    a. What do you believe is the upper population size in 2021?
    b. What do you believe is the lower population size in 2021?
    c. What do you believe is the most likely population size in 2021?
    d. How confident are you that the population size estimates (minimum and maximum number of individuals) encompass the true value, given your knowledge of the system and available data? Think of this as the probability you will be right. If you are very confident the true population size is within the range you provided (between min and max), then you may want to say 90–95% confidence (there is always uncertainty, so 100% confidence is unreasonable).
2) Please estimate time to effective extinction. Effective extinction is defined here as fewer than 10 breeding females, or approximately 20 birds. Using your knowledge of all available data and personal experience working with the birds in their natural habitat:
    a. What is your best estimate for time of effective extinction (in years, referenced on year 2021. Can use 0.5 year increments)?
    b. What is a reasonable minimum time for effective extinction (in years, referenced on year 2021. Can use 0.5 year increments)?
    c. What is a reasonable maximum time for effective extinction, assuming no change in current conditions (in years, referenced on year 2021. Can use 0.5 year increments)?
    d. How confident are you that the range of time estimates (minimum and maximum time) encompass the true value, given your knowledge of the system and no changes in current conditions? Think of this as the probability you will be right. If you are very confident the true time to effective extinction will be within the range you provided, then you may want to say 90–95% confidence (there is always uncertainty, so 100% confidence is unreasonable).

The results of the expert elicitation are shown in Appendix III, Tables 2 and 3. In addition, we queried Dr. Crampton (Director, Kaua'i Forest Bird Recovery Project) and Dr. Mounce (Director, Maui Forest Bird Recovery Project) about the percentage of individuals they thought could be captured from the forest if need be, assuming two to three banding teams working to catch birds for two to three years. Dr. Crampton thought ≥80% of 'akikiki, but only 10% of 'akeke'e, maybe 20% if techniques of catching them at the nest are developed. On Maui, Dr. Mounce thought that 80% of kiwikiu could be caught, maybe higher if there was a fully funded effort. For 'ākohekohe, Dr. Mounce estimated 40% of individuals could be caught.

Appendix III, Table 1. Participants of species assessment by island. Kauaʻi forest bird biologists provided expert judgement on ʻakikiki and ʻakekeʻe, and Maui forest bird biologists provided expert judgement on kiwikiu and ʻākohekohe.

Island	Name	Affiliation
Kauaʻi		
	Lucas Behnke	The Nature Conservancy
	Lisa Cali Crampton	Kauaʻi Forest Bird Recovery Project
	Justin Hite	Kauaʻi Forest Bird Recovery Project
	Tyler Winter	Kauaʻi Forest Bird Recovery Project
Maui		
	Laura Berthold	Maui Forest Bird Recovery Project
	Fern Duvall	Maui Natural Area Reserve System
	Hanna Mounce	Maui Forest Bird Recovery Project
	Zach Pezzillo	Maui Forest Bird Recovery Project
	Chris Warren	National Park Service

Appendix III, Table 2. Expert judgement of Kauaʻi and Maui island biologists on time to functional extinction (i.e., <10 breeding pairs) in the wild for the four species of concern: ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. We adjusted confidence ranges to have the same range (90%) to average values across experts (Hemming *et al.* 2017). Scores show year (and partial year) of extinction with minimum (min), most likely, and maximum (max). Percent of confidence (% conf) is shown for raw scores.

		Raw scores (by year)				Corrected scores for 90% confidence		
ʻAkikiki								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E1	2022	2022.5	2024	0.85	2022.0	2022.5	2023.9
	E2	2022	2023	2026	0.9	2022.1	2023.0	2025.7
	E3	2022	2023.5	2026	0.85	2022.1	2023.5	2025.9
	E4	2022.5	2024	2026	0.85	2022.6	2024.0	2025.9
					Mean	2022.2	2023.3	2025.3
ʻAkekeʻe								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E1	2023	2026	2030	0.7	2022.6	2026.0	2030.6
	E2	2029	2033	2041	0.7	2028.4	2033.0	2042.1
	E3	2024	2028	2031	0.5	2021.6	2028.0	2032.8
	E4	2025	2031	2027	0.7	2024.1	2031.0	2026.4
					Mean	2024.2	2029.5	2033.0
Kiwikiu								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E5	2024	2027	2030	0.9	2024.3	2027.0	2029.7
	E6	2024	2030	2040	0.9	2024.7	2030.0	2038.9
	E7	2026	2028	2030	0.5	2024.8	2028.0	2031.2
	E8	2023	2026	2030	0.65	2022.3	2026.0	2030.9

				Mean	2024.0	2027.8	2032.7
ʽĀkohekohe							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E5	2025	2028	2032	0.8	2025.0	2028.0	2032.0
E6	2029	2035	2045	0.95	2029.9	2035.0	2043.4
E7	2028	2033	2036	0.5	2025.0	2033.0	2037.8
E8	2026	2031	2035	0.75	2025.7	2031.0	2035.3
				Mean	2026.4	2031.8	2037.1

Appendix III, Table 3. Expert judgement of Kauaʽi and Maui island biologists on current (2021) wild population sizes for the four species of concern: ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. We adjusted confidence ranges to have the same range (90%) to allow for averaging values across experts (Hemming *et al.* 2017). Scores show population values with minimum (min), most likely, and maximum (max). Percent of confidence (% conf) is shown for raw scores.

	Raw scores				Corrected scores for 90% confidence		
ʽAkikiki							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E1	22	32	44	0.85	21	32	45
E2	20	30	50	0.95	21	30	49
E3	35	56	85	0.8	32	56	89
E4	40	60	120	0.85	39	60	124
				Mean	28	45	76
ʽAkekeʽe							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E1	100	300	400	0.85	88	300	406
E2	700	1300	2000	0.85	665	1300	2041
E3	250	600	850	0.5	-30	600	1050
E4	150	350	600	0.75	110	350	650
				Mean	208	638	1037
Kiwikiu							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E5	110	150	250	0.95	112	150	245
E6	114	117	120	0.8	114	117	120
E7	90	120	200	0.9	90	120	200
E8	145	170	255	0.9	145	170	255
E9	85	120	180	0.8	81	120	188
				Mean	108	135	202
ʽĀkohekohe							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E5	1193	1768	2411	0.95	1223	1768	2377
E6	1630	1669	1770	0.85	1628	1669	1776

E7	1000	1400	1700	0.95	1021	1400	1684
E8	1768	2050	2200	0.9	1768	2050	2200
E9	1200	1400	1700	0.75	1160	1400	1760
				Mean	1360	1657	1959

Appendix IV. Native Hawaiian Perspectives

Native Hawaiian Perspectives Elicitation Participants

This process involved an interagency hui (group) composed of representatives from U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), and the Office of Native Hawaiian Relations (ONHR). The hui convened in the fall of 2021 to develop a biocultural assessment for conservation management considerations regarding four critically endangered Hawaiian forest birds at risk of extinction (ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe).

This biocultural assessment is intended to complement a biological assessment for the four forest bird species by providing Native Hawaiian cultural perspectives and assisting conservation managers in understanding the broader context and implications of their actions and ultimately, making informed decisions.

To guide the development of the biocultural assessment, the interagency hui invited a group of Native Hawaiian forest and forest bird experts and cultural practitioners to share their perspectives on proposed conservation management actions. While their input is not all-inclusive, nor a substitute for formal consultation with the Native Hawaiian community (National Historic Preservation Act, Section 106, 35 CFR 800), it provides content for the biocultural assessment and context for agency leadership in their deliberations and management action recommendations. It should also be noted that the considerations below do not represent recommendations of the group as a whole or as a committee; nor was such consensus sought.

This biocultural assessment is based upon the input of a select group of participants who were invited to participate and share their individual experience, knowledge, and cultural viewpoints related to the proposed management actions for four Hawaiian forest birds: ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe. Additionally, the experts provided perspectives regarding Hawaiian forest birds and their habitat. These opinions do not represent the views of their respective positions or their employer organizations.

It should also be noted that the interagency hui's invitation to participate and advise the preparation of the biocultural assessment should not be construed as initiating formal consultation with the Native Hawaiian Community under the provisions of the National Historic Preservation Act. Formal consultation for specific management actions will be conducted in accordance with applicable federal and state regulations.

The interagency hui sought out responses from participants as individuals. While meetings were held with multiple individuals present, they were not designed in a manner that sought consensus or decision-making to develop a collective recommendation.

Meeting #1 – November 10, 2021

The first meeting of the participants and the interagency hui was held via video conference. The purpose of the meeting was to introduce the participants, provide an overview of the decision-making process and timeline, summarize the status of the four endangered Hawaiian forest birds, describe the proposed conservation management actions, and engage in a discussion to answer questions and receive feedback. Summary information on the status of ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe was provided to participants as well as those who were unable to attend.

Meeting #2 – November 30, 2021

The second meeting of the participants and interagency hui was held via video conference. The purpose of the meeting was to provide more in-depth information regarding the status of the four endangered Hawaiian forest birds and the proposed conservation management actions. Biologists from U.S. geological Survey (USGS) and FWS provided the presentations, and copies were provided to meeting participants who were unable to attend. A facilitated discussion to answer questions and receive feedback from the participants followed the presentations. The FWS representatives furnished additional information regarding a briefing for agency leadership on December 6 and put forth a request for input to inform the preparation of the biocultural assessment.

Agency leadership briefing – December 6, 2021

A virtual briefing on the status of ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe and biological analysis of proposed conservation management actions was provided to leadership from FWS, NPS, USGS, the State of Hawaiʻi Department of Land and Natural Resources, the State of Hawaiʻi Division of Forestry and Wildlife, and The Nature Conservancy. The interagency hui invited participants to attend the virtual briefing and provided copies of the briefing materials. Although the biocultural elicitation had not yet commenced, the meeting included a short presentation to set the cultural context for the biological and ecological presentations regarding the four Hawaiian forest birds and proposed management actions.

Post-briefing request for information

After the December 6, 2021, briefing to agency leadership, the interagency hui transmitted a request for information and comments to the participants. The request communicated that information received would be combined with input from the meetings in November and together would form the basis of the biocultural assessment report. The communication listed a submittal deadline of December 13, 2021.

This appendix contains all the information received from the participants verbatim. It is provided without attribution to individual advisors, unless they chose to identify themselves. Also, light editing was conducted to correct misspellings and insert diacritical marks on Hawaiian language.

Interagency Hui and Native Hawaiian Participants

In the fall of 2021, FWS convened a working group (interagency hui) of individuals from NPS and ONHR to assist them in the development of a biocultural assessment for proposed conservation management actions regarding four Hawaiian forest birds. Members of the interagency hui are:

- Michelle Bogardus, FWS
- Stanton Enomoto, ONHR
- Melia Lane-Kamahele, NPS
- Wendy Miles, FWS
- Megan Nagel, FWS
- Benton Kealiʻi Pang, FWS
- Lisa Oshiro Suganuma, ONHR
- Nanea Valeros, FWS

On October 29, 2021, the interagency hui invited a select group of individuals to participate in a series of meetings and share their experience, knowledge, and cultural viewpoints related to the proposed conservation management actions for four Hawaiian forest birds: ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe. The following individuals accepted the invitation and attended one or more meetings held in November and December 2021 or provided written feedback for the biocultural assessment (in alphabetical order):

- William Ailā, Jr.
- Paulokaleiokū Timmy Bailey
- Keahi Bustamente
- Joseph Kualiʽi Camara
- Kamakana Ferreira
- Noah Gomes
- Sam ʽOhu Gon III
- Pōmaikaʽi Kanīʽaupiʽo-Crozier
- Keahi Manea
- Kai Markell
- Bret Nainoa Mossman
- Nāmaka Whitehead
- Brad Kaʽaleleo Wong

Biocultural Assessment for Four Endangered Hawaiian Forest Birds at Risk of Extinction

The information provided below represents a disaggregation and sorting of information received from the participants into four categories: (1) observations from past conservation actions; (2) Hawaiian forest birds; (3) native forests and habitat; and (4) proposed conservation management actions.

1. Observations from past conservation actions:

Excerpts below are statements from the participants that pertain to historical and recent conservation actions to protect at-risk or endangered species. We divided comments into subgroups: bird conservation efforts by Queen Liliʽuokalani, lessons from Papahānaumokuākea, and other conservation efforts integrating traditional knowledge. Excerpts have been lightly edited to correct misspellings and Hawaiian language diacritical marks.

<u>Regarding conservation efforts by Queen Liliʽuokalani</u>:

"Queen Liliʽuokalani translocated ʽōʽō. If appropriate for aliʽi, we can do it. As long as it does not have severe impacts on the birds here."

"We do have some examples of birds being moved in the past. Queen Liliʽuokalani moved Hawaiʽi ʽōʽō to Kauaʽi in the 1880s as the Hawaiʽi ʽōʽō were declining. ʽŌʽō on Kauaʽi were still okay. Brought some to Oʽahu and unfortunately died. Queen Liliʽuokalani mentioned the birds in her book in the 1890s."

"Our kūpuna were innovative. Queen Liliʽuokalani had translocated ʽōʽō from one island to another. If aliʽi thought appropriate, perhaps may be appropriate today as long as not severe impacts on those already there."

"… I thought it was great to hear the story of Liliʽu doing translocation of mamo before we even thought of translocation being a thing. And I bet there are other stories as such, as well as examples within moʽolelo/kaʽao that won't necessarily provide us specific guidance or situations such as the Liliʽu one, but can give us proper perspectives to use and maybe overall lessons learned."

Regarding lessons learned from Papahānaumokuākea Marine National Monument (PMNM):
"...experience with translocation in Papahānaumokuākea—Nihoa miller bird translocation, a practitioner was part of the crew—perhaps this can be considered? Laysan movement involved practitioner."

"I think we can all agree that the prevention of extinction of the manu are of utmost importance. Our current scientific studies and practices are very helpful as tools to understand these manu and to help provide the optimal chance for survival. And I see cultural practices and protocols as additional tools for our scientific community here in Hawaiʽi to utilize in the conservation of our environment. What we should look to address in relation to this, is to conduct these scientific studies and practices in heavy collaboration with cultural practitioners experienced with manu and forest ecosystems, as we had discussed. Not just as consulting parties, but folks that can actually participate in translocation and monitoring practices."

"This is what I had compared to what we had done in Papahānaumokuākea, with the inclusion of a practitioner or a culturally knowledgeable individual along with some of the translocation practices. I would be the first to acknowledge that even for PMNM, we haven't always been the best at it, but when we do include practitioners, the experience of the accesses or activities becomes greatly enhanced. There is so much value with sharing perspectives to better our work and open our eyes to new ideas or thoughts for management."

"In relation to the above, the inclusion of cultural protocols to best understand how we should translocate (or even where to) is also a must, and part of the lessons we have learned from PMNM activities. Ancestral knowledge is a powerful tool, and as Kai had mentioned in the meeting, acknowledging the unseen here in Hawaiʽi should be emphasized whether our western science can understand it or not. For the practitioners that do see those things, there are meaningful impacts that we have not been utilizing best as of yet."

"Further research into traditional sources of information (i.e., mele, oli, moʽolelo, kaʽao, Hawaiian language newspapers, etc.) can additional help with how we see forest and manu conservation, or can at least provide us with ʽike Hawaiʽi.... Putting resources to looking into those things would be an awesome thing to do and enhance the research methodologies for the protection of these species."

Regarding other conservation efforts integrating traditional knowledge:
"Ultimately in Hawaiʽi we lost much of our connection and history with our manu and that's something that we are working to rebuild. Just as we learned from Mau Piailung to bring back navigation, we are actively learning how to reconnect to manu. Part of that comes from looking elsewhere in the Pacific, in particular we can learn a lot from Aotearoa."

"They used brave, pioneering methodology, and we're not doing enough of that these days, with too much reporting and not enough doing."

"We feel that these birds need to move off a nature reserve into wider, bigger habitats, for their own well-being."

"Kakaruia [black robin of New Zealand] were down to just three birds but today there are 280. This is thanks to taking a risk and using foster parents and later translocating a population to a different island. One population of kakaruia is down to 30 birds and in consultation with the local Moriori and Māori imi and iwi no idea was considered 'too crazy'."

"Back to... Kumulipo, a whole lot of information in there that we do not know they are referring to. There are many bird references that we do not know. Historical view limited and cultural information lost because so much of our people died. Also limited archaeological information preserved in the wet forest. A lot of unknown as well as information there to be interpreted and used."

2. Cultural significance of the four Hawaiian forest birds:
Excerpts below are statements from the participants that pertain to the cultural significance of ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe individually or collectively as Hawaiian forest birds. We divided comments into subgroups based on: Native Hawaiian relationship to birds as ʽohana, kūpuna, ʽaumākua, kupua, and akua; traditional uses of forest birds; cultural appropriateness of conservation management actions; and the significance of the names of the four Hawaiian forest bird species. Excerpts have been lightly edited to correct misspellings and Hawaiian language diacritical marks.

<u>Regarding Native Hawaiians' relationship to forest birds:</u>
"Birds are kūpuna and akua. They perform important functions we cannot do."

"The birds are kūpuna. Elements of who shaped us Hawaiians and forest ecology."

"…It is very well known and established that the ʽaumākua, as well as most if not all akua, are our ancestors. This is well-documented in a number of sources, not the least of which is Kumulipo. There are countless examples of our people interacting with, and caring for the kinolau of an ʽaumākua or an akua. The relationship of a Hawaiian with an ʽaumākua and with an akua is not the same as a relationship with the Christian God. We have an inalienable kuleana to maintain and interact with the akua and ʽaumākua, and time and time again we see in our histories and stories the consequences of not honoring that relationship. This means that we are responsible to care [for] these birds. They are a part of the akua processes happening at an ecological level in the forest; akua processes that we know are already damaged and not functioning as well as we need them to. If we expect them to take care of us in the way that they always have, we need to take care of them, even to hoʽomana them.

Kōkua aku, kōkua mai, it is the Hawaiian way to give help and to receive it. It is a Western perspective to see ourselves as humans as being outside and above the natural processes of the world. We know better, we are a part of those cycles and have been taught from our oldest stories and genealogies that we are ʽohana to the ʽāina and everything upon it. That means we have a responsibility to that ʽohana. We forget that far too often these days, instead [of] choosing to think of the ʽāina and the akua as some foreign object far removed from everyday human life. But they are honored and respected family, and we should treat them as such. If your aunty, cousin, uncle, etc. falls down and has a heart attack, are you going to just leave them there to die? No! Of course not! It may be their time to go or it may not, but you are going to drive them to the hospital and help them in any way you can. To do anything less would not only be irresponsible, but cruel. The respect we should show these birds as manifestations of akua is the respect that one would show any elder in one's family. Similarly, the loss of one of these species is like the loss of a family member. We mourn, we pick up, we move on, and we care for those still with us; but we also remember them and their legacy, and without them, life will not ever be quite the same."

"When we lose a Hawaiian species, we lose a part of ourselves. Echoing other comments and perspectives, allowing/accepting the extinction of a Hawaiian species is an ʽohana issue and decision. Much like "pulling the plug" on a loved one, it is a personal choice, and sometimes the only way this is a peaceful decision is when we know we have done everything in our power to give them a fighting chance. Other times when the situation is the fault of another, peace comes from justice being served, or at least by setting precedence and putting things in place so that moving forward, no other ʻohana will suffer the same fate."

"They are bio-cultural indicators of place, with certain species having close associations with wahi pana. They are storied in moʻolelo as the eyes of the forest, messengers, and protectors of high ranking aliʻi and exceptional individuals. They are kupua, who possess amazing powers; kūpuna (ancestors), who were born many wā (eras) before kanaka and have shaped our identity as Hawaiians; and akua, who facilitate ecological processes like pollination and seed dispersal that kanaka are unable to replicate. Kānaka, therefore, have a reciprocal responsibility (aloha) with forest birds, to tell their stories, honor their functions and roles in our shared environment, and ensure our mutual survival and health."

"…these birds are ʻohana to me and to many kānaka."

"Keep the birds in mind. These are our ancestors."

"…there are not many kānaka involved in these decisions, and so it is the kuleana of all those who are, to enter these kinds of mindsets and see these manu as ʻohana. I know that they can do that."

<u>Regarding traditional uses of forest birds:</u>
"In context of culture—what are cultural traditions of the use of birds? Use birds for different purposes—food, ʻahuʻula, kāhili."

"We need to look at how the birds were used in traditional times."

"Forest birds are prized for their feathers, which were used to make royal adornment for our aliʻi."

"Value our resources by utilizing them; lessens value if put into a museum or book. Hardest to agree is where do we prioritize our species? If do not get to utilize resource, then value of resource diminishes."

"Birds were such valuable things. Bird feathers were the most valuable possessions of Hawaiians. As they have gone extinct, moving further away from value. Working with birds on a daily basis, losing value of these birds and their spirituality."

"I think back to what the bird catchers would do—they would put a kapu on it and let them recover on their own. Different factors back then and they were able to recover on their own."

"Given that birds are so important and valued, need to get them back to the point where they can be utilized again. Focus on ʻiʻiwi because last remaining that were used for featherwork. Want to be able to have ʻuaʻu and ʻiʻiwi."

"The loss of our native birds is probably the number one reason why there are no forest bird hunters today. We know they would have done something, this was their livelihood and their tradition, taught from father to son for centuries. It was not an obsolete tradition either, the value of the native birds had not diminished in the 19th century as there was still strong demand from the aliʻi and from foreigners for featherwork throughout that period. They certainly would have thought that it was pono to do something to try to stop the extinction of the native birds, but what did they do?"

"It is very well recorded that a traditional Hawaiian natural resource management practice implemented to support declining resources is to implement a kapu on the declining resource, allowing populations to stabilize and laupaʻi hou, to multiply over time… There is evidence that historic measures were taken in the 19th century to manage forest bird populations in a similar way. A letter from several Hilo bird hunters to Kamehameha V in the 1860s is on record at the Hawai'i State Archives (HSA, ID Lands, Doc. No. 89) requesting that he lift the kapu on forest birds so that they could hunt them. Similarly, there are Hawaiian language newspaper records (Ka Lahui Hawaii 21 September 1876, p. 3) of an unsuccessful bill in the legislature to prohibit the hunting of forest birds important in featherwork. There is absolutely no reason to believe that there were not other efforts to place kapu on native birds earlier in Hawaiian history."

"… I think it's obvious that the ali'i and the bird hunters would have felt a spiritual obligation to conserve critically endangered birds as well. Some might argue that these four species are not birds known to be important to featherwork, or are not known to be kinolau of akua or 'aumakua, and so they don't deserve the same level of respect or devotion that the people in the old days might have shown something like an 'i'iwi, mamo, or 'ō'ō. The truth is though, we know virtually nothing about our relationships with birds in the old days. I have been studying everything I can get my hands on regarding 'ike ku'una on native birds for more than ten years now. What I have could fill a text book, but it is increasingly evident to me is that what was written down about our ancestors and their relationship with birds is really only a small fraction of what there was to know about that relationship."

"There are huge unanswerable questions about even the more widely remembered aspects of our relationships with native birds, such as featherwork, and even with well known charismatic species like 'i'iwi, there are things that were once common knowledge that virtually nobody knows today."

"Concern is the effects to our birds. We need to be in the context of it. We need to value our resources. Putting them in captivity or away, decreases their value."

"Hard to prioritize our species. We will value them, if we cannot utilize them. This seems to be missing here. Need to bring in the cultural as much as the scientific."

"Birds are valuable. We need to do everything we can to utilize them again. We have a change to save featherwork if we save the 'i'iwi. I want people to utilize 'ua'u again and use feathers."

"Absolutely agree to building back to a place of abundance and ability to utilize resources again."

<u>Cultural appropriateness of conservation management actions</u>
"Is it proper to "play god" and bring birds back?"

"....Who are we to play role such as akua?"

"Important to invoke the akua through akua and protocol. We are the vessel to invoke and call upon akua. Be sure to address the spiritual realm."

"Should humans interfere with akua processes? In the old days, relationship between kānaka and akua was not the same as in western societies. It is rather a give and take relationship. To intervene then is not sacrilegious. Traditional spiritual ideas do not rule out human intervention."

"Kūpuna had a lot of prophesies, not sure whether climate change all man-made. Kūpuna faced extinction and relocated all over the place to survive beyond disease, epidemic, economics."

"Need to invoke the divine. 'Ike pāpālua – nānā i ke kumu – invite others in to divine what should be done? Preserve what is left or let them go. Not just pule and protocol, but communicating with akua, kupua."

"When your ʻohana is sick, you don't let red tape or unrealized risk of an experimental treatment get in the way of trying to heal them. You do what it takes to save them. We have tried to heal our birds by sheltering and protecting them in captivity, but that has only led to them losing who they are."

"You take risks to save your ʻohana, you break down walls and build new ones, and you throw the rules out the window. We do everything and anything possible to keep them in this world. That is what is needed for our manu today."

"Nothing is crazy or impossible when it's for your ʻohana."

"Once again, we find ourselves at the precipice of a wave of extinctions of Hawaiian birds, perhaps heralding the loss of many other native organisms in the next century. Unlike most previous extinction events of Hawaiian bird species, this time we have the power and opportunity to intervene. Before we can consider the different possibilities in which we can intervene, we need to consider whether or not it is our kuleana to do so. I was taught that as Hawaiians we look to the past and to those that came before us to help us in making decisions about the future, and so I think it is pertinent to ask: What would the old people have done back in the day if they were faced with this decision? What would the bird hunters do if they were here now?"

"I feel like there is a tendency to view pre-industrial indigenous societies with an overly romantic lens, and that this has occurred with Hawaiians and our relationships with the ʻāina. Pre-contact Hawaiians were not conservationists. Nobody in the world at all was a conservationist until the 19th century. What our ancestors were was extremely practical. They understood that actions had consequences, and that their interactions with their environment had both positive and negative consequences that affected their ability to survive. Very often this led to them caring for their resources in a way that would be called conservation today, but to them it was just the most logically and spiritually appropriate thing to do."

"Obviously these kapu could not prevent the decline and extinction of most of the birds important to featherwork. While such kapu would have been effective prior to Western contact, it seems doubtful that people in 19th century Hawaiʻi would have yet figured out that the decline of native birds during that time was different—disease was a totally new agent of decline that had not been experienced before. Simply prohibiting human interference with the birds would never have been enough to save them. Regardless, it's obvious that if they had the technology and opportunity that we do today, the bird hunters and the aliʻi in the old days would have utilized it to save the royal feather birds."

"Would not compare (birds) to iwi. Compare spiritually to Kumulipo."

"Don't compare birds to our iwi. But it can be compared to our ʻaumākua, Kumulipo."

<u>Significance of the names of the four Hawaiian forest birds</u>

"…I will share a quick makawalu (deconstruction) I did of the names, ʻakikiki, ʻakekeʻe, and ʻākohekohe. It is known that the names of many species of Hawaiian forest birds are reflective of their calls. Names also capture important information about species function, habits, relationships with other species, and/or the ways they were perceived by our kūpuna. Please note that this was a very quick exercise that is merely suggestive of the possibilities held in these names given by our kūpuna:

- ʽAkikiki—somewhat (ʽa) tiny (kikiki), perhaps in reference to their size, or nibbles (ʽaki) swiftly (kiki), perhaps in reference to their feeding behavior. There could also be a relationship to the ʽūkīkīkī (early stage of the ʽōpakapaka and ʽulaʽula), the kiki (a bird like a plover that was caught with a net), the ʽakiʽaki (a seashore rush), and/or limu ʽakiʽaki (a seaweed that grows on rocks in the surf zone)."

- ʽAkekeʽe—somewhat (ʽa) crooked (keʽeke), perhaps in reference to its offset lower mandible. There could also be a relationship to the kekeʽe or ʽaha (coronetfish), which has a pointed beak and swims near the surface of the water, often in schools (ʽaha means meeting, assembly, gathering), perhaps as ʽakekeʽe prefer to forage in family groups."

- ʽĀkohekohe—in the nature of (ʽā) kohekohe (a native sedge and barnacle). The tuft of feathers atop its head somewhat resembles the tufted inflorescence of the kohekohe sedge, particularly when its floral parts (stamens and styles) are exerted, and its red nape resembles the red leaf sheaths of the kohekohe sedge. Its mottled feathers also somewhat resemble a kohekohe (or ʽōkohekohe) barnacle studded piece of driftwood."

"It is not surprising at all that we know little about the significance of the four endangered species in question, but there are hints that they may have been important to someone. In the Kumulipo there is a bird listed called the kikiki, which could easily be an alternative name for the ʽakikiki. A recorded alternative name for the ʽakekeʽe is ʽōʽūholowai, which is also the name for a formerly famous kind of kapa from ʽōlaʽa, Hawaiʽi that was made from māmaki. The ʽākohekohe appears in an overlooked legend in Fornander about the origins of the relationship that native birds have with ʽōhiʽa. There are numerous yellow, hook-billed mystery birds in records that could easily be the kiwikiu by another name. On top of all of that, Hawaiian families still have secrets today that they don't share with anyone. There could very well be someone alive today with a value for these birds that I've never even heard of. My point is that just because we don't know the cultural significance of these birds today, it does not mean that they don't have any practical significance. When it comes to Hawaiian tradition, there is far more that we don't know than what we do know, and it is better for us to remember that than to let something potentially important fade away just because we as individuals are not familiar with it."

"...at least a couple dozen resources talking about birds and there were so many other names and synonyms. So much more that we do not know."

3. Hawaiian forests and forest bird habitat:
Excerpts below are statements from the participants that pertain to Hawaiian forests and forest bird habitat. Excerpts have been lightly edited to correct misspellings and Hawaiian language diacritical marks.

"That the birds are living lineages of ancestors that preceded our gods and should be treated with reverence. That they are not separate from their place and taking them from their place is not trivial, but that intent should be communicated to both place and birds and the desired outcome of the movement—to save them. That what is intended is a positive outcome of the continued physical presence of the birds in Hawaiʻi as irreplaceable biocultural treasures."

"Birds serve a purpose and function in our ecosystem. We are who we are because of how the environment has shaped us. When something changes Hawaiʻi, it changes who we are."

"ʻAha moku system disturbed since 1779."

"Protect ʻaha moku system to have it equal to scientific systems and value our resources again by making them useable. Swinging too scientific."

"When I look at the phrase 'he Hawai au,' to me it does not mean I am a descendant of the Hawaiian race. To me it gives great insight into our language and the way our kūpuna viewed the world, quite simply 'I am Hawaiʻi.' The water is Hawaiʻi, the ocean is Hawaiʻi, our mauna (mountains) are Hawaiʻi, our birds are Hawaiʻi, and I too am a part of the fabric and mana that makes Hawaiʻi unique and special in the world."

"I am a Hawaiian practitioner, and though I have had training and immersion in hula, oli, ʻōlelo and other aspects of Hawaiian culture, my practice is to mālama ʻāina and wai. As such I have chosen to be a natural resource manager for the Department of Hawaiian Home Lands (DHHL). I know this comment process is not meant to be professional in nature, but I cannot help but provide comments on behalf of my department, because there are real-time actions we can take to give these species a fighting chance and proactively help all manu ʻōiwi moving forward."

"DHHL has the unique fiduciary responsibility and huge kuleana to deliver lands to Native Hawaiians to support their rehabilitation. DHHL has trust lands in Kahikinui, Maui, to the 9,700 ft elevation with some of the best remaining high elevation native forest on leeward Haleakalā. DHHL lands in Humuʻula on Mauna Kea cap in elevation the USFWS Hakalau Wildlife Refuge, Hakalau, Puaʻākala, Honohina, and Maulua sections at around 6,500 ft. It also caps all sections of the Hilo Forest Reserve."

"The use of these lands for conservation purposes can be viewed by some beneficiaries and contrary to DHHL trust obligations. DHHL needs assistance and partnerships with federal and state agencies to create pathways so that DHHL can support the protection and expansion of native habitat while upholding our trust obligations through pono land uses. Projects like fencing in Kahikinui and the Kanakaleonui Bird Corridor in Humuʻula are partnerships that are already in place and can be expanded. Understanding the importance of DHHL trust lands as habitat to critically endangered forest birds ignites a desire in me to find innovative solutions and land uses that serve both kānaka and the environment."

"An important way to gain the support, trust of native Hawaiians and compassion for the plight of our manu ʻōiwi is to show that we are being aware and mindful of their best interest when considering issues that affect or include the use of trust lands. I look forward to finding pathways to prevent extinction and to proactively expand native forest bird habitat with you all. Mahalo for reaching out and for the opportunity to provide manaʻo."

"They need as many of us as possible doing what we can to keep them going and to keep them functioning in the forest."

"Anecdotally, Volcano Village had not had mosquitoes and now have."

"I can agree with getting rid of invasive species."

4. Proposed conservation management actions:
Excerpts below are statements from the participants that pertain to the proposed conservation management actions for the four Hawaiian forest birds: *Wolbachia* insect incompatibility technique (IIT); captive care; translocation; and other comments on management actions. Excerpts have been lightly edited to correct misspellings and Hawaiian language diacritical marks.

Wolbachia IIT
"By suppressing mosquito populations within the birds' current habitat, this strategy could be the least disruptive to the birds. Efforts to implement this strategy should include extensive multipronged communication efforts within the Hawaiian community, to eliminate any misinformation about negative impacts to human health and ensure the use of this strategy does not damage the relationship between Hawaiian communities and these forest birds."

"I am in full support of continuing the *Wolbachia* plan. It is a relatively natural, innovative way to control mosquito populations and disease in the short-term. I also strongly recommend that we consider the possibility of GMO control of mosquitoes in Hawaiʻi in the long term. I'm sure that mosquitoes have a purpose and a function in this world, but that purpose and function is not indigenous to Hawaiʻi. We humans brought them here, and they are clearly causing problems. It is our responsibility to fix that problem."

"...*Wolbachia* option closest to pest control is easiest to accept. Even though an innovation, the idea of being mosquito birth control. Reducing threat. Do not feel it is inconsistent with culture. Not as difficult to accept. Extend manu to being pili to us and our ʻohana. Tool is extension of same idea to treat disease among us."

"*Wolbachia* is easy for me to accept. Taking a known pest species down. No ecological or cultural place for mosquitoes. If manu are pili to us, using the tool to control disease is similar to controlling disease to us."

"...*Wolbachia* easiest for me to accept. Worry that it's least socially acceptable option due to the misinformation related to COVID. May pit our community against our community. Scientists care more about the birds than about us."

"...agree with pest control, but point is not focused on sterilizing mosquitoes, but remember we are talking about native birds, our ancestors, what makes us kānaka. So much more threatening our birds that cannot look at it as one chance to save our birds."

"GMO mosquitoes could cause concern and opposition."

Captive care
"Hawaiian forest birds should not be moved outside of Hawaiʻi for any reason. They are intimately connected to their environment, and it would be torturous to move them so far from the plants, climate, and ecosystems they are familiar with. If captive propagation efforts are pursued within Hawaiʻi, every effort should be made to ensure the birds are comfortable in their temporary environment, including replicating the social systems, environmental conditions, and species compositions they are accustomed to. A supplemental benefit of captive propagation is that it could allow for increased interaction between kānaka and these birds in a controlled and safe environment, similar to the educational visits that are currently conducted at the Keauhou Bird Conservation Center. This could increase pilina and understanding between kānaka and the birds, as well as community support for their recovery."

"I don't think that captive breeding is the ideal situation. I have seen the problems that ʻalalā and palila have had with captive breeding and a loss of culture. Together with the data shared with us about ʻakekeʻe in captivity, it seems to me that we can't depend on captive-breeding programs as a catch-all solution for all critically endangered species. That being said, I also think back to the analogy of sending a family member to the hospital for recovery. If we need to do it then let's do it, but there need to be clear, articulated plans and timelines to return these species to the forest in a reasonably expeditious manner, ideally before the loss of the founder generation who hold culture critical to long-term survival of the species. I am against sending any of these birds to facilities in the mainland U.S. I don't see the long-term practicality of it, the trauma of such a long journey seems dangerous and unnecessary, and removing these birds so far from Hawaiʻi feels wrong."

"Not in favor of captive breeding out of Hawaiʻi because not their natural habitat in which they would stand a better chance."

"I do not support captive breeding outside of Hawaiʻi. Taking birds away from their habitat does not sit right with me."

"Captive breeding has not been a problem, but agree they should not be taken out of Hawaiʻi. Spiritual aspect of their presence here. Laments of Henry ʻŌpūkahaʻia (d.1818) and others who died away from home."

"Discussion about taking birds to mainland facilities caused a drop and is worse. Do realize it is an option that can buy birds some time."

"The idea of taking birds outside of Hawaiʻi not okay at all."

"I agree captive propagation has been around and relatively non-controversial. But taking them out of Hawaiʻi is not right. Examples of kānaka who dies away from their homes. Captive propagation in the islands should be prioritized."

"Don't take birds out of Hawaiʻi."

"After the last meeting with leadership it really felt that some of our major concerns were not even touched on. Nearly every member of the bio-cultural group expressed that they were not in favor of captivity on the continent. That was not made clear in the last meeting to leadership."

<u>Translocation</u>

"I support the idea of translocation to Hawaiʻi. We know that the loss of culture in a bird species can cause perhaps insurmountable problems in a species' recovery. Keeping the birds on the landscape in some form will help them to maintain themselves as a species. I also think that the birds serve a purpose in the ecosystem... helping them to continue to serve that function, even on another island for a short period, feels like the right thing to do."

"Culturally appropriate translocation not an issue back in the day. Concern with these birds is that the birds still fly to other areas where disease is not necessarily controlled. "

"...favor translocation for a few reasons."

"Translocation may be more acceptable in our Native Hawaiian community."

"Given predation of ʻalalā by ʻio, do we have information about predation? Translocated birds could be wiped out by the ʻio."

"This is a strategy that was practiced by at least one of our ali'i, Lili'uokalani, who moved 'ō'ō from Hawai'i Island to Kaua'i. If this strategy is pursued, all efforts should be made to ensure the translocated birds do not significantly impact any native forest birds resident to the translocation area, including 'io."

"Ask permission of Hawai'i Island whether they would welcome translocation."

"Incorporating pule and communicating intent to both place(s) and birds (both the ones being moved and the ones in the new locations) and all communities involved is appropriate."

"Translocation may not be culturally appropriate."

"Not in favor of translocating birds. If happened naturally, different."

<u>Other management considerations (including no action & extinction)</u>

"Vector control, translocation, captive breeding—probably a combination."

"...need a lot more time to reflect. Part of me believes to let them go in their natural habitat."

"A lot of people would say to let them go. Kūpuna often make decision to let them go."

"We should take care of them as much as possible. If no success, we can let them go."

"Letting a forest bird go extinct while we have hope is not appropriate. Only when all hope is lost should we allow it."

"Putting into context of extinction, not sure that have authority to play akua to try these different measures. Culturally seen thousands of things go extinct. This is not something new to us culturally."

"Wouldn't we do everything we could to help our kūpuna persist if chance of succeeding? If no chance, then do not make them suffer."

"It is my opinion that we should do what we can to save the 'akikiki, 'akeke'e, 'ākohekohe, and kiwikiu: 1) as long as there is a strong chance of success, and 2) we can do so without causing them pain and suffering. If either of the above conditions are not met, then I feel it would [be] more appropriate to allow the birds to go extinct in their natural environment without further intervention."

"...part of me thinks we should let them go, a part of me thinks about our kūpuna, resilience and innovation. Utilized new technologies to benefit our people and environment."

"Kai'ulani was hapa and could not rule kingdom, but Kalākaua described everyone with mana. 'Alalā mixed breeding, hybrid, with similar species even from other places. Always still have genealogical ties."

"Proper communication of intent and outcomes to birds, places, and ecosystems therein. Proper pule for removal of defilement and blights modified from agriculture pule for those purposes. Pule for healing. Blessings of all facilities and staff involved."

"Protocols for each potential action by the lineal and cultural descendants of the islands upon which actions will be taken."

"Pule and other protocols should be incorporated into all aspects of the program."

"All rare species recovery efforts, including for these four critically endangered species of birds, must be compatible with maintaining and improving the health of larger native ecosystems and landscapes. For example, efforts to recover native forest birds often require increased human presence in intact native ecosystems that could result in the inadvertent introduction and/or spread of invasive plant or insect species. The whole is more important than the individual."

"Additional research be conducted into ʻōiwi relationships with and perspectives on forest birds. This should include discussions with cultural practitioners and scholars of indigenous knowledge, Hawaiian language newspaper, oli, moʻolelo, and kaʻao research into forest birds and perspectives on extinction. While the current consultation effort was a great start, it was rushed and there is much more work to be done."

"All staff working with the birds should have basic and continuing cultural competency training, including at minimum an understanding of the kinship relationship between kanaka and forest birds and the ability to enter the bird's space in a culturally appropriate way."

"Hire staff with dual knowledge of biology/botany/ecology and ʻōlelo Hawaiʻi/cultural practice to lead additional research and consultation efforts. These should be regular staff, not interns or contractors, compensated at a level similar to other agency staff and suitable to their knowledge and skills."

"I don't know what will be decided, but I hope that whatever it is considers the behavior and culture of the birds on equal footing with their genes."

"I think that we all have a fairly good idea that the endangered species crisis in Hawaiʻi is only going to get worse in coming decades. It seems that much more would be possible if we could have the public's full support when it is needed. Conservation initiatives here always seem to come under strong pushback from the public. There are of course a lot of nuanced socio-economic, historic and political reasons for why there isn't always public support of critical conservation programs in Hawaiʻi. One problem that I see that needs to be addressed is the rebuilding and fortification of native Hawaiian relationships with the ʻāina. Time and time again, Hawaiians express the idea that we should not invest in rare organisms that have no practical purpose. Endangered organisms almost always have practical purpose, even purpose directly relevant to our lives, but we as Hawaiians are prevented from maintaining a relationship of purpose with them. We need to invest in finding ways to navigate the United States federal legislative system to regain native Hawaiian ʻāina rights. We should be able to harvest native organisms (even endangered ones) within reason, as do our Native American counterparts. Re-establishing indigenous rights and relationships with endangered ecosystems needs to become a major priority for Hawaiian conservation. There will never be full Hawaiian support of conservation efforts if we do not establish reasonable avenues for Hawaiians to maintain their relationship with the land."

"…Please also consider inquiring with DOFAW about their own cultural working group for these four endangered species. In that group we have been discussing the creation of mele and moʻolelo, partly in an attempt to engage the public with these birds, and to create tangible ways for ourselves to contribute to their survival."

Biocultural Considerations for Decision-Makers

The following section summarizes the main points and conclusions from the biocultural assessment based on verbal and written input from the native Hawaiian participants:

Considering the connections among Native Hawaiians, Hawaiian forest birds, native forests, and other interconnected elements of Hawaiian cosmology

Native Hawaiians have a deep and genetic kinship with Hawaiian forest birds and revere, honor, and deify them as family, ancestors, guardians, spirits, and gods, connecting through the realms of wao kānaka (people), wao lani (chiefs), and wao akua (gods). Further, Hawaiian forest birds are integral to native forests, which in turn, are integral to ecology and ecosystem functions of an ahupuaʽa, moku, moku nui, and the greater pae ʽāina.

This centuries-long relationship between Native Hawaiians and forest birds and their reverence for forest birds' relationships with the gods was and continues to be honored through the use of feathers for adornments and ceremonial objects; acknowledged in Kumulipo (cosmological and genealogical chants), ʽōlelo noʽeau (proverbs), and moʽolelo (stories); deification as ʽaumākua (guardians), kupua (spirits), and akua (god-forms); and respected and managed through decrees of aliʽi (chiefs) for kapu and translocation to other islands.

Thus, the relationship of Native Hawaiians to forest birds is inextricably connected and Native Hawaiians have kuleana (right and responsibility) for their well-being as the means of sustaining that relationship. They also bear the kaumaha (weight; burden) of the kuleana and decisions. The possible loss (extinction) of Hawaiian forest birds is a loss of identity and connectivity for kānaka as a tangible connection to species and place.

Acknowledgement of the bond between native species and Native Hawaiians and Hawaiian traditional knowledge has manifested in recent conservation actions (e.g., Papahānaumokuākea MNM) where cultural practitioners were involved in the planning and execution of a translocation action. Protocol and ceremony were conducted in honor of that relationship and to invoke the role of the spiritual realm, leading to not only a successful management action, but more so to the survival of the species.

So there is precedent (historical and recent) for Native Hawaiians exercising their kuleana, traditional knowledge, and cultural practices in conservation actions for the preservation and continuity of their relationship with an endemic native species. Appropriate intentions are necessary to manifest the desired outcomes, thus the intent for perpetuating these Hawaiian forest birds must be for their various roles in Hawaiian cosmology.

Concerning captive care outside of Hawaiʽi

It is the connection of Native Hawaiians/kānaka to place and to all the things that exist in that space (habitat/ecosystem) that are paramount. Maintenance of that relationship is essential for their survival as a species. When one element or variable is removed from the whole, the relation is strained and the likelihood of survival diminishes. As such, adverse biocultural impacts require biocultural mitigation, and some impacts will lack adequate mitigation.

This is the reason why many participants expressed their disagreement with the relocation and captive breeding of ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe to sites outside of the pae ʽāina o Hawaiʽi. Without connection to kānaka, place, and habitat, the adverse impact would be too great and very likely decrease the chance for survival. Other advisors however, viewed the separation (outside of Hawaiʽi) as temporary and an opportunity for the application of new methods or actions to increase forest bird populations—with the goal of returning the forest birds to their natural environment in the near future.

If removal and captive care outside of Hawaiʽi is conducted, decision-makers and conservation managers need to be fully aware of the effects of straining the cultural connection and make all necessary measures to maintain it if captive breeding is to be successful. Such measures could include the recreation of the bird's habitat (plants, climate, food, etc.) and access for kānaka to conduct protocol, communicate with, and monitor the condition of the birds.

Concerning species extinction
Species extinction is understood and accepted within a Native Hawaiian world view. After death, all things return to the earth (papa). While available means to sustain a species should be implemented, they should not be exercised to the extent of causing harm, pain, or adversely affecting the connection.

It is the notion of the connection and "quality of life" that distinguishes a Native Hawaiian cultural perspective from that of the government agencies responsible for natural resources management. Such agencies are charged (often statutorily) with preserving biodiversity and preventing the extinction of species at nearly all costs or by whatever means necessary. This mission is anathematic to Native Hawaiian culture, and it is the view of many cultural advisors that species extinction is acceptable over undue or excessive harm to the connection or the bird's quality of life.

With the goal of preserving the connection and the quality of life of ʽakikiki, ʽakekeʽe, kiwikiu, and ʽākohekohe, Native Hawaiian practitioners should be afforded equal access to the birds during the implementation of the management actions with the goal of maintaining the relationship with the birds. And, if through the exhaustion of available management actions, extinction is likely to occur, it is imperative that Native Hawaiians be allowed access to the remaining birds and undertake whatever cultural actions necessary to preserve the legacy of the species. Such actions may include composition of oli, mele, poetry, or other means of storytelling; recordation of bird song; photography, sculpture, painting, or other visual art forms; and possibly the recovery of feathers (after death) for cultural implements.

Concerning proposed conservation management actions
The participants expressed different and occasionally divergent points of view regarding the application of the various management options: *Wolbachia* IIT, captive care, and translocation.

Several preferred the application of *Wolbachia* as it would address the invasive species (mosquitoes) directly as opposed to affecting the forest birds and their habitat. Concerns and skepticism were also expressed regarding broader public perceptions about the introduction of yet another foreign organism to Hawaiʽi and the impacts of unintended consequences, as well as fears of potentially introducing genetically modified organisms to the state.

Other advisors accepted that translocation (within the pae ʽāina) was a viable option with the condition that appropriate cultural protocols to seek permission from the birds as well as the receiving island, site, and habitat were observed, and that participation and continued involvement by kānaka was provided.

Similarly, others understood the value of captive care as a temporary means of removing the forest birds from immediate threats (avian malaria) and allowing the birds to breed in captivity and increase their population. Again, such management actions were conditioned with Native Hawaiian cultural practitioner participation to conduct appropriate cultural protocols to seek permission from the birds and that continued involvement by kānaka was provided.

Regarding other concerns from participants
Concerns were expressed by some participants about the timing and process for engagement on the deliberations and decision-making for the management actions regarding: ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe. In summary, they felt that engagement occurred too late in the process and without parity to proposed biological management actions whereby the mission of the government agencies would supersede and dismiss any biocultural considerations. Some further expressed skepticism and distrust that this is yet another example (based on many prior experiences) where their time, effort, and input would be wasted and abused as a "check-the-box" exercise by decision-makers and summarily disregarded in lieu of a pre-determined action.

Recommendations were made by several participants of their kuleana (right and responsibility) to Hawaiian forests and forest birds and advocated for greater inclusion of Native Hawaiian cultural practitioners and resource managers across the spectrum of Hawaiian forest bird conservation actions—including scientific research, management planning, deliberation and decision-making, implementation, and monitoring.

In addition to the inclusion of Native Hawaiians in management actions was the acknowledgement and need for continued research and understanding of cultural references and traditions associated with Hawaiian forest birds. Such actions would work in concert with greater participation and inclusion of cultural practitioners in conservation management actions.

Concluding comments and considerations for decision-makers
The connection among Native Hawaiians, Hawaiian forests, and forest birds is well established, centuries old, and immutable. Native Hawaiians are, through the Kumulipo and other sources, genealogically tied to forest birds, their immediate habitat, and their broader island/archipelagic environment. Thus, the four Hawaiian forest birds at risk of extinction (ʻakikiki, ʻakekeʻe, kiwikiu, and ʻākohekohe) are ʻohana (family).

Native Hawaiians therefore have kuleana (rights and responsibilities) and kaumaha (weight; burden) in the care and stewardship of their ʻohana. Consequently, there is an obligation for government leaders and decision-makers to acknowledge this familial relationship and meaningfully engage the Native Hawaiian community in the care, decisions, and management actions regarding their family members.

The participants engaged in the dialogue thus far, by virtue of their participation, time, energy and heartfelt input, have demonstrated their willingness to be active participants in the conservation planning and management of not only the four forest birds, but all native species at risk of extinction.

Verbatim Responses from Native Hawaiian Participants
The following comments and statements were from individual participants who participated in one or more meetings or submitted written comments. They are grouped chronologically based on the meetings in November, the leadership briefing in December, and the written comments provided after the leadership briefing. The quotations are kept whole per each individual. Light editing was conducted for formatting purposes and to correct misspellings and diacritical marks as necessary on Hawaiian words.

Input and feedback from November 10 and November 30 meetings:

"In context of culture—what are cultural traditions of the use of birds? Use birds for different purposes—food, ʻahuʻula, kāhili. Status quo of ancient times not necessarily comparable. Putting into context of extinction, not sure that have authority to play akua to try these different measures. Culturally seen thousands of things go extinct. This is not something new to us culturally. Would not compare to iwi. Compare spiritually to Kumulipo. Culturally appropriate translocation not an issue back in the day. Concern with these birds is that the birds still fly to other areas where disease is not necessarily controlled. Native Hawaiians adapt to changes as well. Not in favor of translocating birds. If happened naturally, different. ʻAha moku system disturbed since 1779."

"We need to look at how the birds were used in traditional times. It is proper to ʻplay god' and bring birds back—Translocation may not be culturally appropriate."

"Don't compare birds to our iwi. But it can be compared to our ʻaumākua, kumulipo." [Response to comment regarding removal or leave in place for iwi when found or disturbed and options to relocate to protect the iwi.]

"...experience with translocation in Papahānaumokuākea—Nihoa miller bird translocation, a practitioner was part of the crew—perhaps this can be considered? ....Who are we to play roles such as akua. Important to invoke the akua through akua and protocol. We are the vessel to invoke and call upon akua. Laysan movement involved practitioner. Be sure to address the spiritual realm."

"...favor translocation for a few reasons. 1 – think back to what the birdcatchers would do—they would put a kapu on it and let them recover on their own. Different factors back then and they were able to recover on their own. A lot of people would say to let them go. Kūpuna often make decision to let them go. Birds serve a purpose and function in our ecosystem. We are who we are because of how the environment has shaped us. When something changes Hawaiʻi, it changes who we are. Should humans interfere with akua processes? In the old days, relationship between kānaka and akua was not the same as in western societies. It is rather a give and take relationship. To intervene then is not sacrilegious. Traditional spiritual ideas do not rule out human intervention."

"Anecdotally Volcano Village had not had mosquitoes and now have. Given predation of ʻalalā by ʻio, do we have information about predation? Translocated birds could be wiped out by the ʻio. Loved ʻike from everyone. Kūpuna had a lot of prophesies, not sure whether climate change all man-made. Kūpuna faced extinction and relocated all over the place to survive beyond disease, epidemic, economics. Kaiʻulani was hapa and could not rule kingdom, but Kalākaua described everyone with mana. ʻAlalā mixed breeding, hybrid, with similar species even from other places. Always still have genealogical ties. Similar to iwi and all washing out at shores. Not sure kūpuna could foresee that iwi would be washing out—give to Kanaloa or protect them by moving them? All kinds of problems now with people taking iwi. Need to invoke the divine. ʻIke papālua – nānā i ke kumu—invite others in to divine what should be done? Preserve what is left or let them go. Not just pule and protocol, but communicating with akua, kupua. Ask permission of Hawaiʻi Island whether they would welcome translocation."

"Vector control, translocation, captive breeding—probably a combination"

"...need a lot more time to reflect. Part of me believes to let them go in their natural habitat. Alternately, our kūpuna were innovative. Queen Liliʻuokalani had translocated ʻōʻō from one island to another. If aliʻi thought appropriate, perhaps may be appropriate today as long as not severe impacts on those already there. Birds are kūpuna and akua. They perform important functions we cannot do. Wouldn't we do everything we could to help our kūpuna persist if chance of succeeding? If no chance, then do not make them suffer. Not in favor of captive breeding out of Hawaiʻi because not their natural habitat in which they would stand a better chance.

"...*Wolbachia* option closest to pest control is easiest to accept. Even though an innovation, the idea of being mosquito birth control. Reducing threat. Do not feel it is inconsistent with culture. Not as difficult to accept. Extend manu to being pili to us and our ʻohana. Tool is extension of same idea to treat disease among us."

"*Wolbachia* as easy for me to accept. Taking a known pest species down. No ecological or cultural place for mosquitoes. If manu are pili to us, using the tool to control disease is similar to controlling disease to us."

"...agree with pest control, but point is not focused on sterilizing mosquitoes, but remember we are talking about native birds, our ancestors, what makes us kānaka. So much more threatening our birds that cannot look at it as one chance to save our birds."

"Value our resources by utilizing them; lessens value if put into a museum or book. Hardest to agree is where do we prioritize our species? If do not get to utilize resource, then value of resource diminishes. Protect ʻaha moku system to have it equal to scientific systems and value our resources again by making them usable. Swinging too scientific."

"Absolutely agree to building back to a place of abundance and ability to utilize resources again."

"...*Wolbachia* easiest for me to accept. Worry that least socially acceptable option due to the misinformation related to COVID. May pit our community against our community. Scientists care more about the birds than about us. Translocation may be more acceptable in our NHC (Native Hawaiian community)."

"I do not support captive breeding outside of Hawaiʻi. Taking birds away from their habitat does not sit right with me."

"...concern given everything going on. GMO mosquitoes could cause concern and opposition. Captive breeding has not been a problem but agree they should not be taken out of Hawaiʻi. Spiritual aspect of their presence here. Laments of Henry ʻŌpūkahaʻia (d. 1818) and others who died away from home."

"Mahalo everyone. Kākoʻo what everyone has said. Discussion about taking birds to mainland facilities caused a drop and is worse. Do realize it is an option that can buy birds some time. Birds were such valuable things. Bird feathers were the most valuable possessions of Hawaiians. As they have gone extinct, moving further away from value. Working with birds on a daily basis, losing value of these birds and their spirituality. We do have some examples of birds being moved in the past. Queen Liliʻuokalani moved Hawaiʻi ʻōʻō to Kauaʻi in the 1880s as the Hawaiʻi ʻōʻō were declining. ʻŌʻō on Kauaʻi were still okay. Brought some to Oʻahu and unfortunately died. Queen Liliʻuokalani mentioned the birds in her book in the 1890s. There are many bird references that we do not know. Historical view limited and cultural information lost because so much of our people died. Also limited archaeological information preserved in the wet forest. A lot of unknown as well as information there to be interpreted and used. The idea of taking birds outside of Hawaiʻi not okay at all. Given that birds are so important and valued, need to get them back to the point where they can be utilized again. Focus on ʻiʻiwi because last remaining that were used for featherwork. Want to be able to have ʻuaʻu and ʻiʻiwi."

"...at least a couple dozen resources talking about birds, and there were so many other names and synonyms. So much more that we do not know. Knowledge of these birds now make them significant—even if more commonly eaten."

"We don't support mosquitoes. Keep the birds in mind. These are our ancestors. Concern is the effects to our birds. We need to be in the context of it. We need to value our resources. Putting them in captivity or away, decreases their value."

"I can agree with getting rid of invasive species. Hard to prioritize our species. We will value them, if we cannot utilize them. This seems to be missing here. Need to bring in the cultural as much as the scientific."

"I agree captive propagation has been around and relatively non-controversial. But taking them out of Hawaiʻi is not right. Examples of kānaka who die away from their homes. Captive propagation in the islands should be prioritized."

"Don't take birds out of Hawaiʻi. Birds are valuable. We need to do everything we can to utilize them again. We have a change to save featherwork if we save the ʻiʻiwi. I want people to utilize ʻuaʻu again and use feathers."

Input and feedback from December 6 meeting:
"....Mahalo a nui loa Stanton and the biocultural working group. As I saw that "bow tie" model, I kept seeing a pewa, and the function of the pewa of holding the cracks in a bowl or wood piece together. Very informative work."

"...I love mention of the pewa and think that would be a superb fit for your discussion, especially with the manaʻo of repair of something that might otherwise be lost to damage."

"...and the consideration of the whole function of the bowl (forest) as we hold it together with the pewa [biocultural palliative care model]."

Written feedback after December 6 meeting:
"That the birds are living lineages of ancestors that preceded our gods and should be treated with reverence. That they are not separate from their place and taking them from their place is not trivial, but that intent should be communicated to both place and birds and the desired outcome of the movement—to save them. That what is intended is a positive outcome of the continued physical presence of the birds in Hawaiʻi as irreplaceable biocultural treasures."

"Letting a forest bird go extinct while we have hope is not appropriate. Only when all hope is lost should we allow it."

"Incorporating pule and communicating intent to both place(s) and birds (both the ones being moved and the ones in the new locations) and all communities involved is appropriate."

"Proper communication of intent and outcomes to birds, places, and ecosystems therein. Proper pule for removal of defilement and blights modified from agriculture pule for those purposes. Pule for healing. Blessings of all facilities and staff involved."

"Protocols for each potential action by the lineal and cultural descendants of the islands upon which actions will be taken."

"Mahalo for the opportunity to share manaʻo on doing our best to mālama our endangered birds. When I look at the phrase "he Hawaiʻi au," to me it does not mean I am a descendant of the Hawaiian race. To me it gives great insight into our language and the way our kūpuna viewed the world, quite simply "I am Hawaiʻi." The water is Hawaiʻi, the ocean is Hawaiʻi, our mauna are Hawaiʻi, our birds are Hawaiʻi, and I too am a part of the fabric and mana that makes Hawaiʻi unique and special in the world.

"When we lose a Hawaiian species, we lose a part of ourselves. Echoing other comments and perspectives, allowing/accepting the extinction of a Hawaiian species is an ʻohana issue and decision. Much like "pulling the plug" on a loved one, it is a personal choice, and sometimes the only way this is a peaceful decision is when we know we have done everything in our power to give them a fighting chance. Other times when the situation is the fault of another, peace comes from justice being served, or at least by setting precedence and putting things in place so that moving forward, no other ʻohana will suffer the same fate.

"I am a Hawaiian practitioner, and though I have had training and immersion in hula, oli, ʻōlelo and other aspects of Hawaiian culture, my practice is to mālama ʻāina and wai. As such I have chosen to be a natural resource manager for the Department of Hawaiian Home Lands (DHHL). I know this comment process is not meant to be professional in nature, but I cannot help but provide comments on behalf of my department, because there are real-time actions we can take to give these species a fighting chance and proactively help all manu ʻōiwi moving forward.

"DHHL has the unique fiduciary responsibility and huge kuleana to deliver lands to Native Hawaiians to support their rehabilitation. DHHL has trust lands in Kahikinui, Maui, to the 9,700 ft elevation with some of the best remaining high elevation native forest on Leeward Haleakalā. DHHL lands in Humuʻula on Mauna Kea cap in elevation the USFWS Hakalau Wildlife Refuge, Hakalau, Pua ʻĀkala, Honohina, and Maulua sections at around 6,500 ft. It also caps all sections of the Hilo Forest Reserve.

"The use of these lands for conservation purposes can be viewed by some beneficiaries and contrary to DHHL trust obligations. DHHL needs assistance and partnerships with federal and state agencies to create pathways so that DHHL can support the protection and expansion of native habitat while upholding our trust obligations through pono land uses. Projects like fencing in Kahikinui and the Kanakaleonui Bird Corridor in Humuʻula are partnerships that are already in place and can be expanded. Understanding the importance of DHHL trust lands as habitat to critically endangered forest birds ignites a desire in me to find innovative solutions and land uses that serve both kānaka and the environment.

"An important way to the gain the support, trust of native Hawaiians, and compassion for the plight of our manu ʻōiwi is to show that we are being aware and mindful of their best interest when considering issues that affect or include the use of trust lands. I look forward to finding pathways to prevent extinction and to proactively expand native forest bird habitat with you all. Mahalo for reaching out and for the opportunity to provide manaʻo."

"Forest birds are prized for their feathers, which were used to make royal adornment for our aliʻi. They are biocultural indicators of place, with certain species having close associations with wahi pana. They are storied in moʻolelo as the eyes of the forest, messengers, and protectors of high ranking aliʻi and exceptional individuals. They are kupua, who possess amazing powers;

kūpuna (ancestors), who were born many wā (eras) before kānaka and have shaped our identity as Hawaiians; and akua, who facilitate ecological processes like pollination and seed dispersal that kānaka are unable to replicate. Kānaka, therefore, have a reciprocal responsibility (aloha) with forest birds, to tell their stories, honor their functions and roles in our shared environment, and ensure our mutual survival and health. It is my opinion that we should do what we can to save the ʽakikiki, ʽakekeʽe, ʽākohekohe, and kiwikiu:

1. As long as there is a strong chance of success, and
2. We can do so without causing them pain and suffering.

"If either of the above conditions are not met, then I feel it would be more appropriate to allow the birds to go extinct in their natural environment without further intervention."

"Regarding the three options proposed, I offer the following additional thoughts:

1. Translocation—This is a strategy that was practiced by at least one of our aliʽi, Liliʽuokalani, who moved ʽōʽō from Hawaiʽi Island to Kauaʽi. If this strategy is pursued, all efforts should be made to ensure the translocated birds do not significantly impact any native forest birds resident to the translocation area, including ʽio.
2. Captive propagation—Hawaiian forest birds should not be moved outside of Hawaiʽi for any reason. They are intimately connected to their environment, and it would be torturous to move them so far from the plants, climate, and ecosystems they are familiar with. If captive propagation efforts are pursued within Hawaiʽi, every effort should be made to ensure the birds are comfortable in their temporary environment, including replicating the social systems, environmental conditions, and species compositions they are accustomed to. A supplemental benefit of captive propagation is that it could allow for increased interaction between kānaka and these birds in a controlled and safe environment, similar to the educational visits that are currently conducted at the Keauhou Bird Conservation Center. This could increase pilina and understanding between kānaka and the birds, as well as community support for their recovery.
3. *Wolbachia* incompatible insect technique—By suppressing mosquito populations within the birds' current habitat, this strategy could be the least disruptive to the birds. Efforts to implement this strategy should include extensive multipronged communication efforts within the Hawaiian community, to eliminate any misinformation about negative impacts to human health and ensure the use of this strategy does not damage the relationship between Hawaiian communities and these forest birds.

"In addition to the above, I recommend the following:

1. All rare species recovery efforts, including for these four critically endangered species of birds, must be compatible with maintaining and improving the health of larger native ecosystems and landscapes. For example, efforts to recover native forest birds often require increased human presence in intact native ecosystems that could result in the inadvertent introduction and spread of invasive plant or insect species. The whole is more important than the individual.
2. All staff working with the birds should have basic and continuing cultural competency training, including at minimum an understanding of the kinship relationship

between kānaka and forest birds and the ability to enter the bird's space in a culturally appropriate way.

3. Pule and other protocol should be incorporated into all aspects of the program.
4. Additional research be conducted into ʻōiwi relationships with and perspectives on forest birds. This should include discussions with cultural practitioners and scholars of indigenous knowledge, Hawaiian language newspaper, oli, moʻolelo, and kaʻao research into forest birds and perspectives on extinction. While the current consultation effort was a great start, it was rushed and there is much more work to be done.
5. Hire staff with dual knowledge of biology/botany/ecology and ʻōlelo Hawaiʻi/cultural practice to lead additional research and consultation efforts. These should be regular staff, not interns or contractors, compensated at a level similar to other agency staff and suitable to their knowledge and skills.

"Finally, I will share a quick makawalu (deconstruction) I did of the names, ʻakikiki, ʻakekeʻe, and ʻākohekohe. It is known that the names of many species of Hawaiian forest birds are reflective of their calls. Names also capture important information about species function, habits, relationships with other species, and/or the ways they were perceived by our kūpuna. Please note that this was a very quick exercise that is merely suggestive of the possibilities held in these names given by our kūpuna:

- ʻAkikiki—somewhat (ʻa) tiny (kikiki), perhaps in reference to their size, or nibbles (ʻaki) swiftly (kiki), perhaps in reference to their feeding behavior. There could also be a relationship to the ʻūkīkīkī (early stage of the ʻōpakapaka and ʻulaʻula), the kiki (a bird like a plover that was caught with a net), the ʻakiʻaki (a seashore rush), and/or limu ʻakiʻaki (a seaweed that grows on rocks in the surf zone).
- ʻAkekeʻe—somewhat (ʻa) crooked (keʻeke), perhaps in reference to its offset lower mandible. There could also be a relationship to the kekeʻe or ʻaha (coronetfish), which has a pointed beak and swims near the surface of the water, often in schools (ʻaha means meeting, assembly, gathering), perhaps as ʻakekeʻe prefer to forage in family groups.
- ʻĀkohekohe—in the nature of (ʻā) kohekohe (a native sedge and barnacle). The tuft of feathers atop its head somewhat resembles the tufted inflorescence of the kohekohe sedge, particularly when its floral parts (stamens and styles) are exerted, and its red nape resembles the red leaf sheaths of the Kohekohe sedge. Its mottled feathers also somewhat resemble a kohekohe (or ʻōkohekohe) barnacle studded piece of driftwood."

"For the most part, I feel like our discussion at the last meeting involving cultural concerns really encompassed much of our thoughts. It was great to have all those other folks to reiterate some of the same cultural inclusivity points we had for how best we can move forward. To emphasize some of what I remember from OHA's thoughts and experiences with Papahānaumokuākea:

"I think we can all agree that the prevention of extinction of the manu are of utmost importance. Our current scientific studies and practices are very helpful as tools to understand these manu and to help provide the optimal chance for survival. And I see cultural practices and protocols as additional tools for our scientific community here in Hawaiʻi to utilize in the conservation of our environment. What we should look to address in relation to this, is to conduct these scientific studies and practices in heavy collaboration with cultural practitioners experienced with manu and forest ecosystems, as we had discussed. Not just as consulting parties, but folks that can actually participate in translocation and monitoring practices.

"This is what I had compared to what we had done in Papahānaumokuākea, with the inclusion of a practitioner or a culturally knowledgeable individual along with some of the translocation practices. I would be the first to acknowledge that even for PMNM, we haven't always been the best at it, but when we do include practitioners, the experience of the accesses or activities becomes greatly enhanced. There is so much value with sharing perspectives to better our work and opens our eyes to new ideas or thoughts for management.

"In relation to the above, the inclusion of cultural protocols to best understand how we should translocate (or even where to) is also a must, and part of the lessons we have learned from PMNM activities. Ancestral knowledge is a powerful tool, and as Kai had mentioned in the meeting, acknowledging the unseen here in Hawai'i should be emphasized whether our western science can understand it or not. For the practitioners that do see those things, there are meaningful impacts that we have not been utilizing best as of yet.

"Further research into traditional sources of information, i.e. mele, oli, mo'olelo, ka'ao, Hawaiian language newspapers, etc. can additional help with how we see forest and manu conservation, or can at least provide us with 'ike Hawai'i. I thought it was great to hear the story of Lili'u doing translocation of mamo before we even thought of translocation being a thing. And I bet there are other stories as such, as well as examples within mo'olelo/ka'ao that won't necessarily provide us specific guidance or situations such as the Lili'u one, but can give us proper perspectives to use and maybe overall lessons learned. Putting resources to looking into those things would be an awesome thing to do and enhance the research methodologies for the protection of these species."

"After the last meeting with leadership it really felt that some of our major concerns were not even touched on. Nearly every member of the biocultural group expressed that they were not in favor of captivity on the continent. That was not made clear in the last meeting to leadership.

"There is a lot to touch on but building off of Stanton's example, these birds are 'ohana to me and to many kānaka. When your 'ohana is sick, you don't let red tape or unrealized risk of an experimental treatment get in the way of trying to heal them. You do what it takes to save them. We have tried to heal our birds by sheltering and protecting them in captivity, but that has only led to them losing who they are. I don't know what will be decided, but I hope that whatever it is considers the behavior and culture of the birds on equal footing with their genes. Furthermore, there are not many kānaka involved in these decisions, and so it is the kuleana of all those who are, to enter these kinds of mindsets and see these manu as 'ohana. I know that they can do that. You take risks to save your 'ohana, you break down walls and build new ones, and you throw the rules out the window. We do everything and anything possible to keep them in this world. That is what is needed for our manu today. They need as many of us as possible doing what we can to keep them going and to keep them functioning in the forest.

"Ultimately in Hawai'i we lost much of our connection and history with our manu and that's something that we are working to rebuild. Just as we learned from Mau Piailung to bring back navigation, we are actively learning how to reconnect to manu. Part of that comes from looking elsewhere in the Pacific, in particular we can learn a lot from Aotearoa.

> "They used brave, pioneering, methodology and we're not doing enough of that these days, with too much reporting and not enough doing."
>
> "We feel that these birds need to move off a nature reserve into wider bigger habitats, for their own wellbeing." Susan Thorpe, Hokotehi Moriori Trust

"Here Thorpe was speaking on the kakaruia or black robin. Kakaruia were down to just three birds but today there are 280. This is thanks to taking a risk, and using foster parents and later translocating a population to a different island. One population of kakaruia is down to 30 birds and in consultation with the local Moriori and Māori imi and iwi no idea was considered "too crazy."

"Nothing is crazy or impossible when it's for your ʻohana."

"Aloha. Mahalo for inviting me to comment on potential conservation actions to intervene with the likely imminent extinction of the ʻakikiki, ʻakekeʻe, ʻākohekohe, and kiwikiu. I'm not sure who will be reading this statement, so please allow me the opportunity to introduce myself. My name is Noah Gomes. The oldest Hawaiian ancestors in my family that I am familiar with are from Kamaʻo on Lānaʻi and from Kauaʻi. I was born on Oʻahu and raised in Wahiawā on that island, and I now live in Waiākea on Hawaiʻi. I have had a strong interest in native birds since I was a child, and have volunteered for various conservation organizations throughout my life, up to the present day. I have a B.A. in Hawaiian studies and an M.A. in Hawaiian language and literature—both from UH Hilo. The topic of my M.A. thesis was on the traditional Hawaiian bird hunters in the old days, and I have since written a few academic articles related to that subject. I have also contributed to restoring the old Hawaiian names and creating new Hawaiian names for a few native bird species.

"I appreciate the ability to share my opinions, and I have tried to think things through as thoroughly and as responsibly as I can, both from the perspective of a person of part-Hawaiian descent, and as a resident of this archipelago. I apologize for the length of this commentary, with more time maybe I could have edited things down to be more concise with my thoughts, but this is what I was able to come up with in the time I had available to me. I see two major questions that I want to address here:

1. Is it ethical and pono for us to intervene with the probable extinction of these birds?
2. What actions, if any, should be taken to intercede on behalf of these birds?

"Is it pono to intervene?
Once again we find ourselves at the precipice of a wave of extinctions of Hawaiian birds, perhaps heralding the loss of many other native organisms in the next century. Unlike most previous extinction events of Hawaiian bird species, this time we have the power and opportunity to intervene. Before we can consider the different possibilities in which we can intervene, we need to consider whether or not it is our kuleana to do so. I was taught that as Hawaiians we look to the past and to those that came before us to help us in making decisions about the future, and so I think it is pertinent to ask: What would the old people have done

back in the day if they were faced with this decision? What would the bird hunters do if they were here now?

"Hawaiian efforts in conservation:
I feel like there is a tendency to view pre-industrial indigenous societies with an overly romantic lens, and that this has occurred with Hawaiians and our relationships with the ʻāina. Pre-contact Hawaiians were not conservationists. Nobody in the world at all was a conservationist until the 19th century. What our ancestors were was extremely practical. They understood that actions had consequences, and that their interactions with their environment had both positive and negative consequences that affected their ability to survive. Very often this led to them caring for their resources in a way that would be called "conservation" today, but to them it was just the most logically and spiritually appropriate thing to do.

"The loss of our native birds is probably the number one reason why there are no forest bird hunters today. We know they would have done something, this was their livelihood and their tradition, taught from father to son for centuries. It was not an obsolete tradition either, the value of the native birds had not diminished in the 19th century as there was still strong demand from the aliʻi and from foreigners for featherwork throughout that period. They certainly would have thought that it was pono to do something to try to stop the extinction of the native birds, but what did they do?

"It is very well recorded that a traditional Hawaiian natural resource management practice implemented to support declining resources is to implement a kapu on the declining resource, allowing populations to stabilize and laupaʻi hou, to multiply over time. Laudable measures to implement kapu on declining marine resources are even being enacted across the paeʻāina today in Kaʻūpūlehu on Hawaiʻi, ʻEwa on Oʻahu, and the north coast of Kauaʻi. There is evidence that historic measures were taken in the 19th century to manage forest bird populations in a similar way. A letter from several Hilo bird hunters to Kamehameha V in the 1860s is on record at the Hawaiʻi State Archives (HSA, ID Lands, Doc. No. 89) requesting that he lift the kapu on forest birds so that they could hunt them. Similarly, there are Hawaiian language newspaper records (Ka Lahui Hawaii, 21 September 1876, p. 3) of an unsuccessful bill in the legislature to prohibit the hunting of forest birds important in featherwork. There is absolutely no reason to believe that there were not other efforts to place kapu on native birds earlier in Hawaiian history.

"Obviously these kapu could not prevent the decline and extinction of most of the birds important to featherwork. While such kapu would have been effective prior to Western contact, it seems doubtful that people in 19th century Hawaiʻi would have yet figured out that the decline of native birds during that time was different—disease was a totally new agent of decline that had not been experienced before. Simply prohibiting human interference with the birds would never have been enough to save them. Regardless, it's obvious that if they had the technology and opportunity that we do today, the bird hunters and the aliʻi in the old days would have utilized it to save the royal feather birds.

"Hawaiian relationships with akua and ʻaumākua:
Now that we have established that people in the old days would have felt a practical and logical need to save critically endangered native birds, let's look at things from a spiritual angle. It is very well known and established that the ʻaumākua, as well as most if not all akua, are our ancestors. This is well-documented in a number of sources, not the least of which is Kumulipo. There are countless examples of our people interacting with, and caring for the kinolau of an ʻaumakua or an akua. The relationship of a Hawaiian with an ʻaumakua and with an akua is not

the same as a relationship with the Christian God. We have an inalienable kuleana to maintain and interact with the akua and ʽaumākua, and time and time again we see in our histories and stories the consequences of not honoring that relationship. This means that we are responsible to care [for] these birds. They are a part of the akua processes happening at an ecological level in the forest; akua processes that we know are already damaged and not functioning as well as we need them to. If we expect them to take care of us in the way that they always have, we need to take care of them, even to hoʽomana them. Kōkua aku, kōkua mai, it is the Hawaiian way to give help and to receive it. It is a Western perspective to see ourselves as humans as being outside and above the natural processes of the world. We know better, we are a part of those cycles and have been taught from our oldest stories and genealogies that we are ʽohana to the ʽāina and everything upon it. That means we have a responsibility to that ʽohana. We forget that far too often these days, instead [of] choosing to think of the ʽāina and the akua as some foreign object far removed from everyday human life. But they are honored and respected family, and we should treat them as such. If your aunty, cousin, uncle, etc. falls down and has a heart attack are you going to just leave them there to die? No! Of course not! It may be their time to go or it may not, but you are going to drive them to the hospital and help them in any way you can. To do anything less would not only be irresponsible, but cruel. The respect we should show these birds as manifestations of akua is the respect that one would show any elder in one's family. Similarly, the loss of one of these species is like the loss of a family member. We mourn, we pick up, we move on, and we care for those still with us; but we also remember them and their legacy, and without them life will not ever be quite the same.

"Given the above, I think it's obvious that the aliʽi and the bird hunters would have felt an spiritual obligation to conserve critically endangered birds as well. Some might argue that these four species are not birds known to be important to featherwork, or are not known to be kinolau of akua or ʽaumākua, and so they don't deserve the same level of respect or devotion that the people in the old days might have shown something like an ʽiʽiwi, mamo, or ʽōʽō. The truth is though, we know virtually nothing about our relationships with birds in the old days.

"I have been studying everything I can get my hands on regarding ʽike kuʽuna on native birds for more than ten years now. What I have could fill a text book, but it is increasingly evident to me is that what was written down about our ancestors and their relationship with birds is really only a small fraction of what there was to know about that relationship. For example, I have the names of more than two dozen "mystery birds," who were never recorded by Westerners. I have descriptions for many of them too, and the vast majority are clearly things that were real flesh and blood species that people knew and even hunted 200 years ago, but are completely forgotten to obscurity today. There are huge unanswerable questions about even the more widely remembered aspects of our relationships with native birds, such as featherwork, and even with well known charismatic species like ʽiʽiwi, there are things that were once common knowledge that virtually nobody knows today. It is not surprising at all that we know little about the significance of the four endangered species in question, but there are hints that they may have been important to someone. In Kumulipo there is a bird listed called the kikiki, which could easily be an alternative name for the ʽakikiki. A recorded alternative name for the ʽakekeʽe is ʽōʽūholowai, which is also the name for a formerly famous kind of kapa from ʽōlaʽa, Hawaiʽi that was made from māmaki. The ʽākohekohe appears in an overlooked legend in Fornander about the origins of the relationship that native birds have with ʽōhiʽa. There are numerous yellow, hook-billed mystery birds in records that could easily be the kiwikiu by another name. On top of all of that, Hawaiian families still have secrets today that they don't share with anyone. There could very well be someone alive today with a value for these birds that I've never even heard of. My point is that just because we don't know the cultural significance of these birds today, it does not mean that they dont have any practical significance. When it comes to Hawaiian tradition, there is far more that we don't know than what we do know, and it is better for us to remember that than to let something potentially important fade away just because we as individuals are not familiar with it.

"**What actions should be taken?**

Wolbachia *treatment*

I am in full support of continuing the *Wolbachia* plan. It is a relatively natural, innovative way to control mosquito populations and disease in the short-term. I also strongly recommend that we consider the possibility of GMO control of mosquitoes in Hawai'i in the long term. I'm sure that mosquitoes have a purpose and a function in this world, but that purpose and function is not indigenous to Hawai'i. We humans brought them here, and they are clearly causing problems. It is our responsibility to fix that problem.

"Captive-breeding programs

I don't think that captive-breeding is the ideal situation. I have seen the problems that 'alalā and palila have had with captive breeding and a loss of culture. Together with the data shared with us about 'akeke'e in captivity, it seems to me that we can't depend on captive-breeding programs as a catch-all solution for all critically endangered species. That being said, I also think back to the analogy of sending a family member to the hospital for recovery. If we need to do it then let's do it, but there need to be clear, articulated plans and timelines to return these species to the forest in a reasonably expeditious manner, idealy before the loss of the founder generation who hold culture critical to long term survival of the species. I am against sending any of these birds to facilities in the mainland U.S. I dont see the long-term practicality of it, the trauma of such a long journey seems dangerous and unnecessary, and removing these birds so far from Hawai'i feels wrong.

"Translocation to Hawai'i

I support the idea of translocation to Hawai'i. We know that the loss of culture in a bird species can cause perhaps insurmountable problems in a species' recovery. Keeping the birds on the landscape in some form will help them to maintain themselves as a species. I also think that the birds serve a purpose in the ecosystem... helping them to continue to serve that function, even on another island for a short period, feels like the right thing to do.

"Additional recommendations

I think that we all have a fairly good idea that the endangered species crisis in Hawai'i is only going to get worse in coming decades. It seems that much more would be possible if we could have the public's full support when it is needed. Conservation initiatives here always seem to come under strong pushback from the public. There are of course a lot of nuanced socio-economic, historic and political reasons for why there isn't always public support of critical conservation programs in Hawai'i. One problem that I see that needs to be addressed is the rebuilding and fortification of native Hawaiian relationships with the 'āina. Time and time again, Hawaiians express the idea that we should not invest in rare organisms that have no practical purpose. Endangered organisms almost always have practical purpose, even purpose directly relevant to our lives, but we as Hawaiians are prevented from maintaining a relationship of purpose with them. We need to invest in finding ways to navigate the United States federal legislative system to regain native Hawaiian 'āina rights. We should be able to harvest native organisms (even endangered ones) within reason, as do our Native American counterparts. Re-establishing indigenous rights and relationships with endangered ecosystems needs to become a major priority for Hawaiian conservation. There will never be full Hawaiian support of conservation efforts if we do not establish reasonable avenues for Hawaiians to maintain their relationship with the land.

"Lastly, I know it's been brought up before, but please also consider inquiring with DOFAW about their own cultural working group for these four endangered species. In that group we have been discussing the creation of mele and moʻolelo, partly in an attempt to engage the public with these birds, and to create tangible ways for ourselves to contribute to their survival."

APPENDIX V. *WOLBACHIA* IIT LANDSCAPE-LEVEL MOSQUITO SUPPRESSION

We elicited the expert judgement of biologists actively working on bringing the *Wolbachia* IIT approach to Hawai'i to control mosquitoes in forest bird habitat with the goal of breaking the disease cycle. For this group, we spent 1.5 hours on a video conferencing meeting to discuss all available information on the steps needed to implement *Wolbachia*, the timeline likely for implementation of *Wolbachia* IIT, and the probability of success once effectively implemented. At the end of the period, each participant was queried on two questions:

1) Please estimate **time to effective implementation of *Wolbachia* IIT** (estimated year, can be in quarters, such as 2024.5 or 2025.25). Effective implementation is defined here as reproductively fit (competitive) males being released at the right time, right places, and right frequency, at numbers sufficient to reduce mosquito numbers to a level that the transmission of avian malaria is disrupted, which is considered here as 6 months from the start of field applications. The 4 questions that need your expert judgement are:
    a. What is your best estimate for the earliest *Wolbachia* IIT could be effectively implemented in Hawaii forest bird habitat?
    b. What is your reasonable estimate for the latest *Wolbachia* IIT could be effectively implemented in Hawaii forest bird habitat (continuation of current efforts)?
    c. What in your opinion is the most likely date for effective implementation of *Wolbachia* IIT in Hawaii forest bird habitat?
    d. How confident are you that the range of minimum and maximum time estimate you provided encompass the true value, given your knowledge of the process as it is now? Think of this as the probability you will be right. If you are very confident the true time to effective extinction will be within the range you provided, then you may want to say 90–95% confidence (there is always uncertainty, so 100% confidence is unreasonable). If you have less than 70% confidence, could you increase the min/max estimates to increase confidence?

2) Please estimate the **probability of success of *Wolbachia* IIT to suppress *Culex* mosquitoes in Hawaii forest bird habitat**. Success is defined as the application of the tool (*Wolbachia* IIT) to break the avian malaria transmission cycle sufficiently to allow for the persistence of Hawaii forest birds in their native habitat. The 4 questions that need your expert judgement are:
    a. Worst case scenario, what would be the lowest reasonable probability of success of *Wolbachia* IIT being successful in breaking the disease cycle in Hawaii forest bird habitat?
    b. Best case scenario, what would be the highest reasonable probability of success of *Wolbachia* IIT being successful in breaking the disease cycle in Hawaii forest bird habitat?
    c. What in your expert judgment is the most likely probability of *Wolbachia* IIT being successful in breaking the disease cycle in Hawaii forest bird habitat?
    d. How confident are you that the range of minimum and maximum probabilities you provided encompass the true value, given your knowledge of the process as

it is now? Think of this as the probability you will be right. If you are very confident the true time to effective extinction will be within the range you provided, then you may want to say 90–95% confidence (there is always uncertainty, so 100% confidence is unreasonable). If you have less than 70% confidence, could you increase the min/max estimates to increase confidence?

The results of the expert elicitation are shown in Appendix V, Tables 2 and 3.

Appendix V, Table 1. Participants of the *Wolbachia* expert elicitation meeting.

Name	Affiliation
Chris Farmer	American Bird Conservancy
Josh Fisher	U.S. Fish and Wildlife Service
Brad Keitt	American Bird Conservancy
Cynthia King	Hawaii Department of Land and Natural Resources
Dennis LaPointe	U.S. Geological Survey
Ryan Monello	National Park Service
Teya Penniman	American Bird Conservancy
John Vetter	U.S. Fish and Wildlife Service
Adam Vorsino	U.S. Fish and Wildlife Service

Appendix V, Table 2. Expert elicitation for time to effective implementation for *Wolbachia* IIT. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. We adjusted confidence ranges to have the same range (90%) to allow for averaging values across experts (Hemming *et al.* 2017). Scores are values with earliest, most likely, and latest year to implementation. Percent of confidence (% conf) is shown for raw scores.

	Raw scores				Corrected scores for 90% confidence		
Expert	Earliest	Most likely	Latest	% conf	Earliest	Most likely	Latest
E1	2022	2023.5	2027	0.8	2021.8	2023.5	2027.4
E2	2023.5	2023.75	2025	0.9	2023.5	2023.8	2025.0
E3	2023.5	2024.5	2025.5	0.8	2023.4	2024.5	2025.6
E4	2023.5	2024.5	2025.5	0.85	2023.4	2024.5	2025.6
E5	2023.5	2025	2026	0.5	2022.3	2025.0	2026.8
E6	2023.5	2024.5	2026.5	0.9	2023.5	2024.5	2026.5
E7	2023.8	2024.3	2025.8	0.85	2023.7	2024.3	2025.8
E8	2023.5	2023.75	2025	0.85	2023.5	2023.8	2025.1
E9	2024	2025	2027	0.8	2023.9	2025.0	2027.3
				Mean	2023.2	2024.3	2026.1

Appendix V, Table 3. Expert elicitation for probability of success of *Wolbachia* IIT to suppress mosquito populations once effectively implemented. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. We adjusted confidence ranges to have the same range (90%) to allow for averaging values across experts (Hemming *et al.* 2017). Scores are values with lowest, most likely, and highest probability of success. Percent of confidence (% conf) is shown for raw scores.

Probability of success					Uniform 90%		
Expert	Lowest	Most likely	Highest	% conf	Lowest	Most likely	Highest
E1	0.7	0.9	1	0.9	0.70	0.90	1.00
E2	0.65	0.8	0.9	0.95	0.66	0.80	0.89
E3	0.6	0.9	0.95	0.95	0.62	0.90	0.95
E4	0.6	0.85	0.95	0.85	0.59	0.85	0.96
E5	0.75	0.85	0.95	0.7	0.72	0.85	0.98
E6	0.5	0.75	0.9	0.9	0.50	0.75	0.90
E7	0.65	0.85	0.9	0.9	0.65	0.85	0.90
E8	0.75	0.9	0.95	0.9	0.75	0.90	0.95
E9	0.3	0.6	0.9	0.9	0.30	0.60	0.90
				Mean	0.61	0.82	0.94

APPENDIX VI. *WOLBACHIA* IIT IMPLEMENTATION OUTLINE

The following outline plan was prepared October 11, 2021, by Josh Fisher and Adam Vorsino of the U.S. Fish and Wildlife Service Pacific Island Office, to outline the steps needed to implement *Wolbachia* IIT in Hawai'i for conservation purposes:

The *Wolbachia* incompatible insect technique has been identified as a potential tool for suppressing populations of *Culex quinquefasciatus*, to break the transmission cycle of avian malaria in Hawai'i's remaining forest birds. This is a novel approach in landscape mosquito control for *Culex* and has not been attempted for a conservation purpose or within a remote forest setting.

Key elements of the Hawaiian IIT program include:

- Development of incompatible *Culex* line for Hawai'i
- Regulatory permitting (importation and field releases)
- Mass rearing (capacity/sourcing)
- Transport & field releases (deployment)

Some efforts can occur concurrently, while others are contingent on the completion of prior actions. Additionally, there are optional paths towards implementation with varying timelines and uncertainties. Cost estimates and available funding would also affect the ability to move certain elements forward.

There are other needs related to additional research data and continued public outreach that would be beneficial. These actions however are not necessarily limiting and not a focus for this workshop's timeline analysis.

It was also indicated not to include funding as a limiting factor. However, significant resources would be needed for initial build up and most likely a mix of both private and public funding. It is also important to note that current research and development proposals for tool development do not include funding for the application and continued monitoring that would be needed to ensure success of an IIT program into perpetuity.

Mosquito Development

Three different options could be pursued to develop a line of incompatible *Culex*, each with different potential costs, timelines, and likelihood of success.

<u>Option 1</u>: Use the line developed by Michigan State University (MSU). Production by MosquitoMate (MM)

A *C. quinquefasciatus* Hawai'i transinfected line with demonstrated cytoplasmic incompatibility (CI) was developed and completed by MSU. MSU is maintaining this line in its lab, and it could be shipped to University of Hawai'i or MM. However, due to issues related to the patent held by the University of Kentucky, access to this line is in limbo. Despite significant effort, moving this forward has not progressed, and it is uncertain if a resolution can be reached.

<u>Option 2</u>: MosquitoMate develops a new transinfected line, Production by MM

MosquitoMate (the exclusive license holder for the patent) could repeat the process conducted at MSU. Stephen Dobson has indicated this is possible but suggested it would take two to three years to develop a stable transinfected line, including initial quality control assessments. Even though the technology was developed at University of Kentucky Dobson's lab, it is unknown whether MM has the capacity to develop the product, although he may have staff with the required expertise. He has repeatedly stated that he does not have experience with *Culex.* MSU had an existing line of transinfected *Culex* that he used to outcross with the Hawaiʽi line, while MM would have to start from scratch.

Option 3: Verily develops a naturally incompatible line of *Culex,* Production by Verily

Verily, a technology company, is investigating whether a natural strain of *Culex* from Istanbul can show incompatibility. Currently they have confirmed unidirectional CI in the Atilla strain and are continuing the tests to ensure bidirectional CI. Once CI is confirmed, the next step in the process will be backcrossing the strain to resemble the Hawaiʽi biotype.

Option 4: Verily uses MSU line or develops their own, Production by Verily

Verily also is trying to develop a transinfected line of *Culex* that would not be subject to the current intellectual property limitations. There is a great level of uncertainty here. The timeline depicted here is if Verily used the MSU line.

Option 5: University of California San Diego (UCSD) precision-guided sterile insect technique (pgSIT) developed, Production by Hawaii DLNR

While this genetic Sterile Insect Technique is being developed currently in Hawaiʽi's *Culex*, it may be some time before regulatory and public sentiment shift in this direction. This timeline also depicts a long-term buildout of the DLNR insectary.

Regulatory

There are state and federal regulatory requirements that must be met before an IIT campaign can be implemented. Timeframes indicated are best approximations, but experience in Hawaiʽi suggests that additional time will likely be needed.

State regulations:

UH import permit: The University of Hawaiʽi at Mānoa has a Hawaiʽi Department of Agriculture (HDOA) import permit to bring the MSU transinfected line to its lab as eggs or larvae. It needs to be clarified with HDOA that UH can also conduct various fitness tests in the laboratory using the transinfected line. This permit was obtained under an "ecological disaster" exemption versus adding it to the HDOA Restricted A list; the latter option would greatly facilitate future importations.

DLNR/HDOH import permit application: DLNR and Hawaiʽi Department of Health (HDOH) have submitted a joint application to import adult transinfected *C. quinquefasciatus*, *Aedes albopictus*, and *A. aegypti* for immediate field release. This permit would also add these species to the HDOA Restricted A import list. HDOA is requiring that UH first receive the MSU line and demonstrate CI with Hawaiʽi wild mosquitoes and to verify the *Wolbachia* strain of the transinfected mosquito before they move forward with processing the DLNR/HDOH permit application. UH cannot move forward with these steps unless and until the MSU line can be shipped to Hawaiʽi. The amount of time needed to move this permit through the HDOA process is unknown; however, much of the background documentation related to this second permit would benefit greatly from the work done for the UH permit.

<u>Biological control permit</u>: If a mosquito line with a natural *Wolbachia* infection has incompatibility with Hawai'i *Culex*, it would be regulated as a biological control agent under the Hawai'i process. Permitting could take anywhere from 12–24 months or more, depending on HDOA capacity. However, given both the biocontrol agent and *Wolbachia* strain are already present in the state combined with the emergency nature, and that a similar approach is Environmental Protection Agency (EPA) approved (indicating low risk) suggests that there could be opportunity to fast track.

Federal regulations:
<u>Transinfected mosquito</u>: If a transinfected mosquito is used, the EPA regulates it as a biopesticide, subject to registration requirements. There are two paths, which could occur in parallel. One is to seek full registration, which first requires obtaining an experimental use permit (EUP) to demonstrate the safety and efficacy of the tool. Another option is to seek an emergency exemption, while continuing to proceed with the regular biopesticide application.

Obtaining an EUP from the EPA could take 12–24 months, based on previous experience with registering *A. albopictus* (Stephen Dobson, MosquitoMate, written communication, 2021). An application cannot proceed without assured access to the transinfected line, and work under the EUP could take an additional 12–18 months. The emergency exemption (Section 18) could significantly expedite issuance of an EUP, estimated on the timeline as six months, but confirmation with the EPA is needed.

A non-transinfected *Culex* with incompatible *Wolbachia* could be used as a biocontrol agent and would be regulated by the Hawai'i Department of Agriculture. Two years is considered fast for approving a biocontrol agent, six months was estimated for an expedited best-case scenario.

The next action would be to seek permitting for field trials. Once received, field trials would commence in specified areas and then expand to more areas. This can occur while the import permit is being pursued.

Compliance

Compliance with state and federal environmental assessments (Hawai'i Environmental Policy Act [HEPA] and the National Environmental Policy Act [NEPA]) will be needed for release of either a transinfected or naturally incompatible line of *Wolbachia* mosquitoes as a biopesticide/biocontrol agent. A combined HEPA/NEPA process is underway for East Maui. Public input will commence in December 2021, and the environmental assessment (EA) is expected to be complete by May 2022. The selection of a consultant to manage the Kaua'i EA is in process. HDOH is seeking to initiate a statewide EA process for three mosquito species, but that has not officially begun and would not cover important federal lands, especially on Hawai'i Island. No releases can occur until the HEPA/NEPA processes have been completed, but it is not anticipated these requirements will be a barrier, time wise.

Rearing Capacity and Sourcing

Experience with rearing *Culex* sp. in the lab is limited. Rearing capacity optimization requires sufficient laboratory capacity including personnel to focus on developing specific *Culex* rearing protocols. Options are being explored on potential labs (MM, Verily, Hawai'i DLNR) that would be able to scale up their existing facility to deliver the required number of male mosquitoes. Ideally, investing in optimizing mass rearing capacity from an established U.S. mainland facility in order to source mosquitoes in the short term could be pursued while building capacity in Hawai'i. A degree of technology transfer and training associated with this buildout would be needed.

The state has been funded to develop a small-scale insectary that will be equipped with a containment biobubble to maintain tool efficacy and meet both federal and state permitting requirements regarding an Arthropod Safety Level 2 (ASL-2) facility. This facility would need to be placed, modified, outfitted, and staffed. Outfitting with equipment would cost approximately $200,000. Once equipped and fully funded, an additional $150–200,000/year would be needed to operate the facility and would likely be able to produce at capacity (~100,000 IIT males every week) after about two to three years.

Building up *Culex*-rearing capacity within MM is one of the least costly low-tech mainland facility options. Prior to any estimates of costs, MM would need to have the transinfected MSU line in hand. MosquitoMate would also require greater than $100 thousand to perfect mass rearing of the Hawai'i population of *C. quinquefasciatus* that can be adapted to mass-rearing infrastructure in Hawai'i. This optimization is expected to take 15 months to ramp up production to 500k male mosquitoes per week.

Verily, a technology company, is another mainland facility option. Verily has been collaborating on an ongoing IIT project for Palmyra Atoll and has successfully reared a Palmyra population of *C. quinquefasciatus* in their laboratory among other accomplishments. Building up capacity with Verily is expected to take approximately two years to optimize and ramp up production. This is a technology heavy approach. Costs are estimated for a multi-island approach to achieve 500 thousand male mosquitoes per week. Verily has already been developing procedures for mass rearing of Palmyra and Hawai'i *Culex* and testing the sex sorting capability of their production platform. These efforts are significant in that it has been identified by multiple parties (FWS, DLNR, MSU, The Nature Conservancy, and Verily) that these *C. quinquefasciatus* populations are very difficult to rear in captivity. As of yet, Verily has not been funded for this work.

Field Releases (Deployment)

Experience with field releases of *C. quinquefasciatus* is limited. The foundational IIT project on Réunion Island was conducted in field cages. Other IIT programs with a broader deployment experience have been based on *Aedes* sp. and in urban centers with adequate access to control areas. These programs have transported this species either at close to ambient temperatures or via cold storage. Mosquito fitness is affected when storage and transport exceed identified thresholds, but cold storage tolerance of *Aedes* allows greater flexibility in transport and deployment options. Automated deployment options could be important as programs move towards control over larger areas. This is particularly important for *Aedes*, which have limited dispersal. But *Culex* sp. have a potential advantage in an IIT program due to their ability to disperse over greater distances. While aerial deployment may not be a limiting requirement for initial releases and field trials for *Culex*, development of this capacity could greatly expand the scale and efficiencies while decreasing costs of an IIT program in Hawai'i. It would be important to address biological concerns, especially in terms of handling, transport, and release, prior to conforming to a single delivery option.

Information related to the storage and handling of *Culex* is limited. While initial mass rearing experience can inform handling, transport, and field deployment strategies, specific studies should test the various tolerances related to handling, packing, and deployment stresses. The effects of chilling temperature, duration, and compaction on the resulting quality of male adult *Culex* needs to be evaluated in terms of survival, longevity, and mating competitiveness. This type of study would guide manual releases and provide the parameters to develop a more robust and automated deployment strategy. Ideally, work would be conducted with the mosquito product intended to be used; however, using a wild type *Culex* from Hawai'i as proxy is suitable.

Once the tolerance data related to storage and packing of *Culex* is generated, those parameters can then inform various deployment strategies (e.g., hand release, helicopter dispersal, unmanned aerial vehicle, or UAV). This information would also guide engineers in the development of any automated delivery mechanisms modified for handling *Culex* sp.

These research components (tolerance data; field deployment) would ideally be initiated as soon as possible and can occur with wild type *Culex* at an appropriate laboratory. It is estimated to take anywhere from 6-12 months to complete each of these data needs.

Community Engagement
A community engagement strategy has been initiated since 2020 and is ongoing. The group Birds Not Mosquitoes has been developing an outreach effort to connect people working on mosquito control efforts with various community leaders throughout Hawai'i.

There may be additional engagement opportunities as part of other environmental compliance and permitting processes. Initial interactions with key public stakeholders have indicated overall support for an IIT project in Hawai'i.

Continued engagement opportunities are planned, but community engagement does not appear to be a limiting factor at this point. However, this may not always be the case, and it should be considered that community outreach could and likely will get more complicated as the public learns about the project.

Application and Monitoring
Application of an IIT program in Hawai'i on multiple islands and in priority locations would take dedicated personnel. In addition, developing an appropriate monitoring protocol for the forest setting would be important. The Palmyra IIT project has a goal of advancing conservation beyond Palmyra, which includes developing better tools for conservation. Some initial research and development are occurring in Palmyra that can inform other site-specific considerations in the main Hawaiian Islands, such as monitoring and canopy deployment. Continued *Wolbachia* IIT applications and monitoring on Palmyra is estimated to cost between $500K and $1 million annually.

IIT Timeline Assessment
When an effective IIT program can be initiated on the landscape is not explicitly clear, given a degree of uncertainty. Considering the key components to move a *Culex* IIT program forward in Hawai'i, it is likely that IIT management on the landscape will occur between the best- and worst-case scenario timelines.

In a <u>best-case scenario</u>, either the transinfected agent is available for use, or Verily identifies a natural incompatible *Culex* line. Both of these options would then be able to advance regulatory permitting for field trials. It could be expected that mosquito releases at the necessary scale based on these two scenarios could occur in **June 2023**.

In a <u>worst-case scenario</u>, a transinfected mosquito would need to be developed from MM. MosquitoMate would have to build a line from scratch with *Culex* and this would significantly add to the timeline with a moderate level of uncertainty of success. While optimizing rearing capacity could be initiated at MM with a proxy *Culex*, regulatory permitting would not be initiated until after a line is established and stabilized. This would put effective management on the ground after **July 2025**.

It's important to note that additional sterile insect technique tools (i.e., Genetic pgSIT) are simultaneously being developed. A *Culex* pgSIT Hawaiʻi line is in development at UCSD and is projected to be completed in 2023. The probability of developing a usable Hawaiʻi pgSIT line is high; however, genetically engineered mosquito field trials have not been initiated in the United States to date, although some are under review for public health. This would be a change in the current near-term strategy and would likely require additional time for community and stakeholder engagement. Expectation for genetic technologies is about **10–15 years.**

APPENDIX VII. TRANSLOCATION

We elicited the expert judgement of 10 biologists with familiarity of the species and translocation in Hawai'i and beyond on the probability of success of translocations (Table 1). Experts were asked: "Please estimate the probability of success for a translocation of the 4 focal species to Hawai'i Island. Assume that there is no additional information known (with assessment on knowledge you currently have). Also assume host location will be Hakalau Forest NWR, will be a mix of young and old birds, and at least 20 individuals moved. Success is defined as the established population is surviving and reproducing and stable to increasing within a 5–10-year window." Each individual expert's response is shown in Table 2.

Appendix VII, Table 1. Participants of the expert elicitation for estimating probability of success of translocation.

Name	Affiliation
Paul Banko	U.S. Geological Survey
Lainie Berry	Hawai'i Department of Land and Natural Resources
Lisa Cali Crampton	Kaua'i Forest Bird Recovery Project
Chris Farmer	American Bird Conservancy
Dave Leonard	U.S. Fish and Wildlife Service
Hanna Mounce	Maui Forest Bird Recovery Project
Sheldon Plentovich	U.S. Fish and Wildlife Service
Rachel Rounds	U.S. Fish and Wildlife Service
Eric VanderWerf	Pacific Rim Conservation
Chris Warren	National Park Service

Appendix VII, Table 2. Expert elicitation of probability of success of translocation. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. We adjusted confidence ranges to have the same range (90%) to allow for averaging values across experts (Hemming *et al.* 2017). Scores are for minimum (Min), most likely, and maximum (Max) probability of success by species. Percent of confidence (% conf) is shown for raw scores.

	Raw scores				Corrected scores for 90%		
'Akikiki							
Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
E1	0	20	40	0.8	0.0	20.0	40.0
E2	30	50	70	0.8	30.0	50.0	70.0
E3	40	60	75	0.75	38.7	60.0	76.0
E4	40	60	80	0.8	40.0	60.0	80.0
E5	20	45	70	0.7	16.4	45.0	73.6
E6	20	30	50	0.8	20.0	30.0	50.0
E7	30	65	90	0.8	30.0	65.0	90.0

	E8	5	25	50	0.65	0.4	25.0	55.8
	E9	40	50	60	0.6	36.7	50.0	63.3
	E10	1	15	30	0.75	0.1	15.0	31.0
					Mean	21.2	42.0	63.0
ʽAkekeʽe								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E1	0	20	50	0.8	0.0	20.0	53.8
	E2	20	50	70	0.8	16.3	50.0	72.5
	E3	20	40	50	0.7	14.3	40.0	52.9
	E4	30	50	60	0.7	24.3	50.0	62.9
	E5	20	30	40	0.7	17.1	30.0	42.9
	E6	10	20	50	0.8	8.8	20.0	53.8
	E7	20	50	85	0.85	18.2	50.0	87.1
	E8	5	35	70	0.65	0.0	35.0	83.5
	E9	60	70	80	0.75	58.0	70.0	82.0
	E10	1	10	25	0.75	0.0	10.0	28.0
					Mean	15.7	37.5	61.9
Kiwikiu								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E1	0	5	20	0.9	0.0	5.0	20.0
	E2	30	60	70	0.8	26.3	60.0	71.3
	E3	50	65	80	0.75	47.0	65.0	83.0
	E4	50	70	80	0.8	47.5	70.0	81.3
	E5	15	50	85	0.7	5.0	50.0	95.0
	E6	10	15	30	0.9	10.0	15.0	30.0
	E7	30	60	80	0.9	30.0	60.0	80.0
	E8	15	50	75	0.65	1.5	50.0	84.6
	E9	50	60	80	0.65	46.2	60.0	87.7
	E10	1	15	35	0.75	0.0	15.0	39.0
					Mean	21.3	45.0	67.2
ʽĀkohekohe								
	Expert	Min	Most likely	Max	% conf	Min	Most likely	Max
	E1	0	30	50	0.8	0.0	30.0	52.5
	E2	20	40	60	0.8	17.5	40.0	62.5
	E3	60	70	80	0.8	58.8	70.0	81.3
	E4	50	70	90	0.85	48.8	70.0	91.2
	E5	25	50	75	0.7	17.9	50.0	82.1
	E6	30	50	70	0.95	31.1	50.0	68.9
	E7	33	75	90	0.9	33.0	75.0	90.0
	E8	15	40	75	0.55	0.0	40.0	97.3
	E9	50	70	80	0.75	46.0	70.0	82.0
	E10	1	15	35	0.75	0.0	15.0	39.0
					Mean	25.3	51.0	74.7

APPENDIX VIII. TRANSLOCATION OUTLINE PLAN FOR ʻAKEKEʻE

A draft translocation plan was prepared by David Leonard of U.S. Fish and Wildlife Service, Portland, Oregon, to identify key steps needed in a translocation effort. In addition to the plan written plan by Dr. Leonard, comments and questions from the Hawaiʻi Forest Bird Translocation Group are included in the plan text.

ʻAKEKEʻE TRANSLOCATION PLAN OUTLINE

Decisions needed to inform the plan

Timing of capture / translocation release—When will captures of ʻakekeʻe take place? When will birds be released? At a minimum the decision should consider historical mist-netting information (i.e., is there a period when captures peak), ʻakekeʻe (*Loxops caeruleirostris*) breeding season, and weather. Determining the timing of captures and releases are critical to planning the translocation.

[C. Crampton] – We have had best luck (with capturing ʻakekeʻe) *in late winter/early spring, at two sites, Upper Kawaikoi and the ridge south of HPK.*

[C. Crampton] – I think the factors influencing the release timing decision should be fleshed out more. Is it based on not keeping birds too long? Food availability on big island? "anchoring" birds ready to breed? What does the literature say?

<u>D. Leonard (response to Crampton)</u> – Withers *et al.* 2019, found that survival of New Zealand rifleman (*Acanthisitta chloris*) from capture to release increased with a shorter capture window, shorter holding times, lack of extended aviary housing, and separation of territorial individuals during holding; time from capture to release did not exceed five hours.

Cirl buntings (*Emberiza cirlus*) released in June and July were more likely to survive than those released in August (Fountain *et al.* 2016). Mallee emu-wrens (*Stipiturus mallee*) released in the spring were more likely to remain at the release site and attempt breeding than those released in the autumn (Mitchell *et al.* 2021).

To re-establish western bluebirds (*Sialia mexicana*) on San Juan Island, Slater and Altman (2011) released birds in March through June over four years.

From Slater (2001): "Breeding condition appears to be the most important factor associated with the success of both species' translocations (brown-headed nuthatch [*Sitta pusila*], eastern bluebird [*Sialia sialis*]). Birds translocated closer to the breeding season are less likely to be successful, whether in the translocation process or in establishing a territory. Results suggest that other translocation programs may want to consider timing of translocations when developing translocation methods. Moving birds at least one month before incubation begins may improve success. Another alternative may be to move birds after the breeding season, which was not examined in this study."

Based on work by Fretz (as reported in Freed *et al.* 2007), arthropod abundance in Hakalau Forest NWR peaks August through November.

In regards to anchoring, ensuring translocated birds remain where released, the literature is limited for passerines. However, Molles *et al.* (2008) reported that song playbacks may have contributed to the success of a translocation of North Island kōkako (*Callaeas cinerea wilsoni*).

The benefits of anchoring strategies employed as part of the translocation of kiwikiu (*Pseudonestor xanthophrys*) were mixed at best (Warren *et al.* 2020). Also see paper on reintroducing western bluebirds to San Juan Island (Slater and Altman 2011).

From Slater and Altman (2013):

- Holding bluebird pairs for longer periods (1–3 weeks) in large aviaries appeared more effective than short holding periods (3–5 days) in small aviaries.
- Breeding pairs captured earlier in the breeding season (before mean incubation date) were more likely to establish a territory than pairs captured later in the breeding season.
- Similarly, translocating and releasing pairs with juveniles earlier in the season to allow pairs time to re-nest was more successful than later releases.
- Releasing family groups when young are 2–4 days old appears to reduce dispersal from the release site, although aviary sites need to include patches of shrubby vegetation to provide cover for juveniles.
- Translocations of single females was highly effective and thus provides evidence of a technique to successfully address biased sex ratios in small, reintroduced populations.
- In contrast to the reintroduction of eastern bluebirds in South Florida, paired individuals typically maintained pair bonds, providing support for translocating pairs rather than single individuals.

[P. Luscomb] – I collected most of my forest birds in the fall after breeding and their molt. The birds were in their best shape and there was the least chance of disturbing breeding.

Minimum number of birds—How many birds are necessary for the project to move forward and what is the preferred sex ratio? Comparisons of translocation successes and failures reveals a strong positive relationship between the number of animals released at a new site and the likelihood of translocation success. Small founding populations are sensitive to stochastic, demographic, and environmental events and are unlikely to persist (Griffith *et al.* 1989, Wolf *et al.* 1998, Fischer and Lindenmayer 2000). However, these results are not uniform, and a survey of 31 translocations using small numbers of South Island saddlebacks (*Philesturnus carunculatus*) and New Zealand robins (*Petroica australis*) found most of the releases succeeded, and that there was no relation between the number of birds released and success (Taylor *et al.* 2005). The initial Nihoa millerbird (*Acrocephalus familiaris kingi*) translocation moved 24 birds and the kiwikiu translocation moved 14 birds (7 captive, 7 wild). There are currently 7 ʻakekeʻe (2 females and 5 males) in captivity.

[F. Duvall] – Important would be the actual sex ratios for the species – are ʻakekeʻe sex ratios skewed or not? Do we know, and can we use Hawaiʻi ʻākepa sex ratios as a surrogate for the ʻakekeʻe?

[P. Luscomb] – Just need to have at least one male and one female. The biggest problem when catching birds out of the wild is that we don't know the age of the bird and their relative health status. If you go to a shopping mall and grab 20 people, there is a good chance that you have a few 70+ year old persons that are past their breeding age, as well as people with medical problems that preclude them from breeding. The best option is to have as many birds as possible in every release cohort.

Unsuitable birds—Given the rarity of ʻakekeʻe and the time necessary to capture individuals, are there circumstances that a captured bird would not be considered a candidate for removal from the wild? Or would all birds captured be retained (either for translocation or captivity)?

[C. Crampton] – For ʻakikiki the only thing we are wondering about is not poxy birds (i.e., unsure what to do with birds that are obviously infected with avian pox).

[P. Luscomb] – I think leaving the bird in the wild will be its death sentence, and it no longer has the potential to help the population. We don't know enough about these birds and what would constitute a good breeding candidate. I had a bird in captivity that we received at the zoo in 1971, and it did not breed until after 2000. By bringing the bird into captivity there may be things that the birds could be of benefit to a captive program. We do use birds as tutors to help other birds adapt to captive conditions.

Use of captive facilities—Will ʻakekeʻe be housed at Keauhou prior to being released? This is especially relevant given the time it will require to catch individual birds.

[P. Luscomb] – I think it best to hold birds, that are collected, for a short while in the field holding facility, until they have acclimated to captive conditions. This may only be a few days. With the problem of coordinating helicopter transport, we should plan to be able to hold birds for up to 7–10 days to cover all contingencies. Keauhou would be the best site for the birds, but you can also look at buildings on Kauaʻi. When I do our translocations in CNMI, we use a hotel room to house our birds. We will hold up to 100 birds in a hotel room for up to 3 weeks. The main concern is that the room is mosquito proof and temperature controlled.

If birds will be housed at Keauhou, what will be the quarantine procedures?

[F. Duval] – Mosquito proof enclosures of course; no interactions with other Keauhou birds directly or indirectly via staff. If the time to shipping out is less than 10 days, house birds in the shipping boxes for the duration of holding.

If birds will be housed at Keauhou and quarantining birds before they are transferred to Keauhou is not an issue, will it be preferred to transport birds directly to Keauhou as they are caught or hold birds and transport them after a "cohort" is captured?

[C. Crampton] – I think we should consider housing them in the Alakaʻi for a while too. I see you have this below. Main thing to me either way is they be given malaria prophylactics.

Insufficient number of birds—If the minimum number of ʻakekeʻe cannot be captured, but some individuals have been captured, should these birds be released or remain in captivity?

[F. Duval] – Remain in captivity in quarantine type holding area.

Hard or soft release—Will birds be released using hard or soft techniques or a combination (e.g., captive birds—soft release / wild birds—hard release)? There is evidence that the hard release of wild passerines may be superior, as measured by post-release survival (6 weeks to 7 months), to soft release (Richardson *et al.* 2015). Also see Clarke *et al.* 2002 and Withers *et al.* 2019.

[F. Duval] – Proceed similar to what occurred for Nakula kiwikiu releases—short-term holding at release site followed with quick-turn-around release.

Transmitters—Will radio transmitters be attached to birds in the release cohort?

[C. Crampton] – Some individuals won't be big enough to support tags. Others will be. But do we want to "saddle" them with that? They will only last a few days, or if you get coded tags with a slower pulse rate in a telemetry tower network, I think a few weeks. They move so fast I am not sure you could ever hand track them, so maybe only if you are releasing somewhere there are towers?

[F. Duval] – Yes, essential for this.

Supplemental feeding—Will there be any attempt to provide birds with supplement food post release?

[P. Luscomb] – I think it will be hard to condition wild caught birds to a supplemental feeding regime. The captive birds or wild caught birds that have to be held in captivity for a long period of time can be acclimated to a supplemental feeding program.

<u>An alternative</u>

The Division of Forestry and Wildlife is supportive of using approximately 20 acres of state land (across from the ʻAwaʻawapuhi Trail) on Kauaʻi to construct aviaries / enclosures to maintain birds on-island until mosquito control is in place. This option would likely reduce compliance, costs, and likely be less risky than a translocation to the Island of Hawaiʻi. This alternative could be an interim step in the translocation process and would allow for more opportunistic capture efforts. It could provide an opportunity to collect data to inform husbandry and release protocols.

[F. Duval] – This option seems very intriguing—but could involve years of captive wait. In this case birds should be held to have breeding occur inside the set-up (so a captive-hold to allow/actually encourage captive production) so that breeding potential of the birds is not "lost" during the wait period.

<u>Components / Needs / Timing of ʻAkekeʻe Translocation</u>

The below narrative is not meant to provide the details entailed in planning or conducting a translocation but is an overview of the steps involved in such an effort. Many relevant details are included in the Kiwikiu Reintroduction Plan (Maui Forest Bird Working Group [MFBWG] 2018), although a plan for the ʻakekeʻe would have to be specific to that species.

Short-term objective – Establish a population of ʻakekeʻe on the Island of Hawaiʻi that persists over multiple years.

Long-term objective – Establish a self-sustaining ʻakekeʻe population on the Island of Hawaiʻi to serve as an insurance population until mosquitoes can be eradicated from Kauaʻi and they can be reintroduced to Kauaʻi.

Prepare a translocation plan – A draft plan will undergo internal review as well as external, peer review.

Conduct outreach and inreach – This will include the Native Hawaiian community and local community members, as well as leadership of DOFAW and the FWS, as well as all other partners (see below).

Apply for and secure funding – an estimate of the cost to translocate kiwikiu to Nakula is $600,000, which does not include staff time of many permanent positions in multiple agencies that contribute to the project. The kiwikiu project did not require an EA or an environmental impact statement (EIS; see below).

[C. Crampton] – Or interisland flights of birds (i.e., kiwikiu translocation did not require interisland flights)*.*

Conduct ʻakekeʻe surveys – Conduct periodic searches or surveys for ʻakekeʻe while the translocation plan, site selection, and compliance are being completed. Surveys serve to monitor the location and number of birds to facilitate future capture efforts and to ensure that sufficient wild birds remain for the project to move forward.

[C. Crampton] – We are thinking we should do systematic surveys like occupancy surveys. We currently have a grant for 2022 to study ʻakekeʻe distribution, habitat use, and other ecological information on Kauaʻi.

[F. Duval] – Age and sex ratios of observed birds should be undertaken.

Conduct research – Focus on food availability. Would likely have to be restricted to rapid field assessments or reviews of existing data and published work (see Banko *et al.* 2015; Fretz 2000, 2002); this may be particularly important if a site is selected where Hawaiʻi ʻākepa are present. Some of this information will likely be necessary to complete the compliance.

[C. Crampton] – Availability or diet? Is this research on Hawaiʻi Island or Kauaʻi?

[D. Leonard (response to Crampton)] – Both availability and diet preference of ʻakekeʻe would be appropriate, however, arthropod availability at the potential release sites on Hawaiʻi Island should be the priority. Assuming that we can use information on Hawaiʻi ʻākepa diet as a surrogate. This information would feed into selecting the release site.

Select a short-list of sites – Develop a short list of potential sites, visit sites, and initiate disease monitoring (see below).

Monitor mosquitoes and disease monitoring at short-listed sites – Will include methods to detect adults and larval mosquitoes as well as blood sampling of native and nonnative birds to detect infection rates at the potential release sites. Should occur for one year prior to the release or at least the summer-late fall prior to the release.

Initiate baseline arthropod sampling – Initiate sampling to collect baseline information on arthropods at the potential release sites, focusing on those species most likely to be used by ʻakekeʻe.

Select the release site – Select the release site using the Strengths, Weaknesses, Opportunities, Threats (or SWOT) analysis (White *et al.* 2015).

Complete compliance – The following compliance and permits will likely be required: Section 7 analysis (Biological Opinion), ESA Recovery Permit (10(a)(1)(A) permit), EA or EIS (National Environmental Policy Act – NEPA), and Hawaii State Environmental Policy Act (HEPA). NEPA documents can be drafted without knowing the specific release location; different sites would be included as different alternatives. The document will need to examine a "reasonable range of alternatives" (i.e., no action, hold birds on Kauaʻi, translocate to site A, translocate to site B). If an EIS is required, 10–18 months would be a reasonable time frame for its completion. There are emergency provisions of NEPA to protect valuable natural resources when there isn't time to complete a typical EIS analysis: https://ceq.doe.gov/docs/nepa-practice/emergencies-and-nepa-guidance-2020.pdf. Emergency provisions were used to permit the capture of the six remaining wild California condors and bring them into cavity in the 1980s.

Prepare recipient site – (*based on kiwikiu release at Nakula and contingent on soft versus hard releases*) Construction of release cages and platforms and field installation will take approximately four weeks with a crew of six people. Construction of the basecamp (*which may not be required depending on the release site selected for ʻakekeʻe*) will require approximately two weeks: one week to build the deck and catchment, one week to install infrastructure and get everything working. Additional time will be needed to install predator control grids. The dimensions of the release cages will be determined based on observations of ʻakekeʻe behavior within SDZWA aviaries. A minimum of ¼ of each release cage will be covered by a roof and shade cloth to provide protection from the sun and rain. Each release cage will be covered in mosquito netting. The location and number of aviaries on the landscape will depend on the release site but take into consideration proximity to high quality forest and logistics (i.e., time needed to hike to aviaries). Aviaries will be constructed such that they can be easily broken down and removed following the final releases.

[C. Crampton] – (predator grid) *Likely not necessary given low predation rates on ʻakekeʻe nests unless you want to provide supplementary food.*

Prepare holding site on Kauaʻi – The need for an on-island holding facility will depend on whether birds will be held on Kauaʻi for quarantine and/or to facilitate transport to Keauhou (i.e., transport a group of birds versus individuals as they are captured).

[C. Crampton] – Or directly to the release site (as opposed to going to Keauhou first).

Conduct pre-capture surveys – Prior to mist-netting, staff will survey potential capture sites to determine the locations and local behavior of ʻakekeʻe as well as potential nests. This effort will inform mist-net locations.

Capture ʻakekeʻe – Mist-netting protocols developed by the Kauaʻi Forest Bird Recovery Project will be employed when capturing ʻakekeʻe. In general, the locations of mist nets will be informed by the pre-mist-netting surveys, the location of nesting birds, and where birds have been seen in the past. Mist nets will be deployed once a bird or birds are located. Where possible, aerial mist nets will be deployed. Playbacks will be used except in locations where a nest with eggs is present; playbacks will be used in locations where nests with young are present. ʻAkekeʻe are very difficult to capture, and based on past effort, it is estimated that **<u>each individual will take approximately 400 mist-net hours to capture</u>**.

Immediate post-capture logistics – Captured ʻakekeʻe will be processed as they would under normal banding operations (i.e., banding, taking morphometric measures, blood sampling). If available, a fecal sample will be collected and placed in ethanol for disease screening. Each ʻakekeʻe will be assessed to determine its eligibility to be removed from the wild using a key developed (*<u>to be modified as needed</u>*) for kiwikiu (Maui Forest Bird Working Group [MFBWG] 2018, pages 56–58). Aging and sexing information will be necessary to identify removal candidates (*<u>see "unsuitable birds" [above]</u>*). If a bird is not suitable for translocation, it will be released at its point of capture (*<u>see "unsuitable birds" [above]</u>*). After processing, birds determined to be candidates for removal from the wild will be placed in a holding/transport box (based on design used for kiwikiu; MFBWG 2018, pages 62–64) and hiked to base camp. During the entire time birds are held, minimizing stress is paramount. Prolonged stress will have detrimental effects on the health of individuals.

[P. Luscomb] – I think it best to not process the birds until after they are in captivity a short while and are acclimating and stable. On the kiwikiu project we banded, did their exams, and did blood work on day three.

Base camp logistics – (*<u>specifics will depend on whether birds will be transferred to Keauhou</u>*) – A quiet, dry, and shaded area at camp will be designated to store all holding/transport boxes containing ʻakekeʻe. Qualified staff will care for each bird upon its arrival and throughout the time the bird is held at base camp, including administering medications for avian malaria, as a preventative measure, and subcutaneous fluids as needed. Birds will be evaluated using weight data, activity patterns, posture, body condition, food consumption, and fecal output. Food will be presented to captured birds that has been accepted by similar species in managed care or captivity, specifically live insects. It often takes an extended time period for wild-caught birds to begin consuming a captive diet. Foraging and feeding activity will be documented. Notes will be taken on what items are consumed, and diets modified accordingly.

Transport off Kaua'i – (*specifics will depend on whether birds will be transferred to Keauhou*) – Assuming that birds will be transferred to Keauhou and given the likely length of time between captures, transporting birds individually from base camp to Keauhou as they are captured will likely be the preferred method (as opposed to waiting until several birds could be transported together).

[C. Crampton] – The logistics of getting a helicopter company for this are not trivial…which is why we might want to consider holding them on Kaua'i for a while.

Transport birds to release site – Specifics (e.g., transport method) will depend on the release site selected. Prior to being moved to the release site, all birds will undergo an examination by a veterinarian.

Release birds – (*specifics will depend on the following: will captive 'akeke'e be part of the release cohort, the time it takes to capture the required number of wild birds, whether or not wild birds are held at Keauhou or on Kaua'i and for how long, the rapport among wild birds, the final sex ratio of the release cohort, and will soft or hard release techniques be used [see above].*) If a soft release is employed for both captive and wild birds, ideally the captive birds would be held longer than wild birds to allow them to acclimate to the release site and local weather conditions. Behavioral observations, including food consumption, will be documented to correlate with post-release survival as well as to ensure that birds are successfully acclimating to their new conditions prior to release. The release will be conducted incrementally to potentially anchor birds to the release site and to ensure that post-release monitoring is manageable.

Conduct post-release monitoring – Each bird will have a unique combination of four bands (three color plastic bands and one USGS numerical metal bird band) and most likely radio transmitters (but see above comment by Crampton) to facilitate monitoring individual birds' behavior and movements. If used, radio transmitters will be attached before the birds are released to monitor how the birds react to the transmitter and to modify the attachment as needed. Although not perfect surrogates for the wild birds, attaching transmitters (but not activating them) to captive individuals would allow for extended observations of how the transmitters affect individual behavior. When possible, the birds will be recaptured before transmitter batteries die, and transmitters will be replaced.

Conduct short-term monitoring (<30 days) – (*contingent on the application of transmitters – see comment above from Crampton*) Every attempt will be made to resight each bird every day while the transmitters are active. This intensive monitoring will provide survival data (see below) as well as data on foraging and behavior. These data will be used to assess each bird's health and the ability of the release site to support 'akeke'e, which will inform potential future translocation efforts. Intensive data collection is important to determine individual survival, timing of any mortalities, and timely retrieval of carcasses. The latter will increase the likelihood that a necropsy will be able to determine the cause(s) of mortality and inform methods to mitigate mortality factors during subsequent translocations. Periods of focal behavioral observations of each bird during this period will also be conducted. Data collected during these observations will document foraging behaviors, habitat preferences, and possible social interactions. Every effort will be made to determine if any pairing, territorial, or breeding behaviors are being exhibited.

Conduct extended monitoring – Monitoring will continue after the radio transmitters' batteries are no longer active (if radios are attached to birds). While more difficult, this monitoring will be important to document survival and persistence of birds at the translocation site. Monitoring the persistence, home range size, and foraging behavior over the first year will provide the data needed to inform subsequent translocations. Both short-term and extended monitoring are necessary to determine if the project's short- and long-term objectives are achieved.

Conduct post-release disease monitoring – Continue monitoring to detect adults and larval mosquitoes as well as blood sampling of native and nonnative birds to detect infection rates at the release sites. Plans will be developed to respond (i.e., capture and remove birds, increase mosquito control efforts) in the event that an increase in mosquitoes or malaria prevalence is detected.

Conduct post-release arthropod sampling – Conduct follow-up sampling of arthropods to assess any impacts of ʻakekeʻe to the arthropod fauna of the recipient site.

Literature Cited

Banko, P., R. Peck, K. Brinck, and D. Leonard. 2015. Richness, diversity, and similarity of arthropod prey consumed by a community of Hawaiian forest birds. Hawaiʻi Cooperative Studies Unit, Technical Report HCSU-066. University of Hawaiʻi at Hilo, Hawaiʻi, USA.

Clarke, R. H., R. L. Boulton, and M. F. Clarke. 2002. Translocation of the socially complex black-eared miner *Manorina melanotis*: a trial using hard and soft release techniques. Pacific Conservation Biology 8:223–234.

Fischer, J., and D. B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation 96:1–11.

Fountain, K., C. Jeffs, S. Croft, J. Gregson, J. Lister, A. Evans, I. Carter, Y. M. Chang, and A. W. Sainsbury. 2016. The influence of risk factors associated with captive rearing on post-release survival in translocated cirl buntings *Emberiza cirlus* in the UK. Oryx 51:332–338 https//doi.org/10.1017/S0030605315001313.

Freed, L. A., J. S. Fretz, and M. C. Medeiros. 2007. Adaptation in the Hawaii akepa to breed and moult during a seasonal food decline. Evolutionary Ecology Research 9:157–167.

Fretz, J. S. 2000. Relationship of canopy arthropod prey to distribution and life history of the Hawaii akepa. PhD dissertation. University of Hawaiʻi at Hilo, Hawaiʻi, USA. 186 pp.

Fretz, J. S. 2002. Scales of food availability for an endangered insectivore, the Hawaii Akepa. The Auk 119:166–174.

Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477–480.

Maui Forest Bird Working Group. 2018. Kiwikiu (*Pseudonestor xanthophrys*) reintroduction plan. 84 pp.

Molles, L., A. Calcott, D. Peters, G. Delamare, J. Hudson, J. Innes, I. Flux, and J. Waas. 2008. "Acoustic anchoring" and the successful translocation of North Island kokako (*Callaeas* *cinerea wilsoni*) to a New Zealand mainland management site within continuous forest. Notornis 55:57–68.

Mitchell, W. F., R. L. Boulton, L. Ireland, T. J. Hunt, S. J. Verdon, L. G. M. Olds, C. Hedger, and R. H. Clarke. 2021. Using experimental trials to improve translocation protocols for a cryptic, endangered passerine. Pacific Conservation Biology 28:68–79. https://doi.org/10.1071/PC20097.

Richardson, K., I. Castro, D. Brunton, and D. Armstrong. 2015. Not so soft? Delayed release reduces long-term survival in a passerine introduction. Oryx 49:535–541.

Slater, G. L. 2001. Avian restoration in Everglades National Park (1997–2001): Translocation methodology, population demography, and evaluating success. Final Report. 56 pp.

Slater, G. L., and B. Altman. 2011. Avian restoration in the prairie-oak ecosystem: a reintroduction case study of western bluebirds to San Juan Island, Washington. Northwest Science 85:223–232. https://doi.org/10.3955/046.085.0211.

Slater, G. L., and B. Altman. 2013. Re-introduction of the western bluebird to oak-prairie habitats in Pacific Northwest, USA. Pages 102–106 *in* P. S. Soorae (editor). Global re-introduction perspectives: 2013. Further case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group and Abu Dhabi, AE Environment Agency. Gland, Switzerland.

Taylor, S. S., I. G. Jamieson, and D. P. Armstrong. 2005. Successful island reintroductions of New Zealand robins and saddlebacks with small numbers of founders. Animal Conservation 8:415–420.

Warren, C. C., L. K. Berthold, H. L. Mounce, P. Luscomb, B. Masuda, and L. Berry. 2020. Kiwikiu Translocation Report 2019. Internal Report.

White, T. H., Jr., Y de Melo Barros, P. F. Develey, I. C. Llerandi-Román, O. A. Monsegur-Rivera, and A. M. Trujillo-Pinto. 2015. Improving reintroduction planning and implementation through quantitative SWOT analysis. Journal for Nature Conservation 28:149–159. https://doi.org/10.1016/j.jnc.2015.10.002

Withers, S., D. Armstrong, T. Ward-Smith, S. Parsons, and M. E. Hauber. 2019. Improved methods for reducing translocation mortality and obtaining reliable population projections for reintroduction of the New Zealand rifleman *Acanthisitta chloris*. Bird Conservation International 29:542–557 https://doi.org/10.1017/S0959270918000412.

Wolf, C. M., T. Garland, Jr., and B. Griffith. 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts. Biological Conservation 86:243–255.

Appendix IX. Captive Propagation Expert Elicitation

Summary

In support of the larger effort to address population declines in four species of Hawaiian forest birds, we convened experts in captive care to evaluate each species' suitability for management under captive conditions and to identify ways to optimize their survival, productivity, and post-release survival. We identified three objectives for captive care and asked the participants to rate their confidence in achieving the objectives for each species. Overall, the ratings were optimistic, indicating high confidence in the ability to maintain productive captive flocks whose individuals are suitable for release.

Introduction

Captive care is the care and breeding of species, generally within a managed (captive) environment, for the purpose of insurance against extinction, supplementing or augmenting a wild population, or reintroduction to the wild to (re)establish populations if a species does become extinct in the wild. Species maintenance under captive care can be part of a larger management program for species.

Past experiences with Hawaiian honeycreepers under captive care have shown mixed success in sustaining or growing captive flocks and producing birds that are suitable for release. There are two facilities in Hawai'i managed by the San Diego Zoo Wildlife Alliance (SDZWA), which have generally been successful caring for honeycreepers, but have had less success breeding and increasing flock size. Survival of captive honeycreepers after release into the wild has largely been unsuccessful. Overall, globally, species management under captive care and the resulting reintroduction to the wild has been successful in some species, but not others, indicating that captive care can be an important tool in conservation but may not work for some species.

To identify key elements for successful captive care of Hawaiian forest birds, we brought together an international panel of seven captive care experts to assess strategies specifically for the four species of greatest concern: 'akikiki and 'akeke'e on Kaua'i, and kiwikiu and 'ākohekohe on Maui. Three of these species, 'akikiki, 'akeke'e, and kiwikiu, and several other species are currently being held in captivity, so group recommendations could also benefit these species as well as any new species brought into care.

Methods

The workshop was held virtually over three days at the end of September and beginning of October. Prior to the meeting, we shared information on the species' status and trends, life history and behavior, ongoing field programs, and conservation efforts to date. The first day of the workshop focused on providing background on the species and captive care. San Diego Zoo Global gave a presentation on its facilities that included the physical structure of the aviaries, total number of aviaries, available space, a history of species managed and their outcomes, with a greater focus on the four target species.

We then encouraged the experts to consider multiple options for a captive care program, including expanding existing SDZWA facilities, building new facilities that could potentially be managed by other organizations, and utilizing the capacity of zoos outside of Hawai'i. We also discussed ways to improve existing structures, and how new facilities might differ in terms of size and spacing, how many individuals to collect to start or reinforce a captive population, how soon birds should be collected, and initial recommendations on spacing to reduce stress and improve outcomes.

We considered short-term holding (<5 years) as well as longer-term breeding (>10 years). Short-term holding would entail bringing in birds and releasing them back to their source site once *Wolbachia* incompatible insect technique (IIT) has broken the disease cycle in approximately two to four years or translocating them to the Island of Hawaiʻi once site assessment and regulatory compliance is completed in two to three years. Long-term holding and breeding would be considered if *Wolbachia* IIT implementation is delayed, or the population is too small to support re-establishment or translocation.

We identified three objectives for captive care:

1) Ensure wild-caught birds would still be alive in five years
2) Ability to develop the techniques to maintain and grow the founding population such that we have 1.5 times the founding population within 10 years
3) Have birds approach normal wild survival rates after release and have a high likelihood of reproducing

We discussed each species individually, focusing on how their life history and behavior could influence their suitability for care in captivity. We then asked experts on a species-by-species basis to rate their confidence that we could meet each objective on a scale of 1 to 10. This elicitation was a collective effort during the workshop, and the group reached consensus on the scores, rather than each participant independently scoring each species. In an effort to get a range of scores, after the workshop we asked participants to score each species, but our response rate was too low to evaluate these scores. Scoring was also based on a generic site, we did not specify that birds would be held at SDZWA, new Hawaiʻi facilities, or zoos on the continental United States.

Appendix IX, Table 1. Participants of workshop

Name	Affiliation
Hannah Bailey	San Diego Zoo Wildlife Alliance
Robby Kohley	Pacific Rim Conservation
Peter Luscomb	Pacific Bird Conservation
Bryce Masuda	San Diego Zoo Wildlife Alliance
Scott Newland	Sedgwick County Zoo
Dave Rimlinger	San Diego Zoo Wildlife Alliance
Monique Van Sluys	Taronga Conservation Society, Australia

Results

The collective scores for each species in meeting the objectives for captive care are displayed in Table 2.

Appendix IX, Table 2. Scores for each species of honeycreeper in meeting each of the objectives for captive care. Scores were on a scale of 1–10 with 10 indicating high confidence.

Objective	ʻAkikiki	ʻAkekeʻe	Kiwikiu	ʻĀkohekohe
Ensure wild-caught birds are still alive in 5 years	7	6	8	6
Ability to develop the techniques to maintain and grow the founding population such that we have 1.5 times the founding population within 10 years	9	5	7	7
Birds are approaching wild survival rates after release and have a high likelihood of reproducing	9	9	5	9

The discussion around species-specific captive programs identified ways to address some of the differences in the species. Table 3 shows the experts' suggestions regarding whether a species is an ideal candidate for holding and breeding, timing for collection from the wild, aviary size and spacing, and other considerations.

Appendix IX, Table 3. Species-specific considerations for captive care and collection.

Species	Hold	Breed	Number to collect	When to collect	Aviary size (m)	Aviary spacing	Notes
ʻAkikiki	Yes	Yes	All remaining wild birds	ASAP	1.2x1.8x2.1	Stagger breeding pairs	
ʻAkekeʻe	Yes	Yes, but it will be challenging	Minimum 50 birds, but as many as possible	ASAP	1.2x1.8x4.6	Stagger individuals and breeding pairs	
Kiwikiu	Yes	Yes	Minimum 50 birds, but as many as possible	ASAP	1.2x1.8x2.1	Stagger breeding pairs	Get back into wild as soon as possible
ʻĀkohekohe	Yes	Yes, but it will be challenging	Minimum 50 birds, but after initial collection of 6–10 birds to learn techniques	ASAP	1.2x1.8x4.6	Stagger individuals and breeding pairs	Get back into wild as soon as possible

Discussion

The group of captive care experts had high confidence that with enough birds, resources, and time they could keep individuals alive (60–80% depending on species), develop techniques to increase the size of the captive flock (50–90% confidence depending on species), and have birds survive and reproduce following release back into the wild (>90% confidence for all but kiwikiu).

Overall, experts had high confidence in all three objectives for ʽakikiki. SDZWA currently holds a population of approximately 43 birds. This collection was from wild eggs, and they were able to successfully hatch them and rear them to adulthood. To date, breeding has been relatively unsuccessful, but SDZWA has relied on parent-rearing in order to achieve objective 3. Ongoing efforts are planned to change to hand-rearing. Spacing breeding pairs may also improve reproductive outcomes, according to the expert panel. They agreed that all remaining individuals (<43) should be brought into captivity immediately. In general, ʽakikiki's life history and social system is conducive to captive care, and the ongoing program could focus on improving reproductive success. The panel indicated this species is suitable for a short- or long-term captive program.

ʽAkekeʽe scored 60% and 50% for objectives 1 and 2, respectively. Although its high score (90%) for objective 3 indicates confidence that, if we are able to overcome current challenges to holding and breeding them, we could maintain natural behaviors and have a population that is suitable for release. ʽAkekeʽe is wide-ranging and forages and nests high in the canopy. Several birds are currently held at SDZWA, and they were described as being stressed. Thus, our panel recognized changing cage dimensions to make them taller, increasing cover in the aviaries, and spacing of individuals away from each other could improve the birds' response to captive conditions. A minimum founding population of 50 birds, collected as soon as possible was still the preferred approach for this species, despite current challenges. This could be due to its steep decline and the lack of mosquito-free habitat on Kauai.

Of these four target species, kiwikiu has the longest history of captive care. Captive kiwikiu have been held and bred for over a 20-year period. The program was started in the 1990s through egg collection, but four adult kiwikiu have also been brought into captivity. All captive birds have survived over a year with multiple pairs breeding successfully. However, the flock size was always small, and the low reproductive rate did not maintain or grow the captive flock size. Thus, kiwikiu rated high for objectives 1 and 2. It scored 50% for objective 3, due to its long period of fledgling dependency and complex feeding behaviors. The panel suggested bringing in a minimum of 50 birds as soon as possible, and that returning wild-caught birds to the wild should be a priority. The panel considered them suitable for short-term holding as well as a long-term breeding program.

ʽĀkohekohe scored 60% and 70% for objectives 1 and 2, respectively. Its high score (90%) for objective 3 indicates confidence that, if captive caregivers were able to overcome challenges to holding and breeding them, ʽākohekohe could maintain natural behaviors and have a population that is suitable for release. This species is highly territorial and aggressive, and previous attempts at rearing chicks from eggs indicated they were stressed under captive conditions. Increasing the height of the aviaries, spacing individuals away from other birds, and increasing cover could help overcome challenges associated with objectives 1 and 2. Experts also suggested a holding program, where birds are removed from the wild immediately under a short-term program to withdraw them from the threat of malaria, and then returned to the wild, either at the capture site, or translocated to a safe location.

Generally, the expert panel encouraged removing all species from the threat of malaria as soon as possible. Currently, there is space for 31 additional birds at SDZWA, with additional infrastructure needed if a decision is made to hold additional birds under captive care in Hawai'i. Different types of infrastructure are possible depending how soon facilities are needed, and the length of time birds will be held. If the anticipated plan is to bring birds out from the wild just long enough for *Wolbachia* IIT to break the disease cycle, then short-term facilities near the capture locations might allow for holding birds while maintaining a connection to their natural habitat. Such local care facilities may allow for multiple groups to care for birds, facilitating innovation of captive care approaches. Long-term captive propagation would require more extensive facilities, such as those managed by the SDZWA. International concern about the plight of Hawai'i's native forest birds has led to offers from zoos outside of Hawai'i to help support long-term conservation flocks. Such facilities could provide extra capacity and skill for minimal additional costs and could be an important part of a multitiered conservation strategy.

Appendix X. Hawaiʻi Forest Bird Conservation Workshop Elicitation

Presumptions, assumptions, and available information:

Most Hawaiʻi forest birds across the islands are declining rapidly, with several species likely on the brink of extinction. While Hawaiʻi forest birds face many threats, the overwhelming scientific consensus is that the spread of avian malaria into high-elevation forests is the driving force behind these most recent declines. Specifically, ʻakikiki and ʻakekeʻe on Kauaʻi and kiwikiu and ʻākohekohe on Maui have experienced steep declines in recent years and are approaching population sizes that are unsustainable (i.e., functionally extinct). All available evidence indicates these species will continue to decline, and the longer the time before management actions are implemented the greater the likelihood of extinction because of diminishing population sizes.

Avian malaria is spreading into high-elevation forests as a result of climate change, causing rapid declines in multiple species on the islands of Kauaʻi and Maui. Without intervention, these four species have a high probability of becoming functionally extinct in the wild in the next 10 years (based on expert elicitation). To prevent this outcome, disease would need to be managed *in situ*. How best to ensure the survival of these species until avian malaria can be managed is the subject of this exercise; more specifically, we asked experts to estimate the probability of success of the different management options.

Currently, *Wolbachia* IIT is the only landscape-level tool being actively developed for managing disease in Hawaiʻi forest bird habitat. Expert elicitation of time to effective implementation for these four bird species (application in forest + six months to suppress mosquitoes) resulted in estimates between 2023 and 2026, and an estimated probability of success, once effectively implemented, at 82% (minimum and maximum average probability of success was 61–93%). Effective implementation is defined as releasing the mosquitoes and suppressing the wild mosquito populations in the treatment area.

The development of *Wolbachia* IIT is proceeding as fast as possible given compliance and technical constraints. Development is planned to continue regardless of whether other conservation actions will be taken (e.g., translocations, bringing birds into captivity).

The best place for birds to be is in the wild within their current and historical range. Birds should only be removed from the wild (e.g., brought into captivity, translocated to new disease-free areas) as a last resort to prevent extinction.

Based on discussions with a group of experts on bird husbandry (with strong Hawaiʻi honeycreeper experience), if birds are brought into captivity, then captive holding and breeding, and eventual release back into the wild, the outcome is highly likely to be successful with sufficient founding population sizes, time, and resources.

If birds are translocated, a group of experts provided the following probability of success for each species: ʻakikiki (42% mean, 21–62% min-max), ʻakekeʻe (38% mean, 17–59% min-max), kiwikiu (45% mean, 24–65% min-max), and ʻākohekohe (51% mean, 28–72% min-max). The minimum estimated time needed to prepare and carry out a translocation to Hawaiʻi Island is about two years. Translocations would only be to disease-free sites on Hawaiʻi Island; however, it is difficult to predict how long any site would remain disease free given the speed at which climate change is affecting mosquito distribution. The assumption is that *Wolbachia* IIT would be applied to host locations as soon as possible following application to Kauaʻi and Maui.

For management actions with a captive or translocation component, we assume that only a proportion of the population would be captured. Expert species biologists estimate that approximately 80% of the wild ʻakikiki population could be caught, 10–20% of ʻakekeʻe, 80% of kiwikiu, and 40% of ʻākohekohe (assuming two to three banding crews working for two to three years).

Against the background of uncertainty in time and risk for each approach is uncertainty in the time to extinction for each species, and how many birds would be available for a given action. While each potential action has risk and the probability of success is difficult to estimate, decisions need to be made to minimize the risk of extinction.

Objectives

Objectives are linked such that the probability of success for the objective 2 management action is contingent on objective 1 being met.

Objective 1: Prevent the imminent extinction of species

- Prioritizes immediate actions to prevent imminent extinction
- Timeframe is for actions now through 2024 (three years from now, mean time for effective implementation of *Wolbachia* IIT)
- All three actions to bring birds into captivity immediately (management actions 3, 4, & 5, below) collapsed into a single score for objective 1, but the disposition of the birds (i.e., hold then translocate, hold then release back to capture location, hold for long-term flock) is dealt with in objective 2

Objective 2: Implement management actions that best ensure one or more viable and stable to increasing wild populations in the long term (up to and beyond 10 years)

- Prioritizes actions that benefit long-term population viability of species
- Species held in captivity may become "extinct in wild" but the ultimate goal is to have viable, wild populations; any birds brought into captivity (or their offspring) will be reintroduced back into the wild as soon as conditions allow, and they are determined to be sufficiently healthy and fit for release
- Once implemented, it is assumed *Wolbachia* IIT can continue to be used effectively until additional, higher efficiency options are available

<u>Instructions to experts on how to score each management action in terms of the probability of success in achieving objective 1 and objective 2:</u>

- For each management action, score your probability of success of achieving objective 1 and objective 2 on a scale from 0–100%.
- Provide the reasonable min and max probability of success scores, and the most likely probability of success score.
- **Use 80% confidence level** to gauge your level of confidence of your min and max scores. In other words, this level of confidence indicates that you are reasonably certain that the true probability of success is between your min and max, but you can imagine some unlikely scenarios where it could be better or worse versus a

higher confidence level where there is almost no likelihood that the real percentage is outside your min and max estimates.

Assumptions:

- *Wolbachia* IIT will be implemented regardless of any additional management actions taken (if *Wolbachia* is NOT implemented, then estimated time to extinction for bird species is most likely outcome).
- As applicable, disease monitoring in each species' historical range is conducted to determine when it is safe to return birds (either from established wild populations on Hawaiʻi Island or from captivity) to the wild.

Management Actions

1) Leave birds in wild and **manage disease *in situ* via *Wolbachia* IIT:** This action relies on *Wolbachia* IIT to break the disease cycle in forest bird habitat, allowing birds to remain in the wild in their native range
    - o Assumes *Wolbachia* IIT will be implemented as soon as possible (mean 2023, range of 2023–2026 based on expert judgement), applied at adequate geographic scales, and has a high but unknown probability of success (82% average probability of success based on expert elicitation) in suppressing mosquitoes and breaking the disease cycle in the core breeding areas of the focal bird species

2) **Direct (wild to wild) translocation** to Hawaiʻi Island high-elevation forest
    - o Removal from wild would not occur until site is ready, translocation plan is written, permits have been obtained, and disease monitoring has been conducted prior to birds being captured and translocated (estimated time to prepare for a translocation is about two years)
    - o Assumes that *Wolbachia* IIT would be applied at release location as soon as possible, but may be later than applications to Kauaʻi and Maui

3) **Bring birds into captivity as quickly as possible** to halt ongoing mortality due to disease, hold/breed in captivity for two to three years and **then translocate** to Hawaiʻi Island site (wild to captive to wild translocation)
    - o Presumes wild to wild translocation is preferred, but if extinction risk is high in the next two to three years, then would need to bring wild birds into captivity until ready to translocate
    - o Assumes that the overall decision is to translocate birds, and this action would initiate the planning, permitting, and host-site monitoring necessary to translocate birds, but removing from the wild while all the necessary steps are being completed
    - o Assumes that *Wolbachia* IIT would be applied at release location as soon as possible, but is likely later than applications to Kauaʻi and Maui

4) **Bring birds into captivity as quickly as possible** to halt ongoing mortality due to disease, hold and breed in captivity until *Wolbachia* IIT has successfully broken the disease cycle, **then release back into native range**
    - Assumes short-term holding until *Wolbachia* IIT is implemented (~2023)
    - Assumes long-term captive flock is not necessary for the persistence of the species (versus management action #5, below)
    - Assumes the longer we wait to bring birds into captivity, the more likely extinction will occur because of diminishing size of population

5) **Bring birds into captivity as quickly as possible** to halt ongoing mortality due to disease, **establish and grow long-term breeding flock** to reintroduce populations to wild (if extinct in wild), to source conservation introductions, and to supplement recovering wild populations
    - Assumes adequate facilities and knowledge would facilitate successful reproduction in captivity and long-term funding commitment
    - Assumes a captive flock will be needed for the prospects of the species existing in the wild
    - Assumes the longer we wait to bring birds into captivity, the more likely extinction will occur because of diminishing size of population

Appendix X, Table 1. Participants of expert judgement elicitation on probability of success of alternative management actions.

Name	Affiliation
Paul Banko	U.S. Geological Survey Pacific Island Ecosystems Research Center
Lainie Berry	Hawaiʽi Division of Forestry and Wildlife
Lisa Cali Crampton	Kauaʽi Forest Bird Recovery Project
John Ewen	London Zoological Society
Chris Farmer	American Bird Conservancy
Nick Holmes	The Nature Conservancy
Dennis LaPointe	U.S. Geological Survey Pacific Island Ecosystems Research Center
David Leonard	U.S. Fish and Wildlife Service, Portland Regional Office
Peter Luscomb	Pacific Bird Conservation
Bryce Masuda	San Diego Zoo Wildlife Alliance
Ryan Monello	National Park Service
Hanna Mounce	Maui Forest Bird Recovery Project
Eric VanderWerf	Pacific Rim Conservation
John Vetter	U.S. Fish and Wildlife Service, Pacific Island Office
Alex Wang	Hawaiʽi Natural Area Reserve System

Appendix X, Table 2. Results of expert elicitation. Experts who contributed to this elicitation are listed in Table 1, but not necessarily in the order presented in this table. For a given species, management action, objective, and expert, their minimum, most likely, and maximum estimate of success is given at the 80% confidence level.

Species	Action	Objective1	Expert	Min	Most likely	Max
ʽAkikiki	Captivity	Objective1	E1	70	80	90
ʽAkikiki	Captivity	Objective1	E2	60	70	80
ʽAkikiki	Captivity	Objective1	E3	30	50	70
ʽAkikiki	Captivity	Objective1	E4	80	90	100
ʽAkikiki	Captivity	Objective1	E5	60	80	90
ʽAkikiki	Captivity	Objective1	E6	20	60	80
ʽAkikiki	Captivity	Objective1	E7	70	80	90
ʽAkikiki	Captivity	Objective1	E8	70	80	90
ʽAkikiki	Captivity	Objective1	E9	80	90	100
ʽAkikiki	Captivity	Objective1	E10	90	95	100
ʽAkikiki	Captivity	Objective1	E11	60	70	80
ʽAkikiki	Captivity	Objective1	E12	40	65	80
ʽAkikiki	Captivity	Objective1	E13	80	90	100
ʽAkikiki	Captivity	Objective1	E14	70	85	95
			Mean	62.9	77.5	88.9

Species	Action	Objective1	Expert	Min	Most likely	Max
ʽAkikiki	Direct translocation	Objective1	E1	40	50	60
ʽAkikiki	Direct translocation	Objective1	E2	30	50	70
ʽAkikiki	Direct translocation	Objective1	E3	0	40	70
ʽAkikiki	Direct translocation	Objective1	E4	0	5	10
ʽAkikiki	Direct translocation	Objective1	E5	5	20	70
ʽAkikiki	Direct translocation	Objective1	E6	5	25	40
ʽAkikiki	Direct translocation	Objective1	E7	0	10	20
ʽAkikiki	Direct translocation	Objective1	E8	5	15	25
ʽAkikiki	Direct translocation	Objective1	E9	5	10	20

‘Akikiki	Direct translocation	Objective1	E10	0	10	20
‘Akikiki	Direct translocation	Objective1	E11	30	45	60
‘Akikiki	Direct translocation	Objective1	E12	0	5	20
‘Akikiki	Direct translocation	Objective1	E13	0	10	30
‘Akikiki	Direct translocation	Objective1	E14	0	10	30
			Mean	8.6	21.8	38.9

Species	Action	Objective1	Expert	Min	Most likely	Max
‘Akikiki	*Wolbachia*	Objective1	E1	0	10	20
‘Akikiki	*Wolbachia*	Objective1	E2	0	10	33
‘Akikiki	*Wolbachia*	Objective1	E3	0	10	30
‘Akikiki	*Wolbachia*	Objective1	E4	0	5	15
‘Akikiki	*Wolbachia*	Objective1	E5	0	10	40
‘Akikiki	*Wolbachia*	Objective1	E6	5	15	20
‘Akikiki	*Wolbachia*	Objective1	E7	0	5	15
‘Akikiki	*Wolbachia*	Objective1	E8	0	10	20
‘Akikiki	*Wolbachia*	Objective1	E9	0	2.5	5
‘Akikiki	*Wolbachia*	Objective1	E10	0	40	80
‘Akikiki	*Wolbachia*	Objective1	E11	0	20	25
‘Akikiki	*Wolbachia*	Objective1	E12	0	10	30
‘Akikiki	*Wolbachia*	Objective1	E13	0	0	20
‘Akikiki	*Wolbachia*	Objective1	E14	0	0	10
			Mean	0.4	10.5	25.9

Species	Action	Objective1	Expert	Min	Most likely	Max
‘Akeke‘e	Captivity	Objective1	E1	50	70	90
‘Akeke‘e	Captivity	Objective1	E2	20	30	50
‘Akeke‘e	Captivity	Objective1	E3	20	40	50
‘Akeke‘e	Captivity	Objective1	E4	50	65	80

ʻAkekeʻe	Captivity	Objective1	E5	35	65	90
ʻAkekeʻe	Captivity	Objective1	E6	10	30	50
ʻAkekeʻe	Captivity	Objective1	E7	25	50	75
ʻAkekeʻe	Captivity	Objective1	E8	30	50	60
ʻAkekeʻe	Captivity	Objective1	E9	60	70	80
ʻAkekeʻe	Captivity	Objective1	E10	90	95	100
ʻAkekeʻe	Captivity	Objective1	E11	50	60	70
ʻAkekeʻe	Captivity	Objective1	E12	20	40	60
ʻAkekeʻe	Captivity	Objective1	E13	10	30	50
ʻAkekeʻe	Captivity	Objective1	E14	50	65	85
			Mean	37.1	54.3	70.7

Species	Action	Objective1	Expert	Min	Most likely	Max
ʻAkekeʻe	Direct translocation	Objective1	E1	40	50	60
ʻAkekeʻe	Direct translocation	Objective1	E2	0	20	50
ʻAkekeʻe	Direct translocation	Objective1	E3	30	50	80
ʻAkekeʻe	Direct translocation	Objective1	E4	10	30	60
ʻAkekeʻe	Direct translocation	Objective1	E5	35	60	90
ʻAkekeʻe	Direct translocation	Objective1	E6	20	60	80
ʻAkekeʻe	Direct translocation	Objective1	E7	20	45	70
ʻAkekeʻe	Direct translocation	Objective1	E8	20	30	60
ʻAkekeʻe	Direct translocation	Objective1	E9	25	45	65
ʻAkekeʻe	Direct translocation	Objective1	E10	0	5	10
ʻAkekeʻe	Direct translocation	Objective1	E11	0	10	15
ʻAkekeʻe	Direct translocation	Objective1	E12	10	30	50
ʻAkekeʻe	Direct translocation	Objective1	E13	0	30	50
ʻAkekeʻe	Direct translocation	Objective1	E14	0	25	50
			Mean	15.0	35.0	56.4

Species	Action	Objective1	Expert	Min	Most likely	Max
ʽAkekeʽe	*Wolbachia*	Objective1	E1	0	20	40
ʽAkekeʽe	*Wolbachia*	Objective1	E2	0	70	90
ʽAkekeʽe	*Wolbachia*	Objective1	E3	0	25	50
ʽAkekeʽe	*Wolbachia*	Objective1	E4	10	50	80
ʽAkekeʽe	*Wolbachia*	Objective1	E5	20	40	70
ʽAkekeʽe	*Wolbachia*	Objective1	E6	30	70	90
ʽAkekeʽe	*Wolbachia*	Objective1	E7	40	65	90
ʽAkekeʽe	*Wolbachia*	Objective1	E8	10	25	50
ʽAkekeʽe	*Wolbachia*	Objective1	E9	15	30	45
ʽAkekeʽe	*Wolbachia*	Objective1	E10	40	70	100
ʽAkekeʽe	*Wolbachia*	Objective1	E11	0	10	15
ʽAkekeʽe	*Wolbachia*	Objective1	E12	20	50	80
ʽAkekeʽe	*Wolbachia*	Objective1	E13	0	30	50
ʽAkekeʽe	*Wolbachia*	Objective1	E14	0	20	40
			Mean	13.2	41.1	63.6

Species	Action	Objective1	Expert	Min	Most likely	Max
ʽĀkohekohe	Captivity	Objective1	E1	40	60	80
ʽĀkohekohe	Captivity	Objective1	E2	0	40	80
ʽĀkohekohe	Captivity	Objective1	E3	0	10	20
ʽĀkohekohe	Captivity	Objective1	E4	10	30	50
ʽĀkohekohe	Captivity	Objective1	E5	50	75	95
ʽĀkohekohe	Captivity	Objective1	E6	5	20	30
ʽĀkohekohe	Captivity	Objective1	E7	25	50	75
ʽĀkohekohe	Captivity	Objective1	E8	10	40	50
ʽĀkohekohe	Captivity	Objective1	E9	30	45	60
ʽĀkohekohe	Captivity	Objective1	E10	90	95	100

ʽĀkohekohe	Captivity	Objective1	E11	70	80	90
ʽĀkohekohe	Captivity	Objective1	E12	30	50	70
ʽĀkohekohe	Captivity	Objective1	E13	50	75	100
ʽĀkohekohe	Captivity	Objective1	E14	30	60	80
			Mean	31.4	52.1	70.0
Species	Action	Objective1	Expert	Min	Most likely	Max
ʽĀkohekohe	Direct translocation	Objective1	E1	30	50	70
ʽĀkohekohe	Direct translocation	Objective1	E2	30	70	90
ʽĀkohekohe	Direct translocation	Objective1	E3	70	80	100
ʽĀkohekohe	Direct translocation	Objective1	E4	5	20	30
ʽĀkohekohe	Direct translocation	Objective1	E5	60	80	95
ʽĀkohekohe	Direct translocation	Objective1	E6	30	70	80
ʽĀkohekohe	Direct translocation	Objective1	E7	20	45	70
ʽĀkohekohe	Direct translocation	Objective1	E8	20	50	70
ʽĀkohekohe	Direct translocation	Objective1	E9	40	60	80
ʽĀkohekohe	Direct translocation	Objective1	E10	0	15	30
ʽĀkohekohe	Direct translocation	Objective1	E11	60	75	85
ʽĀkohekohe	Direct translocation	Objective1	E12	35	50	75
ʽĀkohekohe	Direct translocation	Objective1	E13	0	50	75
ʽĀkohekohe	Direct translocation	Objective1	E14	35	50	75
			Mean	31.1	54.6	73.2
Species	Action	Objective1	Expert	Min	Most likely	Max
ʽĀkohekohe	*Wolbachia*	Objective1	E1	0	40	70
ʽĀkohekohe	*Wolbachia*	Objective1	E2	0	80	90
ʽĀkohekohe	*Wolbachia*	Objective1	E3	20	40	70
ʽĀkohekohe	*Wolbachia*	Objective1	E4	10	50	90
ʽĀkohekohe	*Wolbachia*	Objective1	E5	50	70	90
ʽĀkohekohe	*Wolbachia*	Objective1	E6	40	80	100

ʽĀkohekohe	*Wolbachia*	Objective1	E7	50	75	100
ʽĀkohekohe	*Wolbachia*	Objective1	E8	25	55	80
ʽĀkohekohe	*Wolbachia*	Objective1	E9	30	55	80
ʽĀkohekohe	*Wolbachia*	Objective1	E10	80	90	100
ʽĀkohekohe	*Wolbachia*	Objective1	E11	30	45	60
ʽĀkohekohe	*Wolbachia*	Objective1	E12	60	80	95
ʽĀkohekohe	*Wolbachia*	Objective1	E13	20	50	100
ʽĀkohekohe	*Wolbachia*	Objective1	E14	20	50	80
			Mean	31.1	61.4	86.1

Species	Action	Objective1	Expert	Min	Most likely	Max
Kiwikiu	Captivity	Objective1	E1	50	70	90
Kiwikiu	Captivity	Objective1	E2	70	85	95
Kiwikiu	Captivity	Objective1	E3	20	50	70
Kiwikiu	Captivity	Objective1	E4	80	85	90
Kiwikiu	Captivity	Objective1	E5	40	80	90
Kiwikiu	Captivity	Objective1	E6	20	60	90
Kiwikiu	Captivity	Objective1	E7	75	85	95
Kiwikiu	Captivity	Objective1	E8	60	75	90
Kiwikiu	Captivity	Objective1	E9	75	85	95
Kiwikiu	Captivity	Objective1	E10	90	95	100
Kiwikiu	Captivity	Objective1	E11	60	70	80
Kiwikiu	Captivity	Objective1	E12	40	60	80
Kiwikiu	Captivity	Objective1	E13	70	80	100
Kiwikiu	Captivity	Objective1	E14	60	70	80
			Mean	57.9	75.0	88.9

Species	Action	Objective1	Expert	Min	Most likely	Max
Kiwikiu	Direct translocation	Objective1	E1	40	60	80

Kiwikiu	Direct translocation	Objective1	E2	20	60	80
Kiwikiu	Direct translocation	Objective1	E3	40	70	100
Kiwikiu	Direct translocation	Objective1	E4	15	35	55
Kiwikiu	Direct translocation	Objective1	E5	30	55	80
Kiwikiu	Direct translocation	Objective1	E6	20	50	80
Kiwikiu	Direct translocation	Objective1	E7	10	25	40
Kiwikiu	Direct translocation	Objective1	E8	10	30	50
Kiwikiu	Direct translocation	Objective1	E9	60	70	80
Kiwikiu	Direct translocation	Objective1	E10	0	5	10
Kiwikiu	Direct translocation	Objective1	E11	0	20	30
Kiwikiu	Direct translocation	Objective1	E12	30	50	70
Kiwikiu	Direct translocation	Objective1	E13	0	30	50
Kiwikiu	Direct translocation	Objective1	E14	25	35	50
			Mean	21.4	42.5	61.1

Species	Action	Objective1	Expert	Min	Most likely	Max
Kiwikiu	*Wolbachia*	Objective1	E1	0	20	40
Kiwikiu	*Wolbachia*	Objective1	E2	0	70	90
Kiwikiu	*Wolbachia*	Objective1	E3	0	20	50
Kiwikiu	*Wolbachia*	Objective1	E4	0	30	60
Kiwikiu	*Wolbachia*	Objective1	E5	20	40	70
Kiwikiu	*Wolbachia*	Objective1	E6	30	50	80
Kiwikiu	*Wolbachia*	Objective1	E7	40	65	90
Kiwikiu	*Wolbachia*	Objective1	E8	5	20	40
Kiwikiu	*Wolbachia*	Objective1	E9	5	20	35
Kiwikiu	*Wolbachia*	Objective1	E10	40	70	100
Kiwikiu	*Wolbachia*	Objective1	E11	0	20	25
Kiwikiu	*Wolbachia*	Objective1	E12	40	60	80
Kiwikiu	*Wolbachia*	Objective1	E13	0	30	50

Kiwikiu	*Wolbachia*	Objective1	E14	10	20	40
			Mean	13.6	38.2	60.7

Species	Action	Objective2	Expert	Min	Most likely	Max
ʽAkekeʽe	Captive breed	Objective2	E1	10	20	40
ʽAkekeʽe	Captive breed	Objective2	E10	25	45	65
ʽAkekeʽe	Captive breed	Objective2	E11	50	60	70
ʽAkekeʽe	Captive breed	Objective2	E12	20	50	70
ʽAkekeʽe	Captive breed	Objective2	E13	0	15	30
ʽAkekeʽe	Captive breed	Objective2	E14	10	50	80
ʽAkekeʽe	Captive breed	Objective2	E2	0	20	30
ʽAkekeʽe	Captive breed	Objective2	E3	0	10	30
ʽAkekeʽe	Captive breed	Objective2	E4	0	10	30
ʽAkekeʽe	Captive breed	Objective2	E5	55	80	100
ʽAkekeʽe	Captive breed	Objective2	E6	5	10	20
ʽAkekeʽe	Captive breed	Objective2	E7	0	25	50
ʽAkekeʽe	Captive breed	Objective2	E8	2	10	20
ʽAkekeʽe	Captive breed	Objective2	E9	20	35	50
			Mean	14.1	31.4	48.9

Species	Action	Objective2	Expert	Min	Most likely	Max
ʽAkekeʽe	Direct translocation	Objective2	E1	30	40	50
ʽAkekeʽe	Direct translocation	Objective2	E10	0	5	10
ʽAkekeʽe	Direct translocation	Objective2	E11	0	10	15
ʽAkekeʽe	Direct translocation	Objective2	E12	20	40	60
ʽAkekeʽe	Direct translocation	Objective2	E13	0	20	40
ʽAkekeʽe	Direct translocation	Objective2	E14	0	30	50
ʽAkekeʽe	Direct translocation	Objective2	E2	0	30	60
ʽAkekeʽe	Direct translocation	Objective2	E3	30	60	90

‘Akeke‘e	Direct translocation	Objective2	E4	5	25	50
‘Akeke‘e	Direct translocation	Objective2	E5	40	60	80
‘Akeke‘e	Direct translocation	Objective2	E6	20	50	60
‘Akeke‘e	Direct translocation	Objective2	E7	10	35	60
‘Akeke‘e	Direct translocation	Objective2	E8	10	25	45
‘Akeke‘e	Direct translocation	Objective2	E9	15	30	45
			Mean	12.9	32.9	51.1

Species	Action	Objective2	Expert	Min	Most likely	Max
‘Akeke‘e	Hold release	Objective2	E1	20	40	60
‘Akeke‘e	Hold release	Objective2	E10	20	40	60
‘Akeke‘e	Hold release	Objective2	E11	60	70	80
‘Akeke‘e	Hold release	Objective2	E12	25	55	75
‘Akeke‘e	Hold release	Objective2	E13	0	20	40
‘Akeke‘e	Hold release	Objective2	E14	40	60	80
‘Akeke‘e	Hold release	Objective2	E2	0	10	20
‘Akeke‘e	Hold release	Objective2	E3	0	30	40
‘Akeke‘e	Hold release	Objective2	E4	20	40	70
‘Akeke‘e	Hold release	Objective2	E5	55	70	85
‘Akeke‘e	Hold release	Objective2	E6	10	30	40
‘Akeke‘e	Hold release	Objective2	E7	25	50	75
‘Akeke‘e	Hold release	Objective2	E8	10	30	50
‘Akeke‘e	Hold release	Objective2	E9	40	55	70
			Mean	23.2	42.9	60.4

Species	Action	Objective2	Expert	Min	Most likely	Max
‘Akeke‘e	Hold translocate	Objective2	E1	30	50	70
‘Akeke‘e	Hold translocate	Objective2	E10	0	3	5
‘Akeke‘e	Hold translocate	Objective2	E11	60	70	80
‘Akeke‘e	Hold translocate	Objective2	E12	20	50	70

‘Akeke‘e	Hold translocate	Objective2	E13	0	15	30
‘Akeke‘e	Hold translocate	Objective2	E14	20	35	60
‘Akeke‘e	Hold translocate	Objective2	E2	0	50	80
‘Akeke‘e	Hold translocate	Objective2	E3	0	40	60
‘Akeke‘e	Hold translocate	Objective2	E4	10	30	50
‘Akeke‘e	Hold translocate	Objective2	E5	40	60	80
‘Akeke‘e	Hold translocate	Objective2	E6	10	40	50
‘Akeke‘e	Hold translocate	Objective2	E7	10	30	50
‘Akeke‘e	Hold translocate	Objective2	E8	15	35	50
‘Akeke‘e	Hold translocate	Objective2	E9	10	27.5	45
			Mean	16.1	38.3	55.7

Species	Action	Objective2	Expert	Min	Most likely	Max
‘Akeke‘e	*Wolbachia*	Objective2	E1	0	10	20
‘Akeke‘e	*Wolbachia*	Objective2	E10	45	75	100
‘Akeke‘e	*Wolbachia*	Objective2	E11	0	10	15
‘Akeke‘e	*Wolbachia*	Objective2	E12	40	60	80
‘Akeke‘e	*Wolbachia*	Objective2	E13	0	20	40
‘Akeke‘e	*Wolbachia*	Objective2	E14	0	40	60
‘Akeke‘e	*Wolbachia*	Objective2	E2	0	80	90
‘Akeke‘e	*Wolbachia*	Objective2	E3	0	20	40
‘Akeke‘e	*Wolbachia*	Objective2	E4	10	50	80
‘Akeke‘e	*Wolbachia*	Objective2	E5	20	40	70
‘Akeke‘e	*Wolbachia*	Objective2	E6	20	60	80
‘Akeke‘e	*Wolbachia*	Objective2	E7	55	80	100
‘Akeke‘e	*Wolbachia*	Objective2	E8	5	15	25
‘Akeke‘e	*Wolbachia*	Objective2	E9	7.5	15	22.5
			Mean	14.5	41.1	58.8

Species	Action	Objective2	Expert	Min	Most likely	Max
'Akikiki	Captive breed	Objective2	E1	20	40	60
'Akikiki	Captive breed	Objective2	E10	25	45	65
'Akikiki	Captive breed	Objective2	E11	60	70	80
'Akikiki	Captive breed	Objective2	E12	40	60	80
'Akikiki	Captive breed	Objective2	E13	20	40	60
'Akikiki	Captive breed	Objective2	E14	20	65	85
'Akikiki	Captive breed	Objective2	E2	10	20	40
'Akikiki	Captive breed	Objective2	E3	0	10	20
'Akikiki	Captive breed	Objective2	E4	0	30	60
'Akikiki	Captive breed	Objective2	E5	65	85	95
'Akikiki	Captive breed	Objective2	E6	10	30	50
'Akikiki	Captive breed	Objective2	E7	20	50	80
'Akikiki	Captive breed	Objective2	E8	30	55	75
'Akikiki	Captive breed	Objective2	E9	50	60	70
			Mean	26.4	47.1	65.7

Species	Action	Objective2	Expert	Min	Most likely	Max
'Akikiki	Direct translocation	Objective2	E1	30	40	50
'Akikiki	Direct translocation	Objective2	E10	0	5	10
'Akikiki	Direct translocation	Objective2	E11	30	45	60
'Akikiki	Direct translocation	Objective2	E12	0	5	20
'Akikiki	Direct translocation	Objective2	E13	0	10	20
'Akikiki	Direct translocation	Objective2	E14	0	10	30
'Akikiki	Direct translocation	Objective2	E2	0	40	70
'Akikiki	Direct translocation	Objective2	E3	0	50	80
'Akikiki	Direct translocation	Objective2	E4	0	5	10
'Akikiki	Direct translocation	Objective2	E5	5	20	60
'Akikiki	Direct translocation	Objective2	E6	5	20	40

ʻAkikiki	Direct translocation	Objective2	E7	10	40	70
ʻAkikiki	Direct translocation	Objective2	E8	2	5	10
ʻAkikiki	Direct translocation	Objective2	E9	0	5	10
			Mean	5.9	21.4	38.6

Species	Action	Objective2	Expert	Min	Most likely	Max
ʻAkikiki	Hold release	Objective2	E1	30	50	70
ʻAkikiki	Hold release	Objective2	E10	20	40	60
ʻAkikiki	Hold release	Objective2	E11	70	80	90
ʻAkikiki	Hold release	Objective2	E12	45	65	85
ʻAkikiki	Hold release	Objective2	E13	30	50	80
ʻAkikiki	Hold release	Objective2	E14	10	50	80
ʻAkikiki	Hold release	Objective2	E2	0	15	30
ʻAkikiki	Hold release	Objective2	E3	30	50	70
ʻAkikiki	Hold release	Objective2	E4	0	45	80
ʻAkikiki	Hold release	Objective2	E5	50	70	80
ʻAkikiki	Hold release	Objective2	E6	10	40	60
ʻAkikiki	Hold release	Objective2	E7	45	60	75
ʻAkikiki	Hold release	Objective2	E8	30	55	75
ʻAkikiki	Hold release	Objective2	E9	60	70	80
			Mean	30.7	52.9	72.5

Species	Action	Objective2	Expert	Min	Most likely	Max
ʻAkikiki	Hold translocate	Objective2	E1	40	60	80
ʻAkikiki	Hold translocate	Objective2	E10	0	3	5
ʻAkikiki	Hold translocate	Objective2	E11	70	85	95
ʻAkikiki	Hold translocate	Objective2	E12	35	55	75
ʻAkikiki	Hold translocate	Objective2	E13	20	30	50
ʻAkikiki	Hold translocate	Objective2	E14	10	20	30
ʻAkikiki	Hold translocate	Objective2	E2	0	30	65

ʽAkikiki	Hold translocate	Objective2	E3	50	70	100
ʽAkikiki	Hold translocate	Objective2	E4	0	30	60
ʽAkikiki	Hold translocate	Objective2	E5	30	60	70
ʽAkikiki	Hold translocate	Objective2	E6	15	50	80
ʽAkikiki	Hold translocate	Objective2	E7	15	45	75
ʽAkikiki	Hold translocate	Objective2	E8	30	55	75
ʽAkikiki	Hold translocate	Objective2	E9	15	40	65
			Mean	23.6	45.2	66.1

Species	Action	Objective2	Expert	Min	Most likely	Max
ʽAkikiki	*Wolbachia*	Objective2	E1	0	5	10
ʽAkikiki	*Wolbachia*	Objective2	E10	5	45	85
ʽAkikiki	*Wolbachia*	Objective2	E11	0	10	15
ʽAkikiki	*Wolbachia*	Objective2	E12	0	10	30
ʽAkikiki	*Wolbachia*	Objective2	E13	0	0	10
ʽAkikiki	*Wolbachia*	Objective2	E14	0	0	10
ʽAkikiki	*Wolbachia*	Objective2	E2	0	50	66
ʽAkikiki	*Wolbachia*	Objective2	E3	0	10	20
ʽAkikiki	*Wolbachia*	Objective2	E4	0	5	15
ʽAkikiki	*Wolbachia*	Objective2	E5	0	10	40
ʽAkikiki	*Wolbachia*	Objective2	E6	5	10	20
ʽAkikiki	*Wolbachia*	Objective2	E7	50	70	90
ʽAkikiki	*Wolbachia*	Objective2	E8	0	2	5
ʽAkikiki	*Wolbachia*	Objective2	E9	0	0	2.5
			Mean	4.3	16.2	29.9

Species	Action	Objective2	Expert	Min	Most likely	Max
ʽĀkohekohe	Captive breed	Objective2	E1	0	20	40
ʽĀkohekohe	Captive breed	Objective2	E10	20	40	60

`Ākohekohe	Captive breed	Objective2	E11	50	60	70
`Ākohekohe	Captive breed	Objective2	E12	35	55	75
`Ākohekohe	Captive breed	Objective2	E13	0	20	40
`Ākohekohe	Captive breed	Objective2	E14	10	70	85
`Ākohekohe	Captive breed	Objective2	E2	0	20	40
`Ākohekohe	Captive breed	Objective2	E3	0	0	10
`Ākohekohe	Captive breed	Objective2	E4	0	20	40
`Ākohekohe	Captive breed	Objective2	E5	50	85	100
`Ākohekohe	Captive breed	Objective2	E6	5	10	20
`Ākohekohe	Captive breed	Objective2	E7	0	25	50
`Ākohekohe	Captive breed	Objective2	E8	2	5	10
`Ākohekohe	Captive breed	Objective2	E9	5	20	35
			Mean	12.6	32.1	48.2

Species	Action	Objective2	Expert	Min	Most likely	Max
`Ākohekohe	Direct translocation	Objective2	E1	10	30	50
`Ākohekohe	Direct translocation	Objective2	E10	0	10	25
`Ākohekohe	Direct translocation	Objective2	E11	70	80	90
`Ākohekohe	Direct translocation	Objective2	E12	40	60	80
`Ākohekohe	Direct translocation	Objective2	E13	0	50	75
‘Ākohekohe	Direct translocation	Objective2	E14	40	55	80
`Ākohekohe	Direct translocation	Objective2	E2	0	70	90
`Ākohekohe	Direct translocation	Objective2	E3	70	90	100
`Ākohekohe	Direct translocation	Objective2	E4	5	20	30
`Ākohekohe	Direct translocation	Objective2	E5	50	80	100
`Ākohekohe	Direct translocation	Objective2	E6	20	60	70
`Ākohekohe	Direct translocation	Objective2	E7	10	35	60
`Ākohekohe	Direct translocation	Objective2	E8	10	35	60
`Ākohekohe	Direct translocation	Objective2	E9	35	52.5	70

			Mean	25.7	52.0	70.0

Species	Action	Objective2	Expert	Min	Most likely	Max
‘Ākohekohe	Hold release	Objective2	E1	30	50	70
‘Ākohekohe	Hold release	Objective2	E10	15	35	55
‘Ākohekohe	Hold release	Objective2	E11	70	80	90
‘Ākohekohe	Hold release	Objective2	E12	40	60	80
‘Ākohekohe	Hold release	Objective2	E13	0	70	100
‘Ākohekohe	Hold release	Objective2	E14	10	65	80
‘Ākohekohe	Hold release	Objective2	E2	0	15	25
‘Ākohekohe	Hold release	Objective2	E3	0	10	20
‘Ākohekohe	Hold release	Objective2	E4	10	30	50
‘Ākohekohe	Hold release	Objective2	E5	50	70	90
‘Ākohekohe	Hold release	Objective2	E6	20	35	50
‘Ākohekohe	Hold release	Objective2	E7	30	60	90
‘Ākohekohe	Hold release	Objective2	E8	5	25	40
‘Ākohekohe	Hold release	Objective2	E9	20	35	50
			Mean	21.4	45.7	63.6

Species	Action	Objective2	Expert	Min	Most likely	Max
‘Ākohekohe	Hold translocate	Objective2	E1	20	40	60
‘Ākohekohe	Hold translocate	Objective2	E10	0	3	5
‘Ākohekohe	Hold translocate	Objective2	E11	80	90	95
‘Ākohekohe	Hold translocate	Objective2	E12	35	55	75
‘Ākohekohe	Hold translocate	Objective2	E13	0	50	75
‘Ākohekohe	Hold translocate	Objective2	E14	10	45	70
‘Ākohekohe	Hold translocate	Objective2	E2	0	45	80
‘Ākohekohe	Hold translocate	Objective2	E3	0	20	30
‘Ākohekohe	Hold translocate	Objective2	E4	10	25	40
‘Ākohekohe	Hold translocate	Objective2	E5	50	80	95

`Ākohekohe	Hold translocate	Objective2	E6	20	40	60
`Ākohekohe	Hold translocate	Objective2	E7	5	30	55
`Ākohekohe	Hold translocate	Objective2	E8	5	25	50
`Ākohekohe	Hold translocate	Objective2	E9	25	40	55
			Mean	18.6	42.0	60.4

Species	Action	Objective2	Expert	Min	Most likely	Max
`Ākohekohe	*Wolbachia*	Objective2	E1	0	30	50
`Ākohekohe	*Wolbachia*	Objective2	E10	85	95	100
`Ākohekohe	*Wolbachia*	Objective2	E11	30	50	70
`Ākohekohe	*Wolbachia*	Objective2	E12	60	90	95
`Ākohekohe	*Wolbachia*	Objective2	E13	20	50	100
`Ākohekohe	*Wolbachia*	Objective2	E14	30	55	85
`Ākohekohe	*Wolbachia*	Objective2	E2	0	85	95
`Ākohekohe	*Wolbachia*	Objective2	E3	20	40	60
`Ākohekohe	*Wolbachia*	Objective2	E4	10	50	90
`Ākohekohe	*Wolbachia*	Objective2	E5	50	70	90
`Ākohekohe	*Wolbachia*	Objective2	E6	30	70	90
`Ākohekohe	*Wolbachia*	Objective2	E7	70	85	100
`Ākohekohe	*Wolbachia*	Objective2	E8	15	40	60
`Ākohekohe	*Wolbachia*	Objective2	E9	25	50	75
			Mean	31.8	61.4	82.9

Species	Action	Objective2	Expert	Min	Most likely	Max
Kiwikiu	Captive breed	Objective2	E1	10	30	50
Kiwikiu	Captive breed	Objective2	E10	25	45	65
Kiwikiu	Captive breed	Objective2	E11	40	50	60
Kiwikiu	Captive breed	Objective2	E12	30	60	70
Kiwikiu	Captive breed	Objective2	E13	0	50	75

Kiwikiu	Captive breed	Objective2	E14	60	70	80
Kiwikiu	Captive breed	Objective2	E2	0	33	50
Kiwikiu	Captive breed	Objective2	E3	0	10	20
Kiwikiu	Captive breed	Objective2	E4	0	20	40
Kiwikiu	Captive breed	Objective2	E5	60	75	100
Kiwikiu	Captive breed	Objective2	E6	5	20	50
Kiwikiu	Captive breed	Objective2	E7	10	40	70
Kiwikiu	Captive breed	Objective2	E8	25	40	60
Kiwikiu	Captive breed	Objective2	E9	35	50	65
			Mean	21.4	42.4	61.1

Species	Action	Objective2	Expert	Min	Most likely	Max
Kiwikiu	Direct translocation	Objective2	E1	30	40	50
Kiwikiu	Direct translocation	Objective2	E10	0	5	10
Kiwikiu	Direct translocation	Objective2	E11	0	30	50
Kiwikiu	Direct translocation	Objective2	E12	40	70	85
Kiwikiu	Direct translocation	Objective2	E13	0	10	20
Kiwikiu	Direct translocation	Objective2	E14	20	30	45
Kiwikiu	Direct translocation	Objective2	E2	0	50	80
Kiwikiu	Direct translocation	Objective2	E3	50	80	100
Kiwikiu	Direct translocation	Objective2	E4	10	30	55
Kiwikiu	Direct translocation	Objective2	E5	30	50	80
Kiwikiu	Direct translocation	Objective2	E6	30	50	80
Kiwikiu	Direct translocation	Objective2	E7	0	25	50
Kiwikiu	Direct translocation	Objective2	E8	5	20	30
Kiwikiu	Direct translocation	Objective2	E9	20	35	50
			Mean	16.8	37.5	56.1

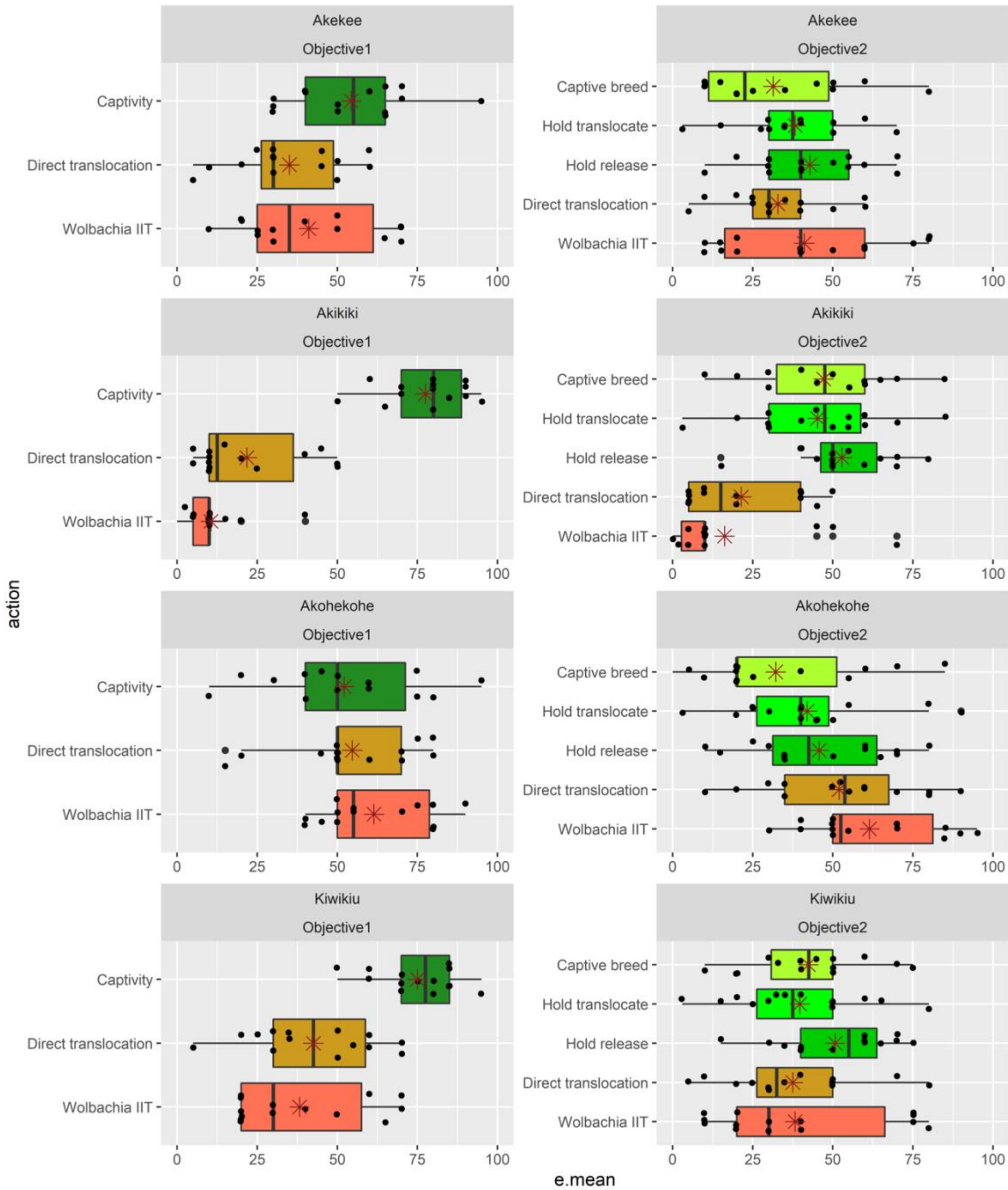
Species	Action	Objective2	Expert	Min	Most likely	Max
Kiwikiu	Hold release	Objective2	E1	30	50	70

Kiwikiu	Hold release	Objective2	E10	20	40	60
Kiwikiu	Hold release	Objective2	E11	70	75	80
Kiwikiu	Hold release	Objective2	E12	40	70	85
Kiwikiu	Hold release	Objective2	E13	20	70	90
Kiwikiu	Hold release	Objective2	E14	50	60	70
Kiwikiu	Hold release	Objective2	E2	0	15	33
Kiwikiu	Hold release	Objective2	E3	20	40	60
Kiwikiu	Hold release	Objective2	E4	15	35	60
Kiwikiu	Hold release	Objective2	E5	50	60	85
Kiwikiu	Hold release	Objective2	E6	10	30	60
Kiwikiu	Hold release	Objective2	E7	40	60	80
Kiwikiu	Hold release	Objective2	E8	25	40	70
Kiwikiu	Hold release	Objective2	E9	50	65	80
			Mean	31.4	50.7	70.2

Species	Action	Objective2	Expert	Min	Most likely	Max
Kiwikiu	Hold translocate	Objective2	E1	40	60	80
Kiwikiu	Hold translocate	Objective2	E10	0	3	5
Kiwikiu	Hold translocate	Objective2	E11	70	80	90
Kiwikiu	Hold translocate	Objective2	E12	35	65	80
Kiwikiu	Hold translocate	Objective2	E13	0	15	25
Kiwikiu	Hold translocate	Objective2	E14	25	35	50
Kiwikiu	Hold translocate	Objective2	E2	0	50	80
Kiwikiu	Hold translocate	Objective2	E3	20	50	70
Kiwikiu	Hold translocate	Objective2	E4	10	30	50
Kiwikiu	Hold translocate	Objective2	E5	30	50	80
Kiwikiu	Hold translocate	Objective2	E6	10	40	70
Kiwikiu	Hold translocate	Objective2	E7	0	20	40
Kiwikiu	Hold translocate	Objective2	E8	10	25	40

Kiwikiu	Hold translocate	Objective2	E9	15	32.5	50
			Mean	18.9	39.7	57.9

Species	Action	Objective2	Expert	Min	Most likely	Max
Kiwikiu	*Wolbachia*	Objective2	E1	0	10	20
Kiwikiu	*Wolbachia*	Objective2	E10	45	75	100
Kiwikiu	*Wolbachia*	Objective2	E11	0	20	25
Kiwikiu	*Wolbachia*	Objective2	E12	55	75	90
Kiwikiu	*Wolbachia*	Objective2	E13	0	20	40
Kiwikiu	*Wolbachia*	Objective2	E14	10	20	40
Kiwikiu	*Wolbachia*	Objective2	E2	0	80	90
Kiwikiu	*Wolbachia*	Objective2	E3	0	30	60
Kiwikiu	*Wolbachia*	Objective2	E4	0	30	60
Kiwikiu	*Wolbachia*	Objective2	E5	20	40	70
Kiwikiu	*Wolbachia*	Objective2	E6	20	40	60
Kiwikiu	*Wolbachia*	Objective2	E7	55	75	95
Kiwikiu	*Wolbachia*	Objective2	E8	5	10	30
Kiwikiu	*Wolbachia*	Objective2	E9	0	10	25
			Mean	15.0	38.2	57.5



Appendix X, Figure. Expert judgement on the probability of achieving either objective 1 (left panel) or objective 2 (right panel) goals. Objective 1 was concerned with preventing the imminent extinction of species, while objective 2 was more focused on implementing management actions that best ensure one or more viable and stable to increasing wild populations in the long term (up to and beyond 10 years). For each management action (y-axis), the probability of success (x-axis) was based on expert judgement with each score represented by a black dot, the mean value by a red asterisk, and the box plots represent the quartile range of responses, with the vertical black line indicating the median value.