

Kiwikiu Reintroduction Plan

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The Maui Forest Bird Working Group



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Kiwikiu (Maui Parrotbill) Reintroduction Plan

Table of Contents

1. Background	8
1.1 Natural History	8
Population abundance and historical range	8
Threats and limiting factors	11
Ecology	13
1.2 Conservation Breeding.....	19
Historical overview of conservation breeding flock.....	19
Current overview of conservation breeding flock	19
Future potential for conservation breeding	19
1.3 Study Sites	21
Kiwikiu current range	21
Reintroduction Site	24
2. Reintroduction	29
2.1 Objectives.....	29
2.2 Site Selection.....	30
2.3 Guidelines for starting Kiwikiu reintroduction.....	34
Habitat restoration, regeneration, recovery	34
2.4 Seasonal Timing	37
2.5 Cohort Composition	37
2.6 Cohort Source	41
2.7 Permitting and Compliance	42
2.8 Logistics	42
Organizational Responsibilities	42
Proposed Predator Control	44
Capture.....	52
Holding	57
Transport.....	67
Release	67
Death and Necropsy.....	69
3. Post-Release Monitoring and Assessment.....	69
3.1 Protocols and data collection	69

Short term (< 30 days)	69
Extended term (31-365 days).....	70
Breeding.....	71
Longer Term (>1 yr).....	72
3.2 Alternatives and future actions	72
Guidelines for determining releases.....	72
4. Resources Needed	73
4.1 People and Roles.....	73
Staff Needed	73
Partners and collaborators	74
5. Literature Cited	75
6. Appendix I. Master timeline for Kiwikiu reintroduction	80
7. Appendix II. Overall Funding Needs.....	Error! Bookmark not defined.
8. Appendix III. Equipment Needs for Capture Site	82
8. Appendix IV. Equipment Needs for Release Site	83

Table of Figures

Figure 1. Current Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) species range (Total area = 29.92 km²) and land management areas. Also shown are the genetic sampling locations, including showing collection sites of initial captive individuals (east). Subpopulations, east and west, are based on analysis of genetic population structure by Mounce et al. (2015). 10

Figure 2. Estimated Kiwikiu abundance from 1980 to 2017 from the Hawai'i Forest Bird Surveys (HFBS). Estimates are presented (\pm 95% CI) from the five years where the entire species range was surveyed based on the current Kiwikiu range (29.92 km²)..... 11

Figure 3. Probability values for capturing different percentages of the total genetic diversity available in the east, west and total wild Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) population modelled while using different numbers of individuals in translocation efforts..... 18

Figure 4. Pedigree of current Kiwikiu conservation breeding population as of June 2018, including alive birds (white shapes), as well as dead birds (gray shapes) that have descendants within the current population. Studbook numbers are indicated within each shape..... 21

Figure 5. Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) reintroduction site land management areas showing completed and planned fencing as of February 2018. The “mosquito line” is approximately 1400 m, and is commonly used to describe the area below which have high rates of avian malaria transmission. 27

Figure 6. Nakula NAR reintroduction site in the Wailaulau unit for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) with base camp for reintroduction operations, forest restoration areas as of 2018, and proposed release aviary sites for reintroduced individuals/pairs..... 36

Figure 7. Photos of banded Kiwikiu demonstrating the plumage differences in the head and face among hatch-year (HY), second-year (SY), and after second-year (ASY). Males (or presumed males in the case of HY) are in the left column and females are in the right. The top row shows two HYS, the middle SYs, and the bottom shows ASYs..... 39

Figure 8. A priori Power analysis results showing the minimum number of tunnels required (inside or outside the grid) to be able to accurately detect a trend in predator density in the two treatments. This analysis indicates that a minimum 35 tunnels are required to detect a trend if pre-treatment densities of predators are 0.1/ha. This also indicates that we are unlikely to be able to detect a trend of 0.1 unless pre-treatment density is exceptionally low (i.e. 0.1) or unless we have a very large number of tunnels. 47

Figure 9. Wailaulau unit, Nakula NAR reintroduction site for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) with base camp for reintroduction operations, proposed release aviary sites for reintroduced individuals/pairs, and proposed predator reduction grid..... 49

Figure 10. Wailaulau unit, Nakula NAR reintroduction site for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) with levels of use for proposed and existing trails..... 51

Figure 11. Sexing key for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*). Regression chart of wing (unflattened wing chord) and culmen (exposed) lengths. Individuals shown are only those found to be in breeding condition, showing a brood patch (Bandit code of 2 -4), indicating females, and a cloacal protuberance (Bandit code of 2 or 3), indicating males..... 56

Figure 12. Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) single compartment holding cages to be used at the capture site’s central camp with remote weighing system and removable perches and floor. 59

Figure 13. Release aviary prototype and release aviary platform in Nakula. 63

Figure 14. Release aviary Site D and a nearby gulch providing good habitat. 65

Figure 15. Prototype supplemental feeding dispenser designs to be placed inside each aviary cell and outside of the release aviary. The exact feeder used will be slightly different modification designed as a hybrid of the two pictured. 66

Table of Table

Table 1. Current Kiwikiu from breeding facilities and ages as of November 2019..... 20

Executive Summary

Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) are among the rarest and most endangered Hawaiian passerine. Recent population assessments estimate total abundance of less than 312 individuals that occupy approximately 30 km². The species in its current range continues to be under threat from invasive mammalian predators and non-native disease. Kiwikiu are specialized insectivores that occupy large home ranges within intact native forest. Likely as a result of this specialization, pairs produce one young each year and offspring stay with the parents for an extended period, up to 18 months. Given low natural productivity, the species relies on adult survivorship and adults live upwards of 16 years in the wild; particularly long for a small songbird. Nest failures are often attributed to predators and heavy rain events, a common feature of the wet, windward forests that they currently occupy. For these reasons the US Fish & Wildlife Service has recommended establishing a second population on the leeward (or southwestern) slope of Haleakalā to increase total population size and protect the species from severe weather events or other catastrophic loss in their small current range. Nakula Natural Area Reserve (NAR) in the Kahikinui region of Maui was selected as the site of the first experimental releases of Kiwikiu to begin establishing a second population. The forest on the leeward (south-facing) slopes of Haleakalā, where Nakula is located, generally exists in a deteriorated state as a result of a century of browsing and grazing damage from non-native ungulates. However, large, intact forest sections remain and the vast majority of this habitat is now either fenced and protected, or will be shortly. Following fencing and eradication of ungulates, the forest in this area has begun to recover through natural regeneration and conservation restoration efforts. This forest is naturally dominated by koa (*Acacia koa*) and ōhi'a (*Metrosideros polymorpha*) and was likely always a more open habitat than the forest that Kiwikiu currently occupy. Kiwikiu are now restricted to wet forest on the windward slopes where the canopy is almost exclusively ōhi'a. When originally described to the scientific community, the species was thought to prefer koa as a foraging substrate. It is possible that Kiwikiu, once established, will do well in a habitat that sees fewer heavy rain events and where koa is a dominant tree.

Herein we propose to begin the process of establishing the species in Kahikinui and lay out the procedures for the first year of Kiwikiu releases in Nakula NAR. We propose to release all of the suitable captive individuals (8) if these individuals pass a pre-release exam, from the San Diego Zoo Global's facilities as well as translocate an additional 12 individuals from the current range. The Nature Conservancy's (TNC) Waikamoi Preserve is the preferred site to capture and translocate wild individuals due to its habitat similarities with Nakula NAR, Kiwikiu population genetics data,

and logistical considerations. This site lies at the western edge of the species' range and contains a genetically distinct population of Kiwikiu. All captive individuals originate from the eastern genetic sub-population. Thus, combining birds from both sub-populations will maximize genetic diversity in the new population. TNC Waikamoi Preserve is also one of the few places in the current Kiwikiu range that contains some koa and thus, translocated birds may be more familiar with this type of forest. Although most of the Maui Forest Bird Working Group preferred TNC Waikamoi Preserve for the first year, permission was not granted by TNC. Therefore, Hanawi NAR will be serving as the first year's source site with Waikamoi Preserve being the possible second year's source site. We propose a soft release in which birds will be housed in temporary field aviaries and provisioned with food within and outside the aviaries. Released birds will be carefully monitored through the use of radio transmitters and color-band resighting to evaluate foraging and breeding behaviors as well as monitor movements within and outside of the release site. This is the first step of a multi-year effort to implement actions explicitly identified in the USFWS species recovery plan to re-establish a population on southern Haleakalā. Following the first year of experimental releases, the results will be evaluated to determine if, and in what ways, additional releases should be conducted. The short term goal of this project is to create a disjunct population of Kiwikiu that survives multiple years. The ultimate goal is to establish a self-sustaining population of Kiwikiu in Kahikinui.

1. Background

1.1 Natural History

Population abundance and historical range

As is the case for nearly all extant native Hawaiian bird species, Kiwikiu or Maui Parrotbill (*Pseudonestor xanthophrys*) have undergone a significant reduction in range and population size since human contact with the Hawaiian Islands. Although apparently never among the most common of Hawaiian passerine species, subfossil evidence shows that Kiwikiu formerly occupied a large proportion of the islands of Maui and Moloka'i (James *et al.* 1987, James and Olson 1991, Simon *et al.* 1997). Some of these subfossils have been found down to 200 m in elevation in the Kahikinui region (H. James, *pers. comm.*, in Mountainspring 1987) and the fossil sites on Moloka'i are coastal dunes (James and Olsen 1991a). This historic range covered multiple forested habitat types from high elevation wet forests to lowland dry forests. No modern observations were made of the species outside of its current range, but Maui was historically under-sampled by early naturalists (Munro 1944). All historic specimens come from a single area of forest at Ukulele near present day The Nature Conservancy's (TNC) Waikamoi Preserve. Observations made in the late 19th century indicated a preference for koa (*Acacia koa*) trees as a foraging substrate in the limited areas that Kiwikiu were historically observed (Perkins 1903). Thus, although not present in large numbers throughout the current range, koa trees may have played an important role in the historical distribution of Kiwikiu.

The current range of the species may be in large part an artifact of the extent of the last remaining large tracts of high elevation native forest instead of a result of forest preference. Wide-scale deforestation for agriculture and livestock grazing has reduced the amount of forest cover on the island of Maui to a fraction of prehistoric levels. The subsequent addition of invasive plant and animal species further eroded the extent of native forest and reduced forest quality throughout the island. Furthermore, introduced avian diseases restrict Kiwikiu to forests above 1400 m in elevation, where disease prevalence is comparatively low. As such, the current range of the species is constrained by the combination of the distribution of high quality native forest and disease prevalence. These factors have resulted in a species range of approximately 30 km² on Maui; the species was extirpated on Moloka'i. The current range of the species is located on the windward slopes of Haleakalā Volcano from TNC Waikamoi Preserve in the west to the Manawainui Planeze in Haleakalā National Park (NP) in the east (Figure 1).

The locally rare, low-density nature of the current Kiwikiu population has confounded efforts to accurately estimate population size since the initial population assessments were attempted by the Hawai'i Forest Bird Surveys (HFBS) in the early 1980s. Unlike many sympatric species, Kiwikiu behaviors and vocalizations are rather inconspicuous, adding to the difficulty in detecting the species using auditory-based surveys. As a result, precision of population estimates have historically been low and estimates have tended to include large confidence intervals. Range-wide estimates of population size that have been conducted in recent decades include Scott *et al.* (1986) which estimated the total population size at 502 ± 230 (95% CI) individuals. More recently, Camp *et al.* (2009) estimated the population at 590 ± 208 individuals as of 2001. Intensive point count surveys specifically targeting the species conducted between 2006 and 2011 throughout the Kiwikiu range, but excluding the area within Haleakalā NP, found similar densities to the 2001 range-wide estimates and from 209–674 birds (point estimate = 421) in 2011 (Brinck *et al.* 2012). Judge *et al.* (2013) surveyed the Haleakalā section the following year, and although there were only eight detections, the estimated population was 495 ± 261 birds within the NP. Although estimates have varied, the large confidence intervals associated with these estimates prohibit conclusions about long-term trends in abundance of the species (Camp *et al.* 2009, Brinck *et al.* 2011).

Maui Forest Bird Recovery Project (MFBRP) and The National Park Service Inventory and Monitoring Program coordinated the most recent range-wide surveys in 2017. Out of the 27 transects surveyed, 11 transects were surveyed within the Kiwikiu range and these legacy transects have information from previous surveys dating back to the original surveys in 1980. Using survey data from the last 15 years the survey coordinators also delineated a more accurate current Kiwikiu range, eliminating several areas where the species was not known to exist or had not been documented for decades despite good coverage from surveys. The recent range-wide study estimated Kiwikiu abundance at between 44 – 312 (95% CI; mean 157) individuals (Figure 2). While alarming, abundance estimates for the species have historically shown significant variability and the low precision of each estimate should not be ignored. However, realistically the overall abundance is fewer than 312, and the population may be declining, though the variance in the estimates precludes finding a significant statistical trend (Judge *et al. In prep*).

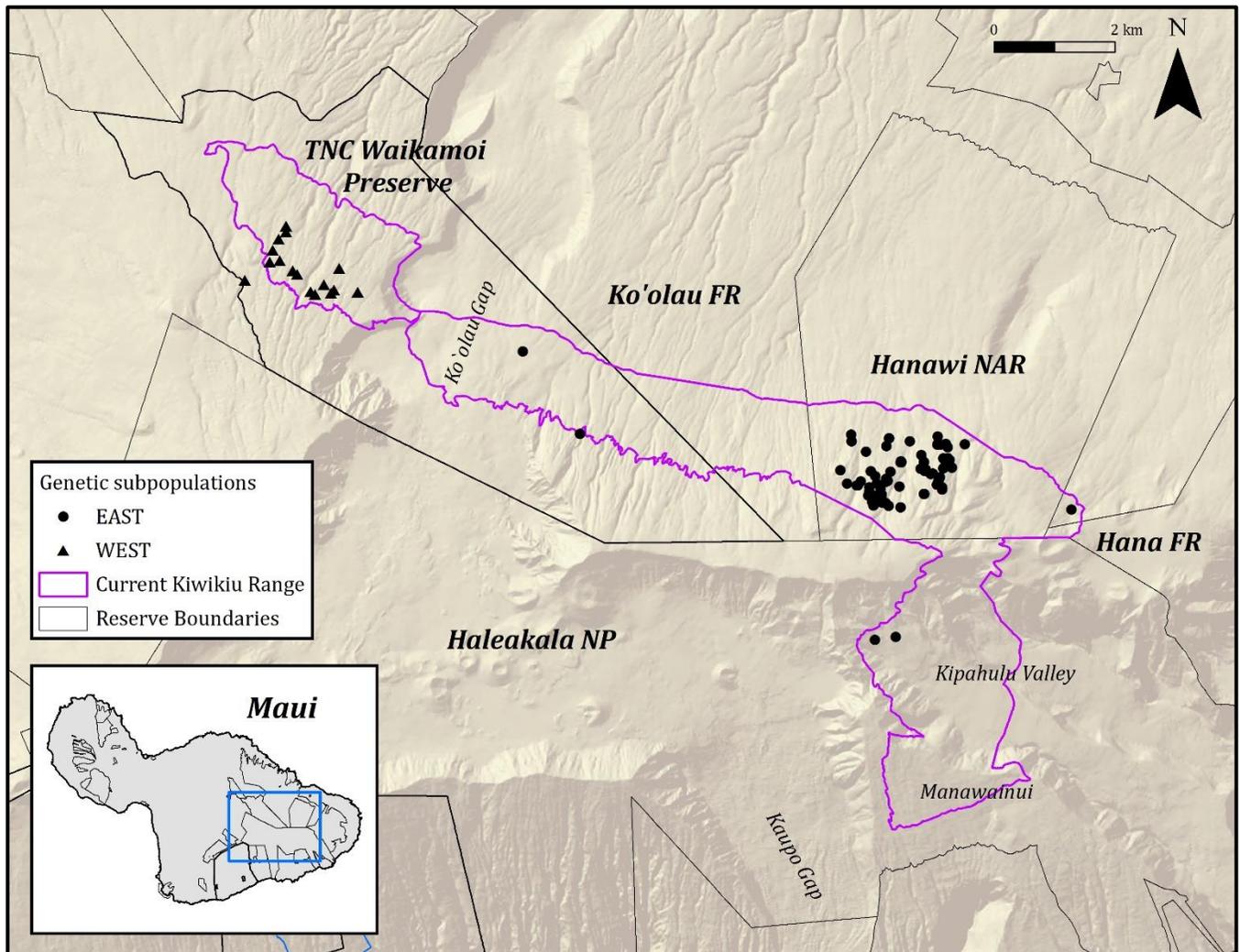


Figure 1. Current Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) species range (Total area = 29.92 km²) and land management areas. Also shown are the genetic sampling locations, including showing collection sites of initial captive individuals (east). Subpopulations, east and west, are based on analysis of genetic population structure by Mounce *et al.* (2015).

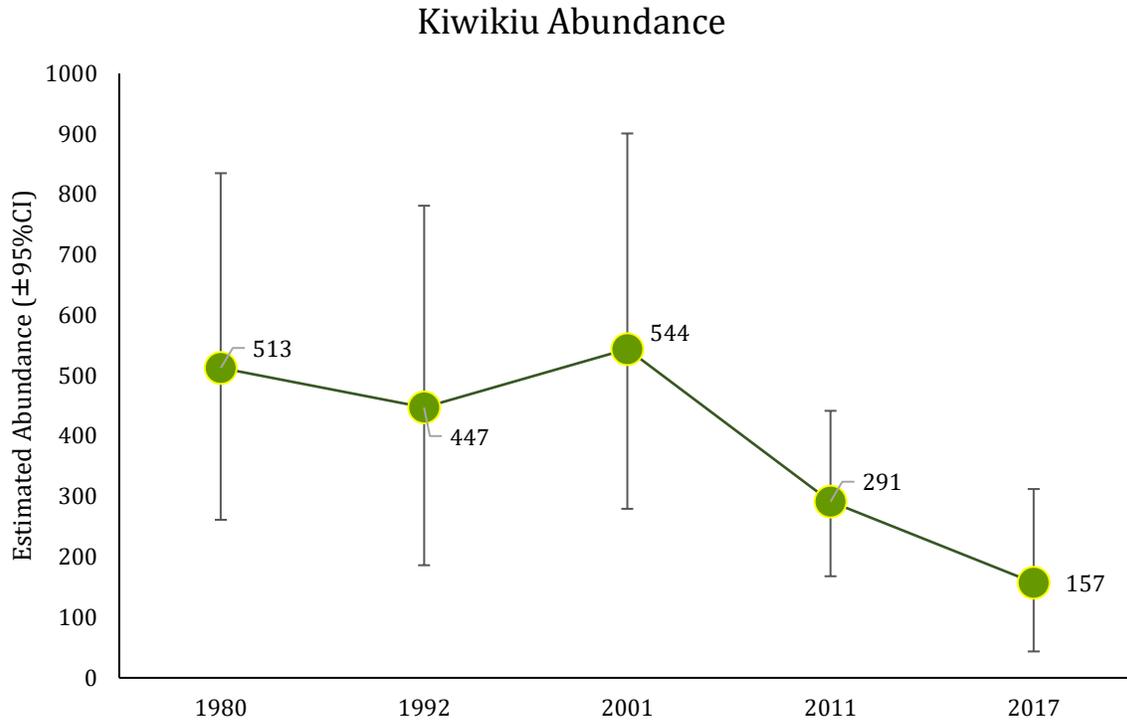


Figure 2. Estimated Kiwikiu abundance from 1980 to 2017 from the Hawai'i Forest Bird Surveys (HFBS). Estimates are presented (\pm 95% CI) from the five years where the entire species range was surveyed based on the current Kiwikiu range (29.92 km²).

Threats and limiting factors

The long-term persistence of Kiwikiu is threatened by a wide variety of factors. Like many other native forest bird species, Kiwikiu are primarily threatened by non-native organisms, loss and/or alteration of habitat, and climate change. However, several specific traits put Kiwikiu at greater risk of extinction than other species. Kiwikiu have rarely been observed outside of pristine native forest and the only nests ever discovered have been in 'ōhi'a (*Metrosideros polymorpha*), the dominant tree species within its current range. This apparent intolerance of non-native vegetation restricts the species to only those areas with contiguous native forest, now nominally windward Haleakalā. With the exception of the endangered 'Ākohekohe (*Palmeria dolei*), all other extant sympatric Hawaiian finches on Maui tolerate non-native and/or mixed native-non-native forests to a certain extent (Motyka 2016). In these areas, these species often utilize ecologically similar non-native plant species to those used in fully native plant communities (e.g., 'Apapane [*Himatione sanguinea*] and 'Iwi [*Drepanis coccinea*] forage on non-native *Acacia* spp. as well as the native koa). However, this kind of resource replacement behavior has not been observed for Kiwikiu. The species also

relies on many understory and subcanopy plant species for forage substrates (i.e., hosts for insect larvae prey) (Mountainspring 1987, Stein 2007). Typically, the understory and subcanopy layers of native Hawaiian forests shows the greatest damage following invasion of feral pigs and other ungulates thereby reducing or eliminating critical components of the forest for Kiwikiu (Pratt and Jacobi 2009). Seed predation of understory plants by rodents may also further reduce forest quality for Kiwikiu.

Several demographic and behavioral traits also put the species at risk. Similar to other native species, Kiwikiu are at risk of predation by invasive small Indian mongooses (*Herpestes palustris*), feral cats (*Felis silvestris catus*), and rats (*Rattus spp.*). The species' habit of foraging in the understory or shrub layer of the forest, closer to the forest floor, may increase this risk. Kiwikiu are also a long-lived species that typically lay single-egg clutches and have a long juvenile dependency period (Simon *et al.* 1997). Such low natural recruitment means that replacement of an individual due to loss from predation or disease is more difficult and the loss to the whole population is perhaps greater than in a more fecund species. Kiwikiu are vulnerable to predation of females on the nest by mammalian predators and this may explain the lower estimated female annual survivorship compared to males (Mounce *et al.* 2014).

Despite the fact that native forest exists at low elevation in places, Kiwikiu are only found above 1400 m. This represents evidence of the species' apparent lack of resistance to introduced avian diseases, principally avian malaria (*Plasmodium relictum*). The primary vector for avian malaria in Hawai'i, the southern house mosquito (*Culex quinquefasciatus*), is unable to persist and breed in high densities at high elevations due to unfavorable environmental conditions, i.e., low temperatures (Warner 1968, van Riper *et al.* 1986, Atkinson and LaPointe 2009). The *Plasmodium* parasite itself also has environmental tolerance levels, e.g., temperature, beyond which they cannot develop inside the mosquito host (LaPointe 2000). Generally, areas below 1200 m in elevation have been shown to have high transmission rates of avian malaria and often cited as the so-called "mosquito line" (Atkinson and Samuel 2010). In reality, temperature affects both vector densities and transmission rates of *Plasmodium* and cooler high-elevations rarely exclude the disease entirely (Atkinson *et al.* 2005, Samuel *et al.* 2015). Thus, upper elevations may protect species, like Kiwikiu, by reducing the risk of infection to the point that the bird species can persist rather than eliminating the risk entirely. The fact that Kiwikiu and 'Ākohekohe only persist at higher elevations, bottoming out closer to 1400 m may indicate that these species are particularly sensitive to the

disease. Any Kiwikiu that moves down in elevation into areas that support high densities of mosquitoes and promote greater development of the *Plasmodium* parasite inside vectors are at significant risk of contracting the fatal disease. The elevational distribution of avian malaria may change throughout the year when wetter, warmer conditions during certain seasons allow mosquitoes and parasites to proliferate at higher elevations only to decline at other times when conditions are less ideal. The area (e.g., elevation) where disease prevalence reaches unacceptable rates for a given bird species may be better modelled as a fluid “zone” rather than a rigid “line”. As temperatures rise due to global climate change, the disease zone is also predicted to rise in elevation, thereby reducing the amount of suitable habitat for Kiwikiu even further. In addition, Kiwikiu nests have been shown to fail most commonly following severe weather events (Simon *et al.* 2000, Becker *et al.* 2010). As global temperatures rise, the frequency and intensity of major weather events may increase in Hawai‘i as is predicted elsewhere (Emanuel 2005, Knutson *et al.* 2010). Such disturbances could have catastrophic effects on the single extant population of Kiwikiu either through reduced reproductive success (e.g., nest failure) or habitat loss.

Ecology

Productivity

Pairs of Kiwikiu typically remain together throughout the year and may attempt to breed whenever favorable conditions present themselves (Simon *et al.* 2000). Active nests have been found in all months except September (MFBRP unpublished data). However, the majority of pairs successfully breed between January and June each year (Mounce *et al.* 2013). Females lay single-egg clutches and males provision females on the nest (Simon *et al.* 2000). Offspring may be provisioned with food by the parents for up to 18 months after fledging. This extended parental investment may explain why only one offspring is typically produced per year; although two fledglings have been observed with pairs on very rare occasions (Baker and Baker 1997, Simon *et al.* 2000, MFBRP unpublished data).

The low-density and cryptic nature of the species has largely prohibited precise estimation of productivity from nests alone (Mounce *et al.* 2013). However, because Kiwikiu typically lay only single-egg clutches and re-nest only after failure, observing a pair with a single offspring is enough to indicate that a pair was successful during a given breeding season. Annual reproductive success can then be estimated using the proportion of successful pairs each year. Using this method, annual reproductive success was estimated to be 46% in Hanawi Natural Area Reserve (NAR) from 2008-

2011 (Mounce *et al.* 2013) and 40% in TNC Waikamoi Preserve from 2011-2014 (MFBRP unpublished data).

Habitat use (diet, foraging behavior, and home range size)

Kiwikiu are insectivorous and forage in a unique way among Hawaiian finches. They use their large parrot-like bill to extract insect larvae from wood and fruits. The Kiwikiu bill is laterally compressed and capable of reaching larvae in narrow openings and cavities. The large bill and strong jaw muscles of the Kiwikiu are used to remove strips of bark and other woody tissue in search of larvae inside. For small stems, Kiwikiu hook their culmen over the branch and cut out strips of woody material with their sharp mandible to expose larvae inside. Insects may also be gleaned from plant surfaces. Plant species with soft wood and/or hollow pith seem to be particularly favored, e.g., ākala (*Rubus hawaiiensis*). Larvae are also often extracted from the fleshy fruits of several understory species, primarily kanawao (*Broussasia arguta*), kōlea (*Myrsine spp.*), pilo (*Coprosma spp.*), and 'ōhelo (*Vaccinium spp.*). Kiwikiu are often observed carefully prodding or squeezing these fruits, presumably feeling for parasitic larvae inside. When a suitable fruit is discovered, the fruit is often cut in half, the larva is removed, and the fruit is discarded. The presence of Kiwikiu in an area can often be determined by bite or testing marks on ripe kanawao berries. Kiwikiu may also eat some small fruits, e.g., pilo, although little fruit consumption is observed in the wild. Some nectar may also be taken either by tongue probing exposed flowers, e.g., 'ōhi'a, or biting closed flowers, e.g., 'ōhelo. Diet studies show Lepidoptera larvae make up the majority of the Kiwikiu diet as well as Coleoptera larvae to a lesser extent (Peck *et al.* 2015).

Home range size for individual Kiwikiu is estimated to be ~ 9 ha on average (9.29 ± 1.29 ha or 9.63 ha ± 1.51 ha [\pm SE] depending on the technique used) and no difference was found between sexes (Warren *et al.* 2015). These estimates were based on resighting data of color-banded individuals in Hanawi NAR and TNC Waikamoi Preserve from 2007-2014. Home ranges were found to be > 50% larger in Waikamoi than Hanawi. A fair amount of variation in home range size was also observed during this time period with home ranges varying between ~ 1 ha and 31 ha in size. Some of this variation can be attributed to the number of times each individual was resighted in a given year, e.g., the smallest home ranges may have been under-sampled individuals. The largest home ranges may be attributed to birds that shifted home ranges during the breeding season. Average pair home range size, i.e., the combined male, female and shared home range, was estimated to be 13.9 ± 10.5 ha or 17.8 ± 12.3 ha depending on estimation technique. Due to the fact that Kiwikiu remain paired throughout the year, an estimate of pair home range size may be a more appropriate metric for

space and habitat use than an estimate of home range for an individual. Pair home range size could also be more relevant in determining the number of breeding pairs the reintroduction area (i.e., Nakula) can support, and estimating carrying capacity of the region. The dataset currently available did not allow for estimation of variation in home range size based on age classes. However, subadult birds likely occupy a larger area than adults with established home ranges (Warren *et al.* 2015). The establishment of a home range and initial pairing has been observed in second-year birds although little information exists on movement patterns prior to this period (MFBRP unpublished data).

Dispersal, movement, survival

Juvenile dispersal remains one of the major unanswered questions regarding demographics of Kiwikiu. Hatch-year birds are difficult to capture and only a small number (15 out of 232 banded Kiwikiu) have ever been banded and only two of these have been resighted beyond their natal year (dispersing a maximum of 2.5 km). However, unbanded second-year birds are encountered regularly during productivity surveys in Hanawi NAR and TNC Waikamoi Preserve. When known pairs are not observed in a given year, i.e., a home range becomes vacant, the area is usually quickly recolonized either by second-year or adult birds by the next breeding season (MFBRP unpublished data). The origins of the new individuals in these cases are often not known. These individuals could be moving into the area from an unknown distance outside the study area or may have been “floating” in the area waiting for a space suitable for home range/territory establishment to become available. Downhill dispersal of juveniles is a potential source of mortality if individuals move into areas where they are under greater threat from avian malaria. Anecdotally, MFBRP banded one second-year bird in Hanawi NAR and subsequently resighted this individual a few months later constructing a nest about 1.5 km away from the capture location. Other second-year birds banded in Hanawi NAR and TNC Waikamoi Preserve have also established home ranges near their banding location. This represents our best current information on second-year bird dispersal and home range establishment. Adult dispersal has been documented in a number of cases within a study site wherein adults shift home range areas within or among years (MFBRP unpublished data). In a few cases pairs shifted home ranges ≥ 1 km following nest failure. Therefore, “missing” known pairs between study years may be the result of adult dispersal rather than mortality as is often assumed in other studies.

Due to the species' cryptic nature, the resight data from productivity surveys conducted by MFBRP typically have not resulted in enough observations per individual to estimate within-year movement patterns. However, behavioral observations suggest that variation in home range size likely occurs throughout the year. As a pair is not tied to a nest site during non-breeding times, a pair's collective home range may be largest outside of the breeding season (typically the fall and winter months). As breeding activities begin, males may defend a territory, a subset of their home range presumably surrounding the nest site. During this time, some males can be found singing from specific perches on a semi-regular basis as he makes his rounds defending the territory (Simon *et al.* 2000, Baker and Baker 1997, MFBRP unpublished data). During the incubation and nestling stages both parents are more reliably found in the area immediately surrounding the nest than at other times (Becker *et al.* 2010). In this period, males often provision females on or near the nest on a regular basis throughout the day, e.g., once per hour. He then may follow a somewhat predictable path to and from the nest. Females may only forage in a small area immediately surrounding the nest site. This period may mark the time when pair home ranges are smallest. After fledging, the hatch-year is provisioned regularly by one or both parents for several months. During this time, known pairs and associated hatch-years are often found well outside the area where they had been found previously (MFBRP unpublished data). Presumably, during this time territory defense has been energetically replaced by offspring care and birds wander wherever resources allow. Non-breeding individuals may also follow regular routes particularly when timing of resources is important, e.g., ripening of kanawao berries. These routes may then vary throughout the year with phenology of various plant species.

Kiwikiu are long-lived passerines capable of living ≥ 16 years in the wild (Mounce *et al.* 2012). Annual survivorship rates in Hanawi NAR was estimated to be high and vary by sex with 0.82 for males and 0.72 for females (overall adult survivorship = 0.78) (Mounce *et al.* 2014). This difference may be attributed to the risks and costs associated with nesting, e.g., predation by non-native mammals. Juvenile annual survivorship was estimated at 0.17 but a small sample size of juveniles ($n = 10$) combined with limited survey coverage across the breadth of the potential dispersal range limits confidence in this estimate (Mounce *et al.* 2014). Thus, juvenile survivorship remains a relatively unknown demographic variable.

Genetics

Concerns about low genetic diversity arise with any organism that has undergone significant range and population size reduction. Knowledge of the current genetic diversity and structure is important when designing a reintroduction strategy to maximize the potential for long term success of the new population. Genetic analysis comparing historic and contemporary samples showed a 96% reduction in genetic effective population size and current genetic diversity to be low (global $F_{ST} = 0.056$) (Mounce *et al.* 2015). This is not unexpected for a species that has reduced dispersal opportunities due to habitat limitations and disease distribution. Increasing overall genetic diversity likely requires a larger population and/or increased metapopulation structure. Reintroducing the species to leeward Haleakalā may accomplish both goals provided the released group contains the maximum amount of genetic diversity that can be feasibly captured (see below).

Although small, the current $\sim 30 \text{ km}^2$ range of Kiwikiu runs $\geq 20 \text{ km}$ around the northwestern rim of Haleakalā volcano. Within this span several large topographic features exist that have the potential to limit gene flow and influence the genetic structure of the species as a whole. Analysis of contemporary samples indicates that genetic structure is influenced by the Ko'olau Gap showing that individuals in TNC Waikamoi Preserve west of the Gap, represent a genetically distinct subpopulation from those to the east (Mounce *et al.* 2015; Figure 1). The eastern subpopulation showed higher levels of overall genetic diversity and allele privatization than the western population. Mounce *et al.* (2015) estimated that a random capture of 25 individuals from the east would ensure the inclusion of 80% of the genetic diversity (Figure 3). Ten individuals would capture the equivalent genetic diversity from the west. A random selection of 30 individuals from across the species' entire range would capture 80% of the total contemporary genetic diversity, 60 individuals would capture 90% and 105 individuals would have to be selected to capture 100% of the genetic diversity. In order to capture the maximum amount of diversity from the current population, the reintroduction group should be comprised of individuals from both the east and west genetic subpopulations. Captive individuals are all descended from the eastern population and should be considered as part of this group when considering their impact on the overall genetic diversity of the release group. Comparatively few individuals from Haleakalā NP were included in this analysis but the relative distance and the presence of several significant topographic features suggest the possibility of further genetic structure particularly in individuals from the southwestern edge of the species' range in the Manawainui Planeze.

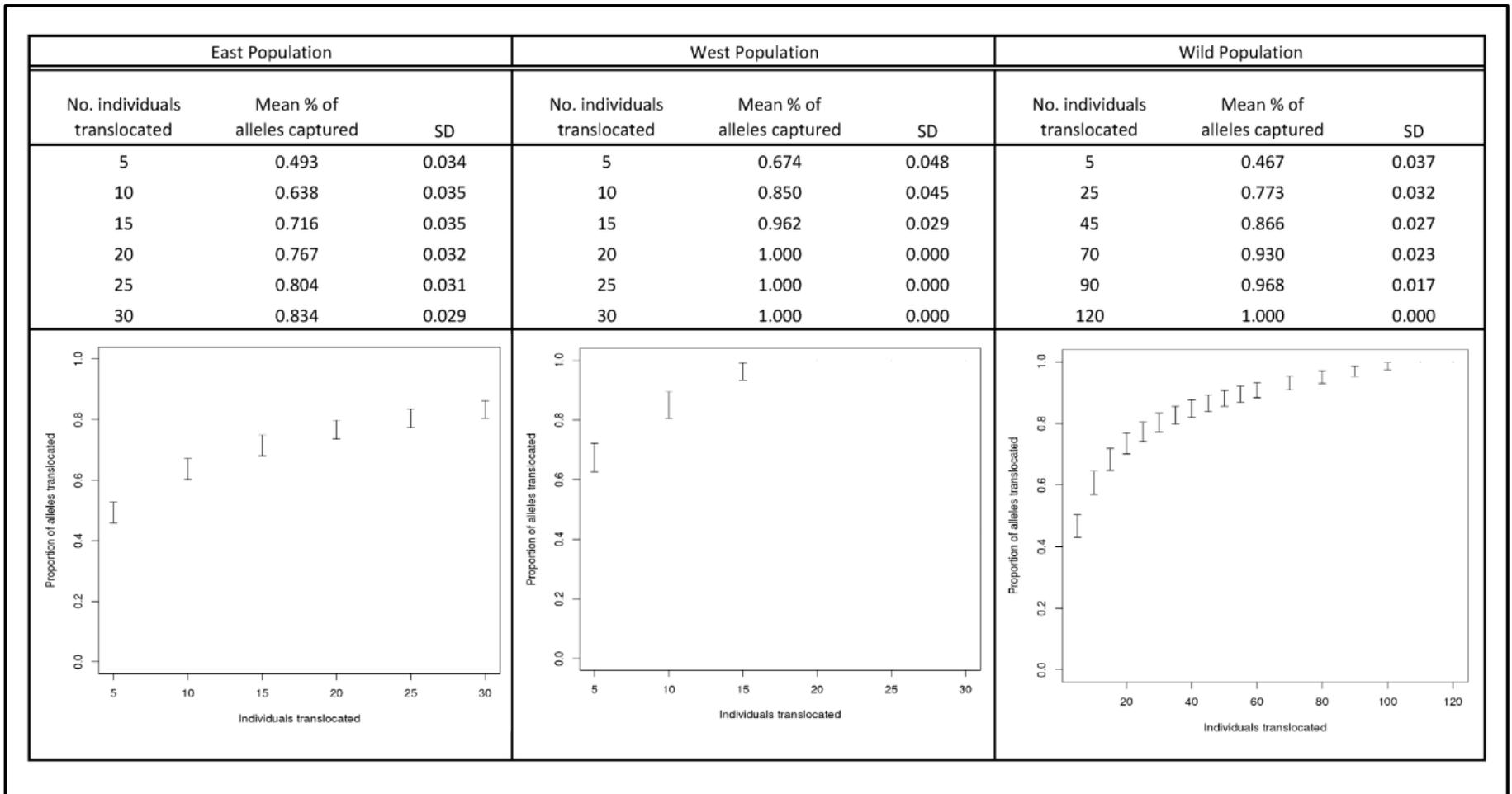


Figure 3. Probability values for capturing different percentages of the total genetic diversity available in the east, west and total wild Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) population modelled while using different numbers of individuals in translocation efforts.

1.2 Conservation Breeding

Historical overview of conservation breeding flock

Conservation breeding efforts for Kiwikiu was initiated in 1997 and the genetic founders of the current flock were collected from the Hanawi NAR part of the eastern subpopulation in 1999, 2001, and 2005 (Figure 1). The current conservation breeding population was derived from six genetic founders (Figure 4). The mean lifespan of the deceased captive birds, both founders and descendants, is 6.86 years (5.43 SD, range = 0.26-16.36, n = 12), excluding three birds that died as nestlings (SDZG unpublished data). All conservation breeding efforts have been conducted by the San Diego Zoo Global (SDZG) staff at facilities on Maui and Hawai'i Islands.

Current overview of conservation breeding flock

As of January 2019, the conservation breeding flock consisted of seven males and two females (Table 1). Current breeding potential in captivity is limited by the relatively small number and old age of the females. The two females currently in captivity are non-reproductive (Table 1). In December 2015, a female was brought in from TNC Waikamoi Preserve, to provide an additional breeding pair. Unfortunately, this individual died in October 2016 and, as she was the only captive bird from the western genetic subpopulation and did not breed in captivity, the captive population now only contains birds with genes from the eastern subpopulation. At present there are eight captive birds (Table 1) that are suitable for release, although this may change if any birds do not pass the pre-release exam (see Section 2.5 for more details).

Future potential for conservation breeding

Reproduction in captivity has been relatively unsuccessful and inconsistent since the first full Kiwikiu breeding season in 2000, in large part due to the small number of birds (and thus breeding pairs) in captivity during this period (Figure 4). Only three Kiwikiu breeding pairs have produced more than two offspring in total over the history of the captive breeding program, and two of the three breeding pairs consisted of the same female (SDZG unpublished data). Various techniques such as increasing protein in the diet during the breeding season, adding carotenoids to the diet for more natural plumage coloration, and providing insects using new distribution methods have been implemented, but conclusions have been difficult to determine due to the small number of breeding pairs in captivity. Furthermore, the high intelligence and unique life history characteristics (e.g., one

egg per clutch and long dependency periods) of Kiwikiu may also contribute to the relatively low reproductive success within the conservation breeding program

Table 1. Current Kiwikiu from breeding facilities and ages as of November 2019.

Studbook	Sex	Founder/ Descendant	Hatch Date	Age	Reproductive history
MP009	Female	Founder	6/12/2001	18 yrs	Never laid an egg in captivity.
MP015	Female	Descendant	3/5/2005	14 yrs	Unreleasable, becomes egg bound
MP017	Male	Founder	1/1/2005*	14 yrs	-
MP018	Male	Founder	1/1/2005*	14 yrs	-
MP022	Male	Descendant	3/2/2012	7 yrs	-
MP023	Male	Descendant	3/2/2012	7 yrs	-
MP024	Male	Descendant	4/2/2012	7 yrs	-
MP026	Male	Descendant	4/15/2013	6 yrs	-
MP027	Male	Descendant	3/23/2014	5 yrs	-

*Estimated hatch date. Adult bird collected from the wild.

Note: in order to be released, each bird will need to pass a physical exam conducted by a SDZG veterinarian prior to release.

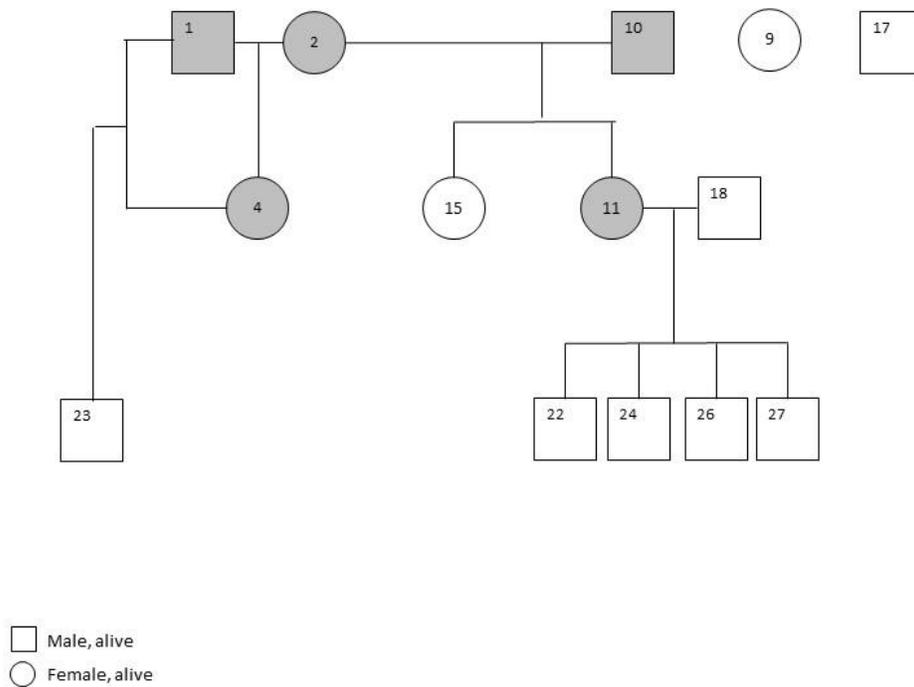


Figure 4. Pedigree of current Kiwikiu conservation breeding population as of June 2018, including alive birds (white shapes), as well as dead birds (gray shapes) that have descendants within the current population. Studbook numbers are indicated within each shape.

1.3 Study Sites

Kiwikiu current range

The current range of Kiwikiu is approximately 30 km² from observations made during the HFBS. This range falls exclusively within Haleakalā NP, Hanawi NAR, Ko‘olau and Hāna Forest Reserves, and TNC Waikamoi Preserve (Figure 1).

Haleakalā National Park

At 134.62 km² Haleakalā National Park (NP) is the single largest unit of conservation land on Maui. The majority of the park is enclosed by ungulate management fencing and is managed for ungulates. The Kīpahulu Valley Biological Reserve in the eastern portion of the park is

characterized mainly by native wet forest containing a wide variety of rare and threatened native flora and fauna. Manawainui Planeze to the south of the Kīpahulu Valley is situated in a transition zone of high precipitation and comparatively dry leeward slopes. The vegetation community in this area reflects this transition zone showing characteristics of the 'ōhi'a-dominated wet forest and the mixed koa-'ōhi'a community of mesic forests. Manawainui marks the southern edge of the Kiwikiu range. In all, roughly 8.5 km² of the total 30 km² Kiwikiu range falls within Haleakalā NP.

History of Kiwikiu conservation in Haleakalā National Park

The upper Kīpahulu Valley has a long history of important historical observations of Kiwikiu. Following the initial collections and anecdotal observations in the late 19th century, the Kiwikiu went unreported until it was rediscovered on the windward slope in what is now Hanawi NAR (see below) by L. Richards in 1950 (Richards and Baldwin 1950). Following those observations, the species again went unreported until 1967 when it was observed in Kīpahulu by W. Banko (1968). No demographic data have been collected in Kīpahulu. However, the Manawainui area was investigated as a potential reintroduction site (Stein 2007). Although the species was not present in high densities in this area, this study highlighted the importance of specific plants, such as 'ōlapa (*Cheirodendron trigynum*) and 'alani (*Melicope spp.*), associated with Kiwikiu occupancy. Additionally, several HFBS transects traverse the park, including Kīpahulu, Manawainui, and the Upper Hāna Rainforest and many of these transects (as well as additional transects) were recently surveyed in 2012 and 2017 and documented the presence of Kiwikiu mostly along the upper elevation portions of the transects (Judge *et al.* 2013, Judge *et al.* *In prep*).

Hanawi Natural Area Reserve

The 30.35 km² Hanawi NAR was created in 1989 to protect critical watersheds and a number of threatened plants and animals. Prior to the creation of the NAR this area was part of the larger Ko'olau Forest Reserve. The highest elevations (> 2000 m) within the reserve contain subalpine native shrubland and bogs and the remainder of the reserve (600-2000 m) is characterized by wet, primarily native forest. The upper elevation forest (> 1600 m) is contained within an ungulate-proof fence protecting some of the highest quality native forest remaining on Maui. The reserve also contains one of the highest concentrations of rare and endangered native forest birds in the state. Hanawi is the site of many of the last sightings of the most critically endangered and possibly extinct bird species on Maui including Po'ouli (*Melamprosops phaesoma*), Maui Nukupu'u

(*Hemignathus affinis*), and Maui 'Ākepa (*Loxops ochraceus*). Hanawi is situated in the center of the Kiwikiu range and is thought to contain the highest density of the species (Brink *et al.* 2012).

History of Kiwikiu conservation in Hanawi NAR

The need for significant conservation actions for the critically endangered Po'ouli and other rapidly disappearing native birds in the upper Hāna district of Maui became apparent by the 1970s (Banko 1971, Scott and Sincock 1977). Following important management actions like ungulate exclusion and removal, research efforts on the status and causes of declines in native forest birds increased during the 1980s and 1990s. During this time, key data on the behavior and ecology of Kiwikiu were collected in Hanawi (Berlin *et al.* 1981, Carothers *et al.* 1983, Mountainspring 1987, Lockwood *et al.* 1994, Simon *et al.* 2000). Maui Forest Bird Recovery Project (MFBRP) was formed in 1997 to research the causes of the declines in bird populations and Hanawi was initially the primary field site for the Project due to the presence of the last remaining individuals of the most endangered species. Following the last sightings of the Po'ouli in 2004 and the lack of sightings of Maui Nukupu'u or Maui 'Ākepa during this time, MFBRP switched its primary research focus to Kiwikiu. From 2006-2011 MFBRP intensively studied the Kiwikiu population in Hanawi and estimated productivity in two study areas within the reserve, Frisbee Meadows and Home Range 3. The datasets collected during this period have been used to estimate a number of important demographic and behavioral variables, such as annual reproductive rates, survivorship, and home range size, vital for conservation efforts including planning the reintroduction of the species to leeward Haleakalā. Rodent removal efforts in Hanawi from 1996-2004 demonstrated that reduction in rodent densities is possible (Malcolm *et al.* 2008); however, beneficial effects of rodent reduction on demographics of native birds at this site were not definitively shown (Sparklin *et al.* 2010).

Ko'olau and Hāna Forest Reserves

The 125.7 km² Ko'olau Forest Reserve (FR) is a very large management unit that wraps around Hanawi NAR (formerly part of the FR) and covers the area of the Kiwikiu range between TNC Waikamoi Preserve and Hanawi NAR. Ko'olau FR and the 53.11 km² Hāna FR cover the small portion of the Kiwikiu range between Hanawi NAR and Haleakalā NP. Relatively little research has been done on Kiwikiu in the areas of these reserves where the species is thought to persist beyond the HFBS transects that go through portions of the reserves. It is thought, however, that densities of Kiwikiu in these narrow portions of their range may be lower than those found in other parts of

their current range based on relatively few observations during HFB surveys. However, the entire area of these reserves where Kiwikiu are found is fenced and protected.

The Nature Conservancy's Waikamoi Preserve

Waikamoi Preserve is a 36.2 km² land parcel owned by Haleakalā Ranch and East Maui Irrigation and managed by The Nature Conservancy. Nearly the entire preserve is contained within ungulate-proof fencing and is ungulate free. The preserve contains a mixture of native and non-native forest. The area between 1500–1800 m in particular is dominated by high quality native forest. While most of the native forest is 'ōhi'a-dominated wet forest, the preserve contains some areas of mesic koa-'ōhi'a forest. Waikamoi marks the western extreme of the current Kiwikiu range.

History of Kiwikiu conservation in TNC Waikamoi Preserve

The area that would become TNC Waikamoi Preserve was historically an area popular among many of the early European naturalists and collectors due to access from the Ukulele dairy. All Kiwikiu specimens were procured in the vicinity of the future preserve (Banko 1986). The first active Kiwikiu nest was discovered in the preserve in 1993 (Van Gelder 1993) and some of the first nesting behaviors were observed at subsequently discovered nests in the preserve (Lockwood *et al.* 1994). Though some banding was conducted there previously, MFBRP significantly expanded research efforts into TNC Waikamoi Preserve in 2011. This was primarily to answer questions about variation in demographics and genetic structure of the species throughout its range. Productivity surveys were conducted by MFBRP during 2011–2014. Despite being on the edge of the species' range, productivity surveys indicate comparable annual reproductive rates but slightly lower densities of Kiwikiu compared to Hanawi NAR (MFBRP unpublished data).

Reintroduction Site

Nakula Natural Area Reserve

Nakula NAR was created in 2011 in an effort to protect some of the last remaining koa-'ōhi'a mesic forests on Maui. The 6.7 km² reserve sits within the center of the Kahikinui region on leeward Haleakalā. After over a century of browsing and grazing damage by feral ungulates the entire preserve is now fenced and ungulates have been removed from the majority of Nakula. The forest within the preserve varies from pockets of mature native forest to savanna and non-native grassland. The reserve is divided into three units, Wailaulau, West Pahihi, and Mauka, based on

fencing and restoration timelines (Figure 5). The Wailaulau unit was selected as the future Kiwikiu release site for the reintroduction program due to the remaining native habitat and high potential for restoration. This unit ranges in elevation from 1100-1900 m and contains the largest area of remaining mature native forest within the reserve. Remnant pockets of mature native forest containing native understory species are found mostly in steep gulches where they were afforded some protection from ungulates. Other areas, particularly higher in elevation, have lost all standing trees and mostly only grasses remain with some native shrubs. The remaining area is characterized by a mosaic of non-native grasslands and savanna containing mature koa, 'ōhi'a, and 'a'ali'i trees, and little understory.

Ungulate Removal

In 2007, the State of Hawai'i Division of Forestry and Wildlife (DOFAW) erected an ungulate-proof fence along the western and southern boundaries of what would later become Nakula NAR. With the addition of another internal fence section in 2012, the 170 ha (1.7 km²) Wailaulau unit of the reserve was the first section to be enclosed by fences and ungulates were removed within the same year. The West Pahihi unit to the east of Wailaulau was fenced in 2015 and restoration efforts are underway in this area. This unit, also incorporating a section of the adjacent Kahikinui FR, experienced heavy grazing and browsing damage and now contains mostly remnant forest with few mature stands of trees. Ungulates were removed from the West Pahihi unit by 2017. The Mauka unit contains the remainder of the reserve above the other two units and contains mostly subalpine shrubland and talus. This area is open to the larger adjacent Kahikinui FR and both areas are now ungulate-free as of 2018.

Habitat Restoration

Restoration efforts began shortly after the Wailaulau unit was fenced and ungulates were eradicated. In 2012, MFBRP initiated experimental restoration trials within this unit to investigate the most efficient and effective techniques for restoring forest in this area. This experiment was completed in January 2016 (Warren *et al.* 2019). The trials showed that natural regeneration within the first few years following ungulate removal was limited to a few species, but that regeneration could be stimulated by disruption of non-native grasses, exposing topsoil. Outplanting success was high for most species and growth rates were enhanced in some species by herbicide application prior to planting. Large-scale outplantings were established by MFBRP and the DOFAW Native Ecosystem Protection and Management (NEPM) program starting in 2012. The NEPM program

began large-scale planting in the West Pahihi unit in 2014. Together NEPM and MFBRP planted > 160,000 native seedlings in Nakula from 2012-2018. MFBRP also established a camp in the center of the Wailaulau unit in 2012 to be used by those conducting restoration and reintroduction work. Due to the protected status of the area, the Plant Extinction Prevention Program has also outplanted several rare and endangered plant species in the Wailaulau unit.

Predator trapping and removal

The presence of mongooses, feral cats, and rats has been documented within Nakula NAR and all likely occupy much of the Kahikinui region. A predator abundance study was conducted by MFBRP in the Wailaulau unit of Nakula in 2014-2015. Densities of rats were comparatively low in Nakula compared to densities seen in Hanawi NAR (MFBRP unpublished data). Black (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) were captured. Three mongooses were also captured but no cats were trapped during this study (although one was seen). This may indicate a low density of cats in the reserve, although the traps utilized may have been inadequate to assess cat numbers. Alternate trapping methods are now being devised. High numbers of mice (*Mus musculus*) were observed during this study in Nakula. While not likely direct predators of forest birds, mice could have a significant impact on regeneration of native flora and invertebrates. As has been seen at the nearby Auwahi Restoration Project, rat densities are expected to increase as forest cover increases (Medeiros *et al.* unpublished). Control methods will be implemented during the Kiwikiu release process. Rodent removal efforts in Hanawi indicated that the reduction of overall rodent density for the larger Nakula area would require great effort and the density reduction is likely to be temporary. However, new trapping technology may increase efficacy of long-term reductions in rodent densities.

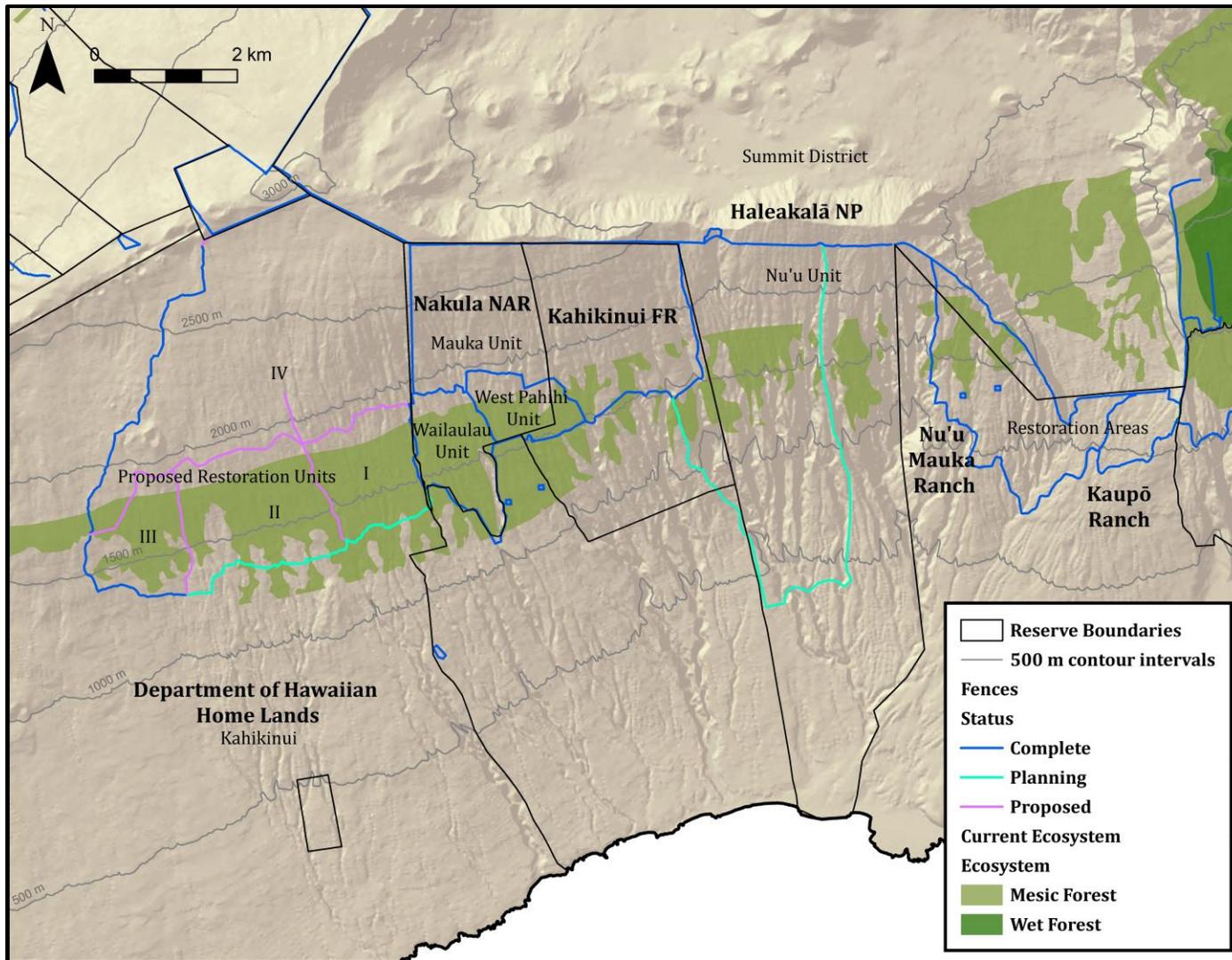


Figure 5. Kīwīkiū (Maui Parrotbill; *Pseudonestor xanthophrys*) reintroduction site land management areas showing completed and planned fencing as of February 2018. The “mosquito line” is approximately 1400 m, and is commonly used to describe the area below which have high rates of avian malaria transmission.

Department of Hawaiian Home Lands

Contiguous with Nakula NAR to the west is a 96.67 km² parcel of land managed by the Department of Hawaiian Home Lands (DHHL). Leeward Haleakalā Watershed Restoration Partnership (LHWRP) is working with the resident community to fence and remove ungulates from an 18.7 km² section of this land containing remnant native forest adjacent to the Wailaulau unit (Figure 5). This section will likely be divided into four management units and collectively will protect the largest remaining section of the existing leeward koa-‘ōhi‘a forest. Although feral ungulates are still present, this area still contains pockets of mature native forest similar to those in the Wailaulau unit of Nakula. Ungulate control efforts in this area were initiated in 2018 and are on-going. The final fence enclosing the greater area is likely to be completed in 2019, followed by the internal units in the future and ungulate removal throughout the area.

Haleakalā National Park – Nu‘u Parcel

Adjacent to Kahikinui FR to the east is a large 17.4 km² parcel recently added to Haleakalā NP and the National Park Service is finalizing fencing to enclose a large ~ 7.6 km² section of land incorporating a portion of the FR. The fence should be completed in 2019 and ungulate removal will commence immediately after. Like Kahikinui FR and Nu‘u Mauka Ranch, much of this area has seen significant loss of top soil resulting in large erosion scars. Little native forest remains except for small stands of ‘ōhi‘a.

Haleakalā Ranch

Haleakalā Ranch leases a ~ 1.25 km² parcel of state-owned land just south of Nakula NAR. This area is divided by the lower half of the Wailaulau unit of Nakula and extends from approximately 1100 to 1550 m. This parcel is actively used by Haleakalā Ranch to graze cattle and sheep. Feral ungulates are also present. LHWRP established two experimental koa outplanting units in this area in 2009. The protection of the last forest patches in this parcel is contingent on the cessation of grazing activities, removal of feral ungulates, and fence installation. However, some remnant forest remains particularly in steep gulches, and there is the possibility Kiwikiu will disperse onto this ranchland.

Kahikinui Forest Reserve

Kahikinui FR is divided into two disjunct units; a 2.87 km² section contiguous with Kula FR and, up until 2011, a 15.64 km² section to the east. Nakula NAR was withdrawn from the eastern unit of Kahikinui FR in 2011 and the FR and NAR are now contiguous along their western and eastern boundary, respectively. The current eastern unit of Kahikinui FR is 8.94 km² in size and contains

some areas of remnant forest, but is largely grassland, talus, and subalpine shrubland. The area above 1500 m is enclosed by an ungulate proof fence and ungulates have been removed from the fenced area. Restoration of the forest has begun in this section as well, and several thousand seedlings were planted in 2014-2018. This section, combined with the Nu‘u unit of Haleakalā NP, despite currently containing little remaining forest, has the great potential to increase the overall amount of leeward mesic forest.

Nu‘u Mauka and Kaupō Ranches

Two private ranches, Nu‘u Mauka and Kaupō, have committed to forest restoration on portions of their lands. These restoration efforts are being conducted by LHWRP in two fenced units, collectively protecting 4.96 km². These units contain large areas of bare rock and soil as well as some patches of ‘ōhi‘a and koa. Much of these areas, however, are below 1200 m in elevation. However, these sections may be critical to connecting the future Kahikinui Kiwikiu population to the windward population across the Kaupō Gap.

2. Reintroduction

2.1 Objectives

The creation of an additional population of Kiwikiu is a critical management action that is necessary to improve the long-term population viability of the species and is a high-priority action listed in the species’ recovery plan, and for US Fish and Wildlife Service (USFWS), DOFAW, and MFBRP. The USFWS (2006) recovery strategy stated that “Reestablishment in southern or western areas of Haleakalā is needed to promote natural demographic and evolutionary processes”, and the Kahikinui region was identified as the leading location. This action will be a conservation translocation and is classified as a reintroduction by the International Union for Conservation of Nature (IUCN) standards because it is releasing Kiwikiu into an area of its indigenous range from which it has disappeared (IUCN/SSC 2013). This plan is focused on the actions needed for reintroduction to succeed over the short-term and to begin the process of achieving long-term success for the population in Nakula. The initial Kiwikiu responses and results from the initial reintroduction are unknown. Planning how to achieve the long-term objective and determining if any modifications or improvements are needed can only occur after assessing the first introductions. The current habitat protection and species management activities must continue, but they are insufficient to prevent the Kiwikiu’s continued decline. Reintroduction is a serious and drastic management activity, but as justified by the USFWS recovery plan (2006) and updated and detailed in this plan, it is necessary to protect this species. Delaying or choosing not to begin the

reintroduction will likely result in a continued population decline (Figure 2). Based on apparent population trajectories, there will not be a better time to begin the actions to create an additional population and avoid the possible extinction of Kiwikiu.

Short-term objective

The short-term goal of this reintroduction is to create a disjunct population of Kiwikiu, separate from the main source population, which survives through multiple years. This plan details the steps necessary to accomplish this objective, and start the leeward Haleakalā population on the trajectory to achieve the long-term objective.

Long-term objective

The long-term objective of the overall reintroduction effort is for the newly established population of Kiwikiu to be self-sustaining, successfully breeding, and to achieve sufficient size to provide significant protection from extinction in case the source population is threatened or extirpated. All of the actions described here work towards accomplishing this objective, but achieving this goal will require substantial resources, committed over a long period, so a detailed strategy is beyond the scope of this plan's recommendations. One of the keys in confidently assessing population establishment is determining the long-term status and fates of the released birds (Seddon 1999). The management and monitoring actions should be adaptively extended into the future to collect these data (IUCN/SSC 2013). A second critical component is conducting additional reintroductions, building upon lessons learned and knowledge gained from the first one. A single reintroduction is insufficient to build a stable and genetically-healthy population, and subsequent efforts will move Kiwikiu from other portions of their current range.

2.2 Site Selection

Selection of a suitable reintroduction site was based on a number of factors, including historical distribution of Kiwikiu, the need to promote natural demographic and evolutionary processes, establishment of a disjunct population to reduce extinction risk, and to increase the ecological breadth of the species to help buffer against climatic fluctuations. Based on these factors, the Revised Recovery Plan for Hawaiian Forest Birds delineated 470.27 km² as recovery habitat for the species on East Maui (315.24 km²), West Maui (90.58 km²), and Moloka'i (64.45 km²) (USFWS 2006). This recovery plan identifies reintroduction to leeward Haleakalā as one of the high priority actions for Kiwikiu.

The USFWS 2006 recovery plan prioritizes evaluating, selecting, and preparing sites for releases and/or translocation of endangered birds to ensure long-term persistence of reintroduced populations, including potentially suitable habitat outside the species' known historic range. The goal is to select and restore habitat that fulfills the year-round requirements for the species to ensure that birds remain in the managed habitat (e.g., sufficient seasonal food resources, nesting and roosting sites). Site selection and subsequent management should include the evaluation of the species' natural history requirements, vegetative analysis, physical qualities (area), elevation, elevational gradient, topography, soil characteristics, prevailing weather patterns, corridor potential, proximity to other conspecific populations, biological limiting factors (e.g., diseases, mosquitoes, predators, food availability, feral ungulates, alien competitors), anthropogenic threats, historical habitat modification and cultural practices of pre-contact Hawaiians, and current level of management and landowner cooperation and integration (habitat conservation plans, safe harbor agreements, etc.). Methods also should consider prevalence of threats identified, and the species' likely response to novel habitat and threats. If areas available for releases do not provide all requirements during some periods of the year but logistical or other concerns necessitate release in these areas, then technologies must be available to support released birds during periods when essential niche characteristics are temporarily absent. Species and areas currently in need of habitat evaluation and selection for releases of endangered birds include:

Leeward Haleakalā, West Maui, and Moloka'i for Maui forest birds

Kiwikiu currently occupy roughly 20% of the identified recovery habitat on East Maui on the northern and eastern slopes of Haleakalā. It is hoped that fencing and ungulate removal below the current range on these aspects of the mountain will allow regeneration of a complex subcanopy and reduce mosquito densities to allow expansion of the population into these areas and increase densities in currently occupied habitat.

The recovery habitat on West Maui and Moloka'i is predominately fenced and ungulate-free currently, but much of the habitat lies below the 1200 m elevation where mosquitoes become more plentiful and *Plasmodium* is able to complete its life-cycle. While the long-term goal for the recovery of the Kiwikiu may be dependent on establishing a second viable population in one or both of these areas, more work is needed to assess the current mosquito abundance and disease prevalence in

the areas and potentially develop methods to reduce or eliminate this limiting factor before reintroductions can begin.

A study of disease prevalence in Nakula NAR and TNC Waikamoi Preserve conducted by MFBRP found higher prevalence of *Culex quinquefasciatus* mosquitoes in Nakula than Waikamoi at similar elevations (Warren et al. *In Prep*). However, this study also indicated comparable rates of *Plasmodium* infections in the bird populations in Nakula compared to other sites at similar elevations on Hawai'i Island, including areas containing 'Akiapōla'au (*Hemignathus wilsoni*), the closest living relative to Kiwikiu (Atkinson et al. 2005, Samuel et al. 2015). Despite comparable infection levels, mitigating any disease risk is preferable. Larval mosquito habitat (particularly for *C. quinquefasciatus*) is largely in stagnant pools in drainages. These locations may be amenable to specific control measures and possible mosquito reductions. Given that these pools are readily accessible, there is a high potential for the reduction in the mosquito populations in Nakula NAR using currently available techniques. Using permitted insecticides to control mosquito larvae in gulches prior to the Kiwikiu release is something that the Maui Forest Bird Working Group is currently investigating and hopes to implement.

While the presence of *Culex* in Nakula was unexpected given the elevation and drier climate, the rates of avian malaria in the native bird population do not appear higher than comparable sites and the conditions in Nakula may increase our ability to control mosquitoes in this habitat. While controlling mosquito vectors are likely how avian malaria can be contained, it is also important to remember that presence of the vector does not mean that the disease is also present. The *Plasmodium* parasite has more restrictive environmental tolerances than its mosquito host (LaPointe 2000). Kiwikiu occupy all of the extant native forest on the windward slopes of Haleakalā above 1400 m and yet the species appears to be in decline or, at the very least, exists at precariously low population levels (Camp et al. 2009, Judge *In Prep*). The presence of avian malaria has been documented in upper elevation habitats within the current Kiwikiu range. However, rates of infection in the current range are not known and cannot be compared to those in Kahikinui. Although not strictly disease-free, Kahikinui is among the only unoccupied high-elevation habitat that can support Kiwikiu. In the long-term, we may be able to manage mosquitoes better in this habitat compared to windward forests.

Non-native mammalian predators represent a significant threat to Kiwikiu in their current range and may be one of the largest contributing factors to their apparent decline; perhaps second only to avian malaria. MFBRP has conducted predator control programs in Hanawi NAR and TNC Waikamoi Preserve to reduce the pressure these mammalian predators exert on native forest birds. It has been demonstrated that rat densities can be reduced in these areas, but the effort required is extremely high (Sugihara 1997, Malcolm *et al.* 2008). These efforts highlight how difficult it is to control these predators in the current Kiwikiu range. New trapping technologies may aid in this, such as Good Nature™ A24 and A18 traps, but these efforts are currently not feasible across the entire range. Another benefit to the more open mesic forest is that rat densities tend to be lower in areas with less forest cover (Medeiros *et al.* unpublished). Current predator densities appear to be lower in Nakula NAR than TNC Waikamoi Preserve (MFBRP unpublished data). While the partners' long-term goal is to increase forest cover in Kahikinui, and thus potentially cause an increase in rat densities, it is possible that predator densities will naturally be lower in this more open habitat. Even after understory density increases in the leeward forests, the height of the lower canopy will likely lead to less connectivity between the understory and canopy. In theory, less connectivity may mean fewer routes for rats and other predators to reach Kiwikiu nests in the canopy.

The western and southern slopes of Haleakalā offer the most immediate opportunity to create a disjunct second population and expand the range and population size of Kiwikiu in the near term. The original mesic forests on these slopes were destroyed or severely degraded by ranching, fires, and feral ungulates over the past few centuries, which likely caused the local extirpation of Kiwikiu. As previously mentioned, some forest exists on state-owned land within the Kahikinui FR and Nakula NAR and on land administered by the DHHL. Restoration and enhancement of this area has begun by the State of Hawai'i, MFBRP, LHWRP and partner agencies and when restored, these areas will provide a mesic koa-ōhi'a forest, which was once a major component of the Kiwikiu range.

Initial restoration has focused within a 170 ha area of the Nakula NAR (Wailaulau unit), which contains some of the most intact portions of this forest, especially in gulches inaccessible to ungulates. Peck *et al.* (2015) found the, "total arthropod biomass and caterpillar biomass at Nakula was as great or greater than that observed at Hanawi and Waikamoi", however their results were limited to the scale of the individual branch or tree – the vegetation density and quality still need to be compared across these sites, but overall woody plant density is almost certainly lower in Nakula. This area is sufficiently physically separated from the current population and creating an additional

population would improve the conservation status of Kiwikiu by reducing the risk of extinction from demographic or environmental stochasticity. It would also serve as the founding population for an eventual connection to the current population through National Park-owned lands to the east. Finally, the reintroduction site is under state control and work can begin immediately when planning is complete.

2.3 Guidelines for starting Kiwikiu reintroduction

Habitat restoration, regeneration, recovery

In 2007, NAR staff completed a fence enclosing much of Nakula NAR and Kahikinui FR in an ungulate-proof fence. Following the boundary fence, DOFAW completed an internal fence in 2012 creating the later-named Wailaulau Unit, with the final stream pass-throughs and ungulates removed in 2013. In spring 2013, MFBRP began field trials to test different restoration methods in the Wailaulau unit (MFBRP 2013). The field trials showed that outplanting seedlings was necessary to restore the habitat and promote a diverse and functional forest throughout the site; neither seed scatter nor unaided natural regeneration were effective techniques. Most species had high (>90%) 24-month survival rates, with the notable exception of ākala and māmaki (Mounce *et al.* 2015). Trials also indicated that natural regeneration of certain species could be enhanced through removal of the non-native grass mat. This treatment effectively promotes natural regeneration, although the remnant seed bank seems to be species-depauperate, with koa and ‘a‘ali‘i being the two most common species. This treatment can be effective as the initial step at landscape restoration, if the effort is followed with outplanting of understory plants. MFBRP and NEPM have built upon these results, and are restoring habitat in the Wailaulau unit to support Kiwikiu and increase the native forest within the reserve. The current outplanting strategy is focused on corridors connecting the remaining forest in the gulches (Figure 6), and along the erosion scars to prevent further soil loss.

In addition to the Wailaulau unit of Nakula NAR, at the regional scale there is forest protection and natural regeneration occurring in the larger leeward Haleakalā region (see Section 1.3 – Reintroduction Site). NEPM is actively restoring other parts of Nakula NAR, particularly the West Pahihi unit (Figure 5) and LHWRP is restoring ranchland and will soon begin outplanting within the DHHL lands. These external restoration efforts are crucial because Kiwikiu are unlikely to remain within the Wailaulau borders. Having a larger restored area with a range of forest types and ages increases the likelihood of the translocated birds remaining in the area. Given the high likelihood

that Kiwikiu will use habitat in areas of the adjacent DHHL and Haleakalā Ranch properties, communications are being facilitated by LHWRP and access issues must be resolved before the translocations begin.

As part of the habitat assessment, aerial imagery is being used to track the forest recovery and the effects of the forest restoration on the overall canopy cover. This will allow the project to control for the original, remnant forest and track the canopy cover that has been produced through the outplanting efforts. At the start of the restoration effort in 2011, canopy cover in the Wailaulau unit of Nakula NAR was roughly 16.5% of the area (Mounce *et al.* 2015). As of 2018, > 40 ha have been planted in the Wailaulau unit, and if all these trees survive and mature, there could be up to 40% canopy cover within the unit not including that produced by natural regeneration. While some of the remaining 170 ha cannot support native forest (e.g., exposed rock or cliff faces, ~ 58 ha), there are still approximately 44 ha of grasslands that could be restored. Many areas contain canopy trees but the understory no longer remains. In these areas outplanting of subcanopy and understory species will likely be needed to restore full ecological function.

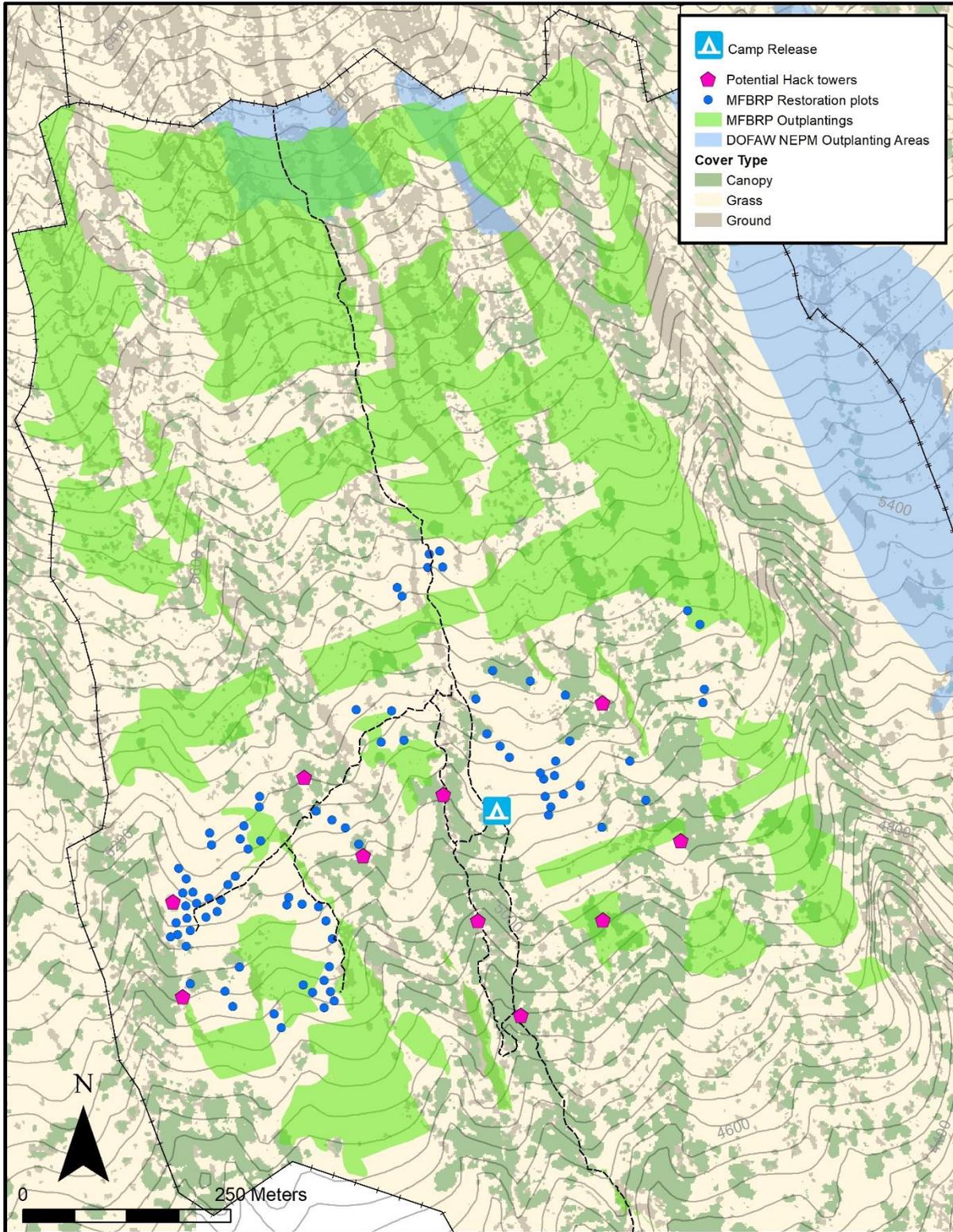


Figure 6. Nakula NAR reintroduction site in the Wailaulau unit for Kiwikiu (*Mau Parrotbill*; *Pseudonestor xanthophrys*) with base camp for reintroduction operations, forest restoration areas as of 2018, and proposed release aviary sites for reintroduced individuals/pairs.

2.4 Seasonal Timing

The initial translocation will take place in October/November, 2019. This time period would minimize the disruption of the source population. During this period, both adults and second-year (SY) birds could be captured. This time period is typically outside the peak in Kiwikiu nesting activity, so there would be a reduced chance of removing birds with dependent nestlings. Before and after a bird is captured, the adult birds' natural behavior will be observed to determine if there are dependent fledglings or juveniles. Any begging juveniles in the immediate vicinity of a captured adult will be assumed to be dependent and the adult will be returned to the wild unless it can be quickly determined that this juvenile is not the offspring of the captured adult (i.e., two adults are travelling with the juvenile). If we cannot capture the desired 12 birds from the wild, due to poor weather or lower-than-anticipated capture rates, we may have additional capture trips to attempt to capture the desired number of Kiwikiu, but we will halt efforts by the end of January to avoid disrupting the source population.

2.5 Cohort Composition

The goal is for the first translocation cohort to be roughly equal parts wild and captive birds. At present there are eight captive birds (Table 1) that are suitable for release, although this may change if one or more birds do not pass the pre-release exam. This plan assumes that all eight birds are releasable. As such, we will attempt to capture and translocate 12 wild Kiwikiu. This will make an initial release cohort goal of 20 birds.

We will attempt to capture breeding pairs from the wild. If we are unable to capture and translocate pairs, we will move single, ideally unpaired birds (e.g., second-year) to the site and pair them in separate, but adjacent, aviary cells to allow them to become familiar and possibly pair up and mate at the new site. The actual number and sex ratio have to be flexible to account for the difficulty in capturing birds. As discussed further below, we will hold the wild birds in temporary field aviaries at the capture site for up to ten (10) days. If we have not captured sufficient birds ($n = 12$) at that time, we will continue to mist-net in the source population, while a portion of the translocation team moves the captured birds to Wailaulau.

The precise sex ratio of the released birds will depend on what individuals can be captured. Wild males are usually easier to capture than females and capturing the precise number of males and females to equal a 50:50 sex ratio may be challenging. Even if we do release an equal sex ratio of

birds, there is no guarantee that birds released from paired aviaries will form a pair and we expect some mate switching to occur. The captive individuals to be released are mostly male (7/8). To maintain a balanced sex ratio including all eight captive birds, we would need to capture six (6) wild females to be paired with the six (6) captive males (one would presumably be paired with the captive female). The remaining six (6) wild individuals to capture would then ideally be three (3) males and three (3) females making the overall translocation goal nine (9) females and three (3) males; a heavy take on females from the source population. Based on the ages of the captive males, only 4-5 individuals are likely to become part of the breeding population. As such, we may be able to achieve an *effective* sex ratio close to 50:50 even if we capture < 9 wild females. The combination of all these factors means a release cohort of more males than females is very likely and acceptable given the composition of the captive flock. An exact 50:50 sex ratio is not necessary in the first year of releases, given that additional releases will be needed to establish a population. A more realistic goal is to capture and translocate 6-8 females and 4-6 males. Combined with the captive birds, the first release group would then be 7-9 females and 11-13 males.

Ideally, we would capture and translocate second-year Kiwikiu (birds in the second year of life; one year old). Birds of this age are likely in the early stages of establishing a home-range, looking for a mate, and establishing a pair. Second-year females may attempt to breed, but most birds of this age do not have the opportunity. Thus, removal from the source population will have less impact on the overall population than breeding adults. In addition, translocating monogamous and territorial passerines of this age may result in higher post-release survival and settlement (Masuda and Jamieson 2012). We also know very little about juvenile (including second-year) movements. It is possible that if an individual does not find a suitable home range area by the time they are ready to breed, they may emigrate from the site including into lower elevation areas where they may be at greater risk of contracting avian malaria. However, while MFBRP has captured and banded a fair number of second-year Kiwikiu in TNC Waikamoi Preserve and Hanawi NAR, they typically make up a very small proportion of captured individuals in a given year. Thus, we are unlikely to have the opportunity to capture 12 second-year birds and some portion of the translocated cohort will have to be older adults.

Hatch-year Kiwikiu will not be translocated. This will avoid removing a bird that is still dependent or being supplemented from its parents. A bird aged one- to approximately 6 months (post-fledging) can be readily aged as a hatch-year bird (Figure 7). Birds younger than one month are known as fledglings and are easily discernible from older hatch-years. However, as birds approach a year in age, they appear physically the same as second-year birds. As such it may not be possible

to avoid taking a bird that is between 12 and 18 months in age (the oldest an individual was observed being fed by parents). Only birds definitively defined by plumage as a second-year (SY; which may include birds ≥ 12 -months) or after second-year (ASY; birds at least in their third year of life) will be selected for translocation. See the Kiwikiu sexing and aging guide in section 2.8 of this plan as well as Figure 7 below.



Figure 7. Photos of banded Kiwikiu demonstrating the plumage differences in the head and face among hatch-year (HY), second-year (SY), and after second-year (ASY). Males (or presumed males in the case of HY) are in the left column and females are in the right. The top row shows two HYs, the middle SYs, and the bottom shows ASYs.

Quite often in both TNC Waikamoi Preserve and Hanawi NAR field sites, MFBRP observed cases where “empty” home range areas become occupied by new individuals. Usually this occurs when a known, banded pair is observed in one year but they are not found the following year. But, a new, often unbanded, pair is observed in the same area as where the known pair had been the previous year. Sometimes these “empty” home ranges are filled by SY birds, but quite often the “new” birds are ASY adults. Usually the “new” birds attempt to breed in the new home range the first year they are observed. These cases do not include times when a neighbor simply expands into the “empty” space but rather times when the known neighboring individuals remain and new birds of unknown origin appear in the gap. This likely indicates that even when an individual or pair dies or emigrates from the site, there are enough additional birds “floating” nearby to fill any available space. Similarly, MFBRP has observed many cases where one half of a known pair (male or female) disappears from one year to the next and the remaining bird nearly always is then seen with a new mate in the new year. One male in TNC Waikamoi Preserve was observed with three different females in three successive years and produced a chick with two of them. For Waikamoi Preserve (2011-2015) and Hanawi NAR (2006-2011) mate identity was known for 13 and 32 individuals, respectively, in more than one year. For these banded birds, we know the identity of their mate in more than one year, and 46% and 34.4%, respectively, switched mates between years (MFBRP unpublished data). There are several cases when a bird switched mates more than once. Fifty-five percent (55%) of newly formed pairs in Hanawi resulted in a hatch-year in their first year as a “new” pair. This challenges the narrative that this is a long-term monogamous species as we observed more readily a decade or so ago. While Kiwikiu seem to naturally be a long-term socially monogamous species, increased adult mortality may be reducing the average length of time pairs are together.

It would be extremely difficult, if not impossible, to determine the impact of the removal of 12 individuals on the source population as a whole. At both MFBRP field sites in TNC Waikamoi Preserve and Hanawi NAR, natural turn-over (“missing” known birds and arrival of “new” birds) was common. Many pairs were consistently found year after year, while others were observed in one year and then never again. Some of this can be attributed to shifting of home ranges outside the study site, while others are certainly due to mortality. Each year however, regardless of which individuals were present, few areas in each study site did not contain a Kiwikiu home range. This turn-over has led many to hypothesize that the species is “saturated” in its current range and that many individuals in the population are non-breeding “floaters” waiting for a home range to become

available. If this is indeed the case, the removal of a pair or individual could provide the opportunity for “floater” individuals to move in and occupy the removed birds’ home ranges. In this scenario, removal of an individual or pair would not represent a net loss in the breeding population for a given site. The removal of a non-breeding “floater” would similarly have a negligible impact on the breeding population.

Capturing already paired individuals could prove important to establishing the species in Kahikinui. However, the chances of capturing six (6) established pairs is very low. Importantly, these six (6) “pairs” are unlikely to all be known breeding pairs. MFBRP has successfully captured a male and female travelling together at the same time on a number of occasions. Often these turn out to be breeding pairs following further observations. However, this is not always the case and several times when MFBRP captured a male and female in the same net, they were later determined to be paired with other individuals. In 2014, MFBRP captured three Kiwikiu, two males and one female, in one net in the span of just a few hours. After further observations it was determined that these belonged to three separate pairs. Thus, even if the capture teams are lucky enough to net a male and female together, there is no guarantee that they are a mated pair. The high frequency of mate switching (presumably after the death of a mate) in both TNC Waikamoi Preserve and Hanawi NAR study sites (as discussed above), indicates that even if a pair is split up, there is a high likelihood that both individuals will be able to find a new mate at the capture and the release sites.

Additionally, annual reproductive success (the proportion of pairs that successfully produce a chick each year) at both TNC Waikamoi Preserve and Hanawi NAR averages < 50% each year. Pairs may re-nest at least three times in a given year but only in the case of nest failure. On average, approximately half of the birds we remove from the source population would not have produced a chick that year. This additionally lessens the impact on the overall productivity of Kiwikiu at a capture site. Limiting captures at a site to a single year may mean that the source population has one bad year of productivity for the breeding adults in the population and may actually provide opportunity for young or “floater” individuals to take their place in the breeding population.

2.6 Cohort Source

There are currently eight captive Kiwikiu in the SDZG facilities that may be suitable for reintroduction (Table 1). SDZG supports releasing all these birds and effectively ending the Kiwikiu breeding program.

Due to the logistics of transporting and housing both field staff and captured Kiwikiu, only one capture site will be used per release year. Hanawi NAR will be used as the source of the wild birds for the first release year. The preferred source of the wild birds for the second release year is TNC Waikamoi Preserve. Other source locations could be areas within Haleakalā National Park. In order to capture genetic diversity from the current population, both birds from the western and eastern populations will need to be translocated (Mounce *et al.* 2015)(Figure 1, Figure 3).

2.7 Permitting and Compliance

DOFAW staff and staff employed under PCSU contract (including MFBRP) are listed as subpermittees on DOFAW's bird banding permit for bird banding activities, including capturing, banding, and affixing color bands and radio transmitters. DOFAW's bird banding permit is currently being renewed on an annual basis, and expires April 30 2019. We will renew the permit before the expiration date. SDZG holds a federal recovery permit for captive individuals. DOFAW staff and staff employed under PCSU contract are covered by DOFAW's Section 6 cooperative agreement with USFWS for bird banding and recovery activities.

Competitive State Wildlife Grant (C-SWG) activities covered by DOFAW's cooperative agreement on listed species include:

- capture of wild Kiwikiu and holding for less than 45 days
- banding of wild Kiwikiu, attaching radio transmitters and color bands
- release of wild Kiwikiu into an area within their historical range

A Section 7 compliance form is being prepared. All activities will fall under NEPA categorical exclusions.

2.8 Logistics

Organizational Responsibilities

MFBRP

- Predator control
- Establish protocols for sourcing birds for translocation
- Coordinate reintroduction plan objectives among partners
- Organize community outreach meetings (in conjunction with DOFAW public relations and LHWRP.)

- Apply for funding and grants
- Capture and translocation of wild Kiwikiu from source populations to Wailaulau
- Post-release monitoring
- Continued habitat restoration

SDZG

- Design and construct release aviaries at Wailaulau
- Transport captive birds from the Maui Bird Conservation Center to Wailaulau
- Care of captive and wild birds in release aviaries at Wailaulau
- Conduct necropsies on dead birds

ABC

- Apply for funding and grants
- Advise reintroduction plan
- Field operations support at capture and release sites

Pacific Bird Conservation

- Care of captured wild birds in field aviaries at capture site
- Advise and aid in construction of field aviaries and transfer cages

DOFAW-Wildlife

- Apply for funding and grants
- Outreach & Public communications
- Organizational support
- Advise and approve reintroduction plan

DOFAW-NARS

- Continued habitat restoration
- Apply for funding and grants
- Organizational support
- Maintain fences
- Invasive species control

DOFAW-Forestry

- Continued habitat restoration
- Fire prevention and suppression
- Ungulate control
- Field operations support at capture and release sites
- Funding and logistical support
- Habitat restoration
- Forest health surveys and monitoring
- Public communications

USGS-BRD

- Advise/assist in radio transmitter attachment and maintenance
- Assist with radio tracking tower equipment and installation

USFWS

- Apply for funding and grants
- Advise and approve reintroduction plan

Proposed Predator Control

Birds are especially susceptible to predators when awaiting release in aviaries and immediately following release as they become acclimatized to the site. To reduce or eliminate the threat of predators, a predator grid of 215 stations and additional traps deployed near the release aviaries (395 traps total) were installed in Nakula NAR during June-August 2018 and activated in October, 2018 (only DOC250s and body-grips were set, A24s will be set March 2019) (Figure 9). The predator control grid will then be active for a full year prior to the first translocation. The predator grid will consist of four trap varieties, GoodNature™ A24, Belisle-brand body grip, DOC250, and Victor® snap traps. An A24 will be placed at each grid station (215 total traps). There will be 40 stations of body grip traps, 20 ground-style stations which allow for two traps per/box (40 traps) and 20 elevated-style stations (20 traps) (60 Belisle-brand traps total). DOC250 traps will be placed at 40 stations (40 traps). Five Victor® snap traps (50 total traps) will be deployed in the immediate vicinity of each release aviary. Unless they are deployed to target a specific cat (see below), one leg hold or other live cage trap will be deployed at each release aviary. Live traps will be monitored daily and will only be active while daily monitoring is possible.

Placement of traps within the grid will be based on spacing from another trap of the same type and spacing from the release aviaries. We will maintain a distance of 50 m between A24-only stations, 50-100 m between DOC250 stations and body grip stations. With few exceptions, we will also maintain a minimum distance of 50 m between DOC250/body grip stations and release aviaries to avoid attracting predators to the aviaries. There will be no minimum spacing from release aviaries for Victor® snap traps. Additional traps will be used to target cats detected on game cameras. “Floating” game cameras will be used to pinpoint an individual cat’s (identified through unique markings) movement patterns. Additional pheromone-baited traps and/or leg-holds will be deployed along identified routes.

Traps will be monitored at different time intervals for the different trap types. The A24 traps will likely only need to be monitored every 3-6 months. Initially we will monitor A24-only stations on a 3-month cycle and the monitoring interval may be modified later based on capture rates. These stations will always be monitored a minimum of every 6 months as per the manufacturer recommendation. Stations containing body grip or DOC250 will be monitored monthly or bimonthly. These stations will be placed on select contours to reduce the number of trails that are accessed at this interval (see Proposed Trail Access below). The traps at the release aviaries (i.e., Victor® snaps) will be checked daily while birds are in the aviaries and as long as birds are utilizing the supplemental feeders. Once birds are no longer using the release aviary sites, these traps will be monitored on a monthly basis along with the body-grip and DOC250 stations or removed. When deployed, leg-hold or other live traps will be monitored daily. If daily access is not possible, these traps will not be used.

We will use a variety of bait types to attract animals to the body-grip and DOC250 traps. Each bait type will be used for a minimum of three months at a time to allow enough time to determine the efficacy of the bait. We will use four bait types initially that have been successful at other sites; sardines (canned in oil), dry cat food mixed with used fry oil, oily fish mixture, and fresh eggs. Additional baits, including pheromone baits, may be used in the “floating” traps to target cats.

Prior to trapping, MFBRP will estimate baseline densities of rats using tracking tunnels along transects within and outside of the trapping grid. We will be following the DOC tracking tunnel guide (Gillies and Williams 2013) for our tunnel monitoring procedures. Gillies and Williams (2013) suggests that tunnels are in place at least three weeks prior to the first survey period. The

tunnels were placed in the field in June, 2018. Baseline estimates were collected in August, September, and October, 2018 just prior to activating the predator grid. These pre-treatment baseline surveys will establish relative abundance of mammalian predators inside the predator reduction grid and outside. Although conducting only three baseline surveys at a similar time of year is not ideal, we feel it is important to make the grid active as early as possible given the timeline for releasing Kiwikiu. We conducted an *a priori* power analysis to estimate the number of tunnels that may be required to detect declines in rodent densities. This analysis indicated two things relevant to this design (Figure 8): 1) If pre-treatment densities of rodents are exceptionally low (i.e., 0.1 rats/ha), we would need at least 35 tunnels (inside or outside the grid) to detect any trend. 2) We are unlikely to be able to accurately estimate a very small decline in rodent densities unless we put out a very large number of tunnels. Given the spacing recommended for these tunnels in Gillies and Williams (2013), it is not possible to have enough tunnels to have very high power in estimating a trend. If we relax the recommended spacing between tracking tunnel lines from 200-m to 100-m, we can easily monitor ≥ 40 tunnel stations inside and ≥ 40 stations outside the grid without getting too far outside the same habitat type (Figure 9). Eighty stations are a manageable number to monitor and this number will allow us to analyze the effects of habitat variability into our results. If the baseline survey indicates higher densities of predators than we think, > 0.3 rats/ha, we may consider adding additional tunnels to increase our power.

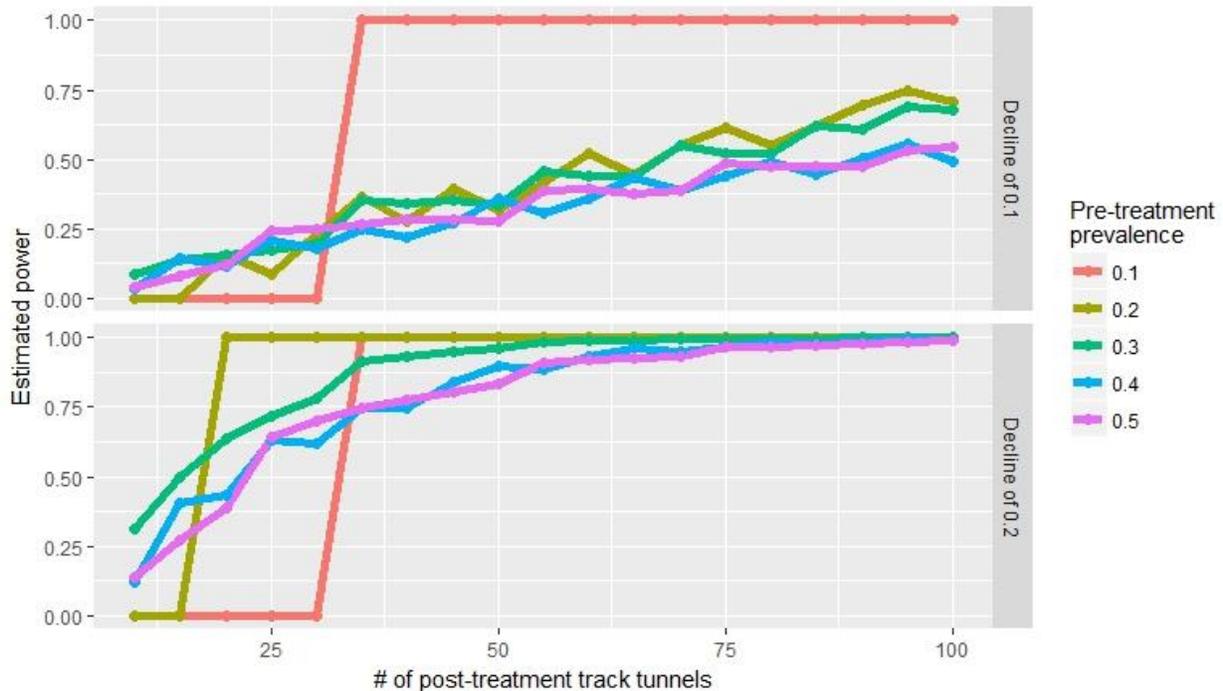


Figure 8. *A priori* Power analysis results showing the minimum number of tunnels required (inside or outside the grid) to be able to accurately detect a trend in predator density in the two treatments. This analysis indicates that a minimum 35 tunnels are required to detect a trend if pre-treatment densities of predators are 0.1/ha. This also indicates that we are unlikely to be able to detect a trend of 0.1 unless pre-treatment density is exceptionally low (i.e. 0.1) or unless we have a very large number of tunnels.

Once the trapping grid is active, we will monitor the tracking tunnels (inside and outside of the predator grid) on a quarterly basis (four times per year) to estimate rodent densities and evaluate trapping efficiency. Designated tracking tunnel stations will be deployed 50 m apart along four separate lines (following contours), 10 tunnels per line, inside and another four lines outside the predator removal grid. All “inside” tracking tunnel stations will be placed > 50 m from the edge of the grid and “outside” stations will be placed ≥ 100 m from the edge of the grid. Tunnel stations inside the grid will be established between trap stations. There will be 40 tracking tunnels deployed inside the grid and 40 deployed outside the grid (Figure 9). Our goal is to reduce rat densities by $\geq 30\%$ in the first year. Comparison of tracking tunnel data inside and outside the grid as well as pre- and post-trapping will allow us to evaluate if we are meeting our predator reduction goals.

Given large home range sizes, cat and mongoose densities will be difficult to estimate with any degree of accuracy within such a small area. For example, the recommended spacing between tunnel lines for mustelids (which is often used as synonymous for herpestids in this context) is

1000 m and spacing between stations is 100 m. Even if we greatly relax the spacing recommendation between lines, we are unlikely to be able to monitor more than 10 stations resulting in very low power to detect a trend. As such, trapping efficiency for these larger predators will be evaluated through capture rates and game camera captures. A series of eight game camera stations (4 inside and 4 outside the grid) will be established along trails at fixed locations to estimate prevalence of cats and mongooses and possibly target specific individuals. Cameras will be placed a minimum of 350 m apart. A scent and physical lure will be placed in front of each camera. Scent and/or physical lures (e.g., tinsel) will be changed every month at the same time the data are downloaded from the cameras. The response variable will be the number of days (24-hour period) per month (30 days) during which a cat or mongoose is captured on camera. All identified individual cats (through unique markings visible in game camera photos) not captured in the grid will be targeted for removal via additional trapping methods deployed (e.g., leg-hold traps). Additional cameras will be used to establish regular foraging routes and facilitate targeted trapping efforts.

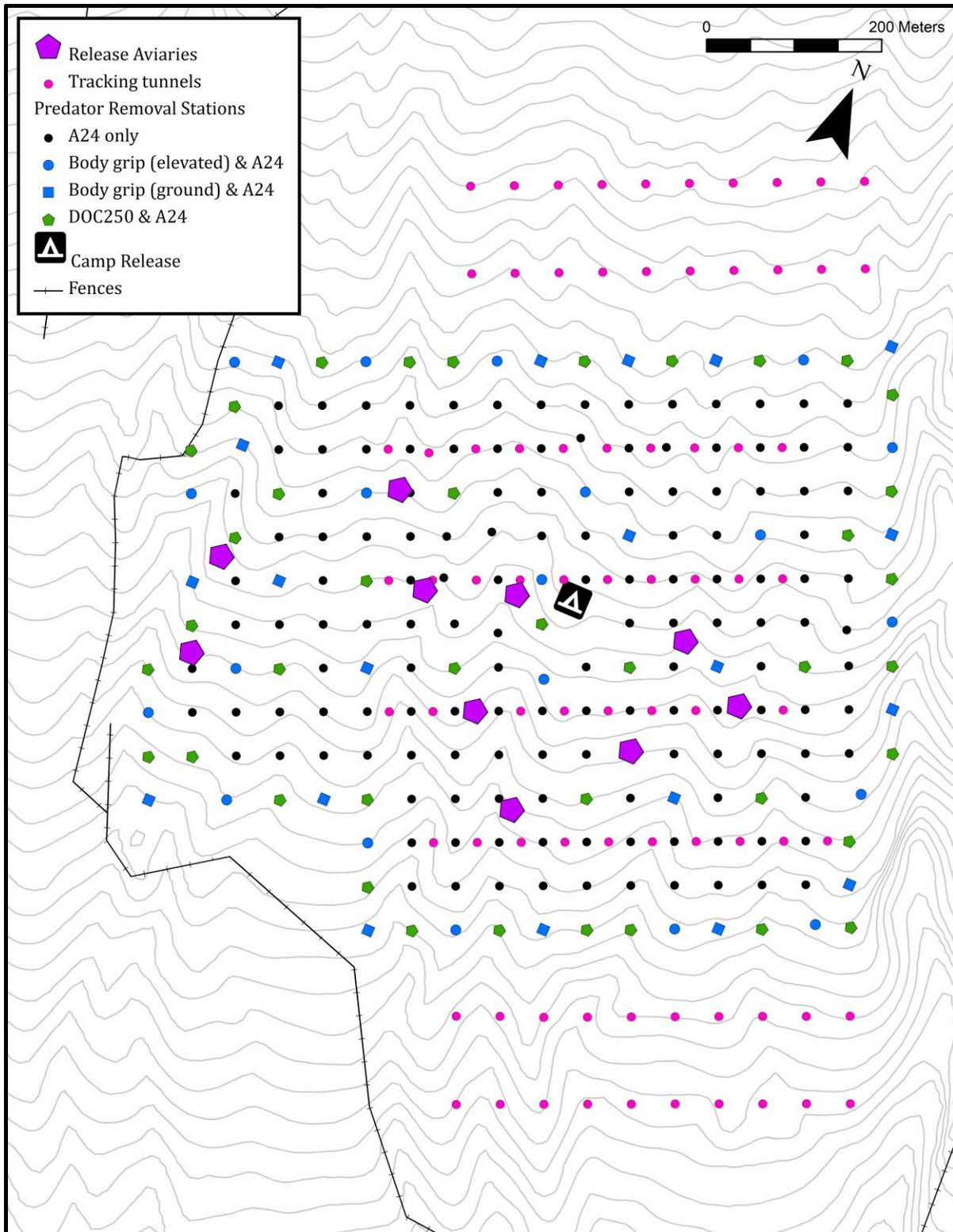


Figure 9. Wailaulau unit, Nakula NAR reintroduction site for Kiwiki (Maui Parrotbill; *Pseudonestor xanthophrys*) with base camp for reintroduction operations, proposed release aviary sites for reintroduced individuals/pairs, and proposed predator reduction grid.

Proposed Trail Access

An additional goal of this project is to cause the least long-term negative impacts within the NAR, so walking will be used for all trail access; no ATV/UTV use will be needed. Four use-levels of trails have been determined based on activities and projected use rates (Figure 10); release aviary trails (high use during releases only), predator control trails (DOC250/body grip trap lines; high use for limited time), predator control trails (A24-only trap lines; low use), other trails (low use).

The highest-use trails will be the release aviary trails, but these trails will only be high-use during releases when daily access is necessary for a three- to four-week period. However, the release aviary trails take advantage of existing flagged trails and overlap some proposed high-use predator control trails. Based on the location of the release aviaries, most of the trails will be two directional (walked in both directions), although one loop is possible to access three of the towers. Sections of the highest-use trails will be regularly evaluated for damage or erosion, and a modified route taken before significant erosion is observed.

Some predator control trails will be high-use for a limited time. For the months prior to the first release, access to body grip stations within the predator removal grid will be needed monthly or bi-monthly. During and after releases, monthly access will be required until the predator detections are negligible. The body grip and DOC250 traps will be placed around the outside border of the grid and three row lines (contours) within the middle of the grid. Body grip and DOC250 traps will be checked along contour trails, and the connector trails snaking mauka-makai the mountain. To reduce impact on each trail, these contour trails can be used in a unidirectional manner in 3-4 loops when checking traps.

Low-use predator grid trails will be used every three (3) to six (6) months to access the stations that only hold an A24 trap. The trails are likely to be unidirectional and can be checked in loops. Tracking tunnel trails will also be low-use and accessed quarterly. Two additional trails are currently flagged and have been used sporadically in the past few years to access planting sites and will either be decommissioned or incorporated into the high-use trails. Three HFBS transects established in 2015 extend mauka-makai throughout the Wailaulau Unit and are flagged and

stations are marked with PVC. These transect trails are rarely used but sections of these routes will be incorporated into the proposed high-use trails.

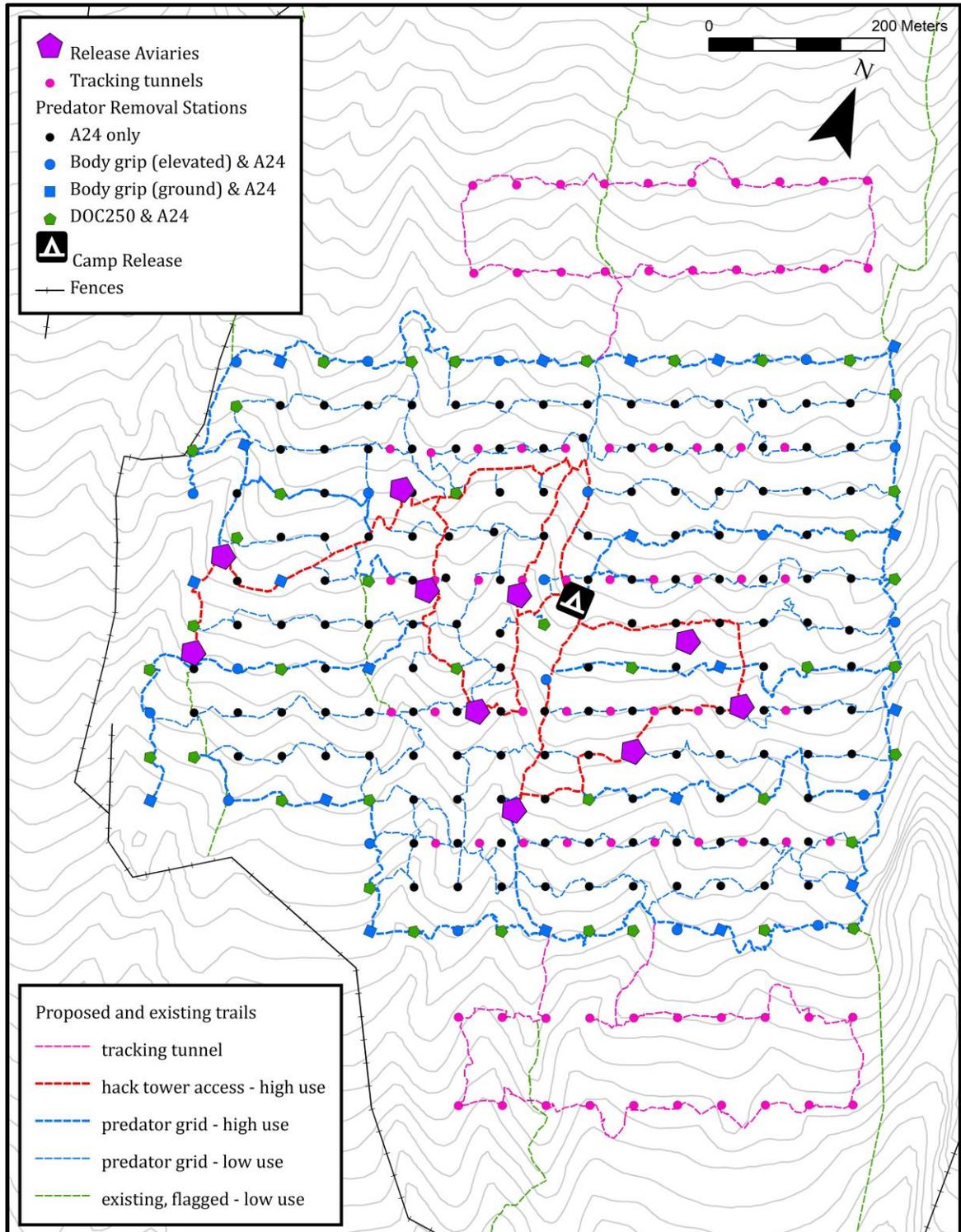


Figure 10. Wailaulau unit, Nakula NAR reintroduction site for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) with levels of use for proposed and existing trails.

Capture

MFBRP will lead and supervise the capture efforts. Multiple teams will operate at the field site to maximize the capture rate. Once captured, the birds will be moved to a set of central holding aviaries at the capture site. Capture attempts will begin October, 2019. No capture attempts will be made until all suitable captive Kiwikiu have been moved to the release site. Captures will be attempted only during acceptable weather conditions following MFBRP protocol; wind < 15 mph and rain < code of 2 (i.e., light rain capable of accumulating on nets). MFBRP protocol also allows continuous playback for up to one hour per net location and limits playback to 30 minutes if a Kiwikiu is observed in the area but not captured. If an individual is not captured on the first attempt, e.g., playback time limit exceeded when bird present, additional attempts will not be made until the following day.

Following capture, each Kiwikiu will be processed as it would under normal banding operations. This includes banding (USFWS steel band and unique color band combination), measurements (needed for sexing), photos, and blood sampling. The blood sample will be collected for all individuals captured, either during the banding operations in the field or prior to release. Only staff that are permitted to band Kiwikiu will lead capture teams and make final decisions regarding transferring a captured bird to a holding aviary. At present permitted banders on staff are Hanna Mounce, Christopher Warren, and Laura Berthold. Others may be present at the capture site and aid the banders in net set up, data recording, and secondary handling (e.g., no measurements, no blood sampling, may carry transfer cage, removing non-target species from nets). In the extremely unlikely case when a bird captured from the wild that is considered to be “unreleasable” (see key below), the bird will be transferred to the Maui Bird Conservation Center (MBCC) or Keauhou Bird Conservation Center (KBCC). Following transfer to a holding aviary, an individual may be released back into the wild based on the recommendations of the on-site veterinarian. The capture team may also decide to release a healthy bird back into the wild to achieve a more ideal sex ratio if additional birds are captured.

Below is a key to be used by the capture teams to determine the eligibility of a captured wild Kiwikiu to be translocated to Nakula. Also included are the key and chart used by field teams to age and sex individual Kiwikiu, necessary for determining eligibility for translocation.

Key to determining eligibility of a captured individual Kiwikiu for translocation.

- 1A. Hatch-year (HY) **release**
- 1B. Second-year (SY) or After second-year (ASY) **see 2**
- 2A. Sex determined as Male or Female **see 3**
- 2C. Sex unknown **return to 1, if still 1B, see 3**
- 3A. Injury noted **see 4**
- 3B. No injuries **see 7**
- 4A. Old injury, scar tissue visible, no open wounds **see 5**
- 4B. Active injury, open wound, e.g., active pox lesions, broken leg(s), broken wing(s). (Does not include missing nails.) **see 6**
- 5A. The injury affects range of motion or otherwise *significantly* influences foraging potential/efficiency of the bird **see 6**
- 5B. The injury is not as described in 5A..... **see 7**
- 6A. The bird can be released safely back into the wild **release**
- 6B. The bird is at significant risk of death if released into the wild **transfer to MBCC**
- 7A. Vascularized brood patch present **release**
- 7B. No vascularized brood patch present **see 8**
- 8A. Begging juvenile observed in close proximity **see 9**
- 8B. No juveniles in vicinity **see 10**
- 9A. Can it be determined that the bird in hand is *not* the parent of the juvenile? Two additional adults in the area feeding the juvenile or being followed by the juvenile **see 10**
- 9B. It cannot be determined if the bird in hand is *not* the parent **release**
- 10A. Bird shows signs of undue or unusual stress, i.e., gaping, sustained raised crest, closing eyes..... **see 6**
- 10B. No unusual stress noted, e.g., bird is active, bright and open eyes, trying to bite **see 11**

- 11A. After second-year **see 12**
- 11B. Second-year **transfer to holding aviary, see 13**
- 12A. Current translocation cohort sex ratio supports additional individuals of this sex
(predetermined) (6-8 females and 4-6 males) **transfer to holding aviary, see 13**
- 12B. Translocation cohort is maxed out for this sex **verify with team, release**
- 13A. Observed feeding on provided food within 24 hours of being placed in holding aviary ... **see 14**
- 13B. Not observed feeding on provided food in 24 hours **release following expert evaluation**
- 14A. Bird shows signs of unusual stress in the holding aviary, e.g., flying repeatedly into walls,
gaping, feather plucking, lethargic, crouched or fluffed.... **release following expert
evaluation**
- 14B. Not as above, or these behaviors cease after 2 hours **see 15**
- 15A. Passes final vet evaluation within holding aviary **eligible for translocation**
- 15B. Fails final vet evaluation **follow vet recommendation which may be to:
i) release; ii) hold and continue to observe; or iii) transfer to MBCC, prioritized
respectively**

Key to Age and Sex Maui Parrotbill

- 1A. Dull grayish-olive body plumage, loosely fitting feathers, possibly underdeveloped bill, mandible pink in color, squeaks **Fledgling**
- 1B. Plumage not as above **see 2**
- 2A. Dull grayish-olive dorsal plumage and dingy white plumage on breast, abdomen, throat, cheeks and superciliaries with or without wing bars (pale yellow-white tips) on median and greater coverts **Hatch-year (HY)**
- 2B. Plumage not as above but partial wing bars present or absent **see 3**
- 3A. White or yellow wing bars are present, mandible *not* orange/pink, mottled yellow and white superciliaries, white in auriculars and throat **Second-year (SY)**
- 3B. Plumage not as described, particular attention to color of auriculars and supercilium and presence of wing bars **see 4**
- 4A. Yellow-olive or gray-olive plumage on nape, back, wing, and tail with solid yellow to bright yellow plumage on the breast, abdomen, throat, auriculars, and superciliaries **After-second-year (ASY)**
- 4B. Plumage not as above, some mixture of traits including bright yellow on face and breast and possibly retained wing bars **After-hatch-year (AHY)**
- 5A. Unflattened wing chord length (wing) less than 70.4 mm **see 6**
- 5B. Wing greater than or equal to 70.4 mm **Male**
- 6A. $2.386 (\text{wing}) - 168.212 < 0$ **Female**
- 6B. $2.386 (\text{wing}) - 168.212 \geq 0$ **Male**

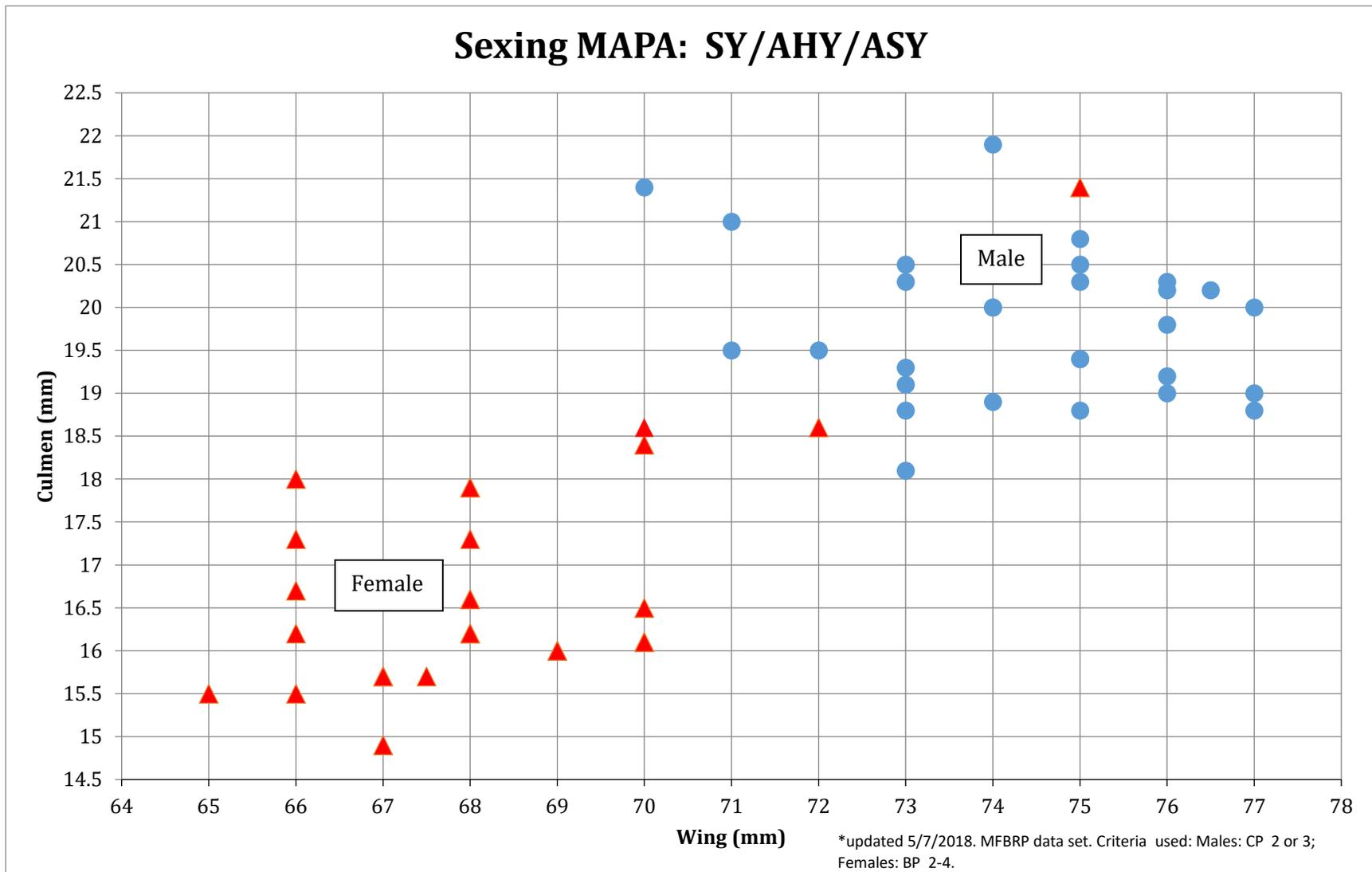


Figure 11. Sexing key for Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*). Regression chart of wing (unflattened wing chord) and culmen (exposed) lengths. Individuals shown are only those found to be in breeding condition, showing a brood patch (Bandit code of 2 - 4), indicating females, and a cloacal protuberance (Bandit code of 2 or 3), indicating males.

Holding

Holding at Capture Source Location

When managing birds brought into captive conditions, we will do everything we can to minimize stress. Prolonged stress can and will have detrimental effects on the health of the bird being managed. There are three basic issues that will drive our management decisions:

1. Birds will be housed in cages that will optimize their conservation of energy and minimize the stress due to the extremes of weather.
 - a. TNC Waikamoi Preserve and Hanawi NAR are can see fairly inhospitable field conditions with lots of rain and very cold nights with temperatures getting down to freezing. We will place birds into solid wall holding boxes. The boxes will provide the birds with an environment that is very stable and moderated. The bird boxes will be placed on a pipe shelf that is in a covered structure (tent). The tent will need to be set up so it can minimize the impacts of the wind and rain, while also allowing adequate ventilation during the hottest part of the day.
 - b. Whenever a bird is held in a bag or holding box, their container will always be placed in the shade whenever possible to avoid overheating.
2. The birds must be able to consume some form of food to maintain its body weight and condition.
 - a. The extremely cold temperatures this species endures requires that each bird be able to consume enough calories to compensate for the energy it expends to maintain proper health. Birds that are not consuming adequate calories will see fat reserves and body tissue consumed, resulting in reduced body condition.
 - b. Birds will be provided gut-loaded mealworms and bee larvae that are likely to be readily consumed based on observations of Kiwikiu previously brought into captivity. A pelleted food mix will be available. Additional vitamin and mineral supplements developed for insectivorous birds will also be provided.
 - c. Weights on birds will be taken in the early morning and also in the later afternoon. These data will be used to monitor and asses the birds' condition daily.
 - d. Feeding activity will be documented. Notes will be taken on what items are consumed and diets modified accordingly.

- e. Fecal output will be monitored. Feces is a good indicator of food consumption. A normal feces should have a large volume of feces (dark portion) with minimal urates (white portion). If the feces are composed of mainly urates that indicates inadequate nutrition and that the bird is now consuming body tissue and its condition is deteriorating. This will signal the need to provide additional and alternative food sources and to more closely monitor the bird's behavior and health.
3. The psychological state of the bird.
- a. Wild birds that are exposed to signs of danger are able to flee, while captive birds are not. Being in close proximity to a source of danger and not able to flee will cause stress and an increase in corticosterone levels. High levels of corticosterone for long periods of time can have negative impacts on the bird's health.
 - b. Maintaining birds in solid boxes with minimal visual contact with the bird handlers and other birds will reduce their stress levels.
 - c. Wherever the birds are held will need to be away from the staff facilities. All staff working around the birds will need to talk softly and not make any sudden loud noises that may startle the birds.

Transfer from field to base camp: Once the field team has finished processing a bird following capture and it has been determined that the bird is eligible for translocation (see above), it will be placed into a transport box and transported to the field camp (hiked) where the birds will be housed. The following information will be attached to each transport box: date of capture, time of capture, net, capture weight, band number, and band combination. The bird transport box should be handled carefully and kept steady at all times. When the bird arrives at the bird holding facility it will be taken inside the bird room and placed on the table until it can be transferred to holding cage.

Housing: Each bird will be placed in a single compartment holding cage at the capture site's central camp. The cage will measure approximately 23 cm (9") wide, 20 cm (8") high, and 40.5 cm (16") deep (Figures 12). The cage will be constructed out of 6 mm (1/4") polyvinyl chloride (PVC) sheet material. The cage will be collapsible and able to be stored flat. The two side walls are solid, and will have a series of 2.5cm ventilation holes along the upper portion of each wall. The right side wall will have ventilation holes along the upper portions of the wall plus a trap door measuring 7.5 cm wide by 10 cm tall. This opening is covered with a sliding door. The door is placed on the upper back portion of the right side wall. The trap door is used to facilitate removing birds from the cage with

minimal stress. The back wall has an opening covered with mosquito-proof pet screen to encourage ventilation of the cage. The cage has two perches. The back perch is secured to the sides of the cage. The front perch is part of the remote weighing system - two support dowels that are attached to the horizontal perch extend up through the top of the cage and attach to a platform (Figures 12). There are two holes cut into the top of the cage that measure 9/16" and are spaced apart so the 3/16" support dowels to the front perch can easily pass through them. Once the cages are built they will be placed onto a pipe frame constructed from EZ Corners pipefittings.

<http://ezcorners.com/index.asp> and 1" conduit pipe EMT. The rack will have two shelves and be able to hold 13 cages. The boxes will be labeled with a number to aide in observations and record keeping.



Figure 12. Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*) single compartment holding cages to be used at the capture site's central camp with remote weighing system and removable perches and floor.

Set up: When the bird arrives at the bird room (tent), the holding cage will be prepped to house the bird. Paper will be placed on the cage floor tray. Food and water containers will also be placed in the cage. The information tag will be moved from the transport box and placed on the holding cage. The bird can then be transferred to the holding cage.

Diet: A diet will be developed by Peter Luscomb (Pacific Bird Conservation) and Bryce Masuda (SDZG). We will identify food items that are readily accepted by this species in captivity. It usually takes a while for wild-caught birds to take to a captive diet. We will have a variety of options available to ensure that we are able to provide the birds with a well balance diet.

One of the primary foods that we will be giving the Kiwikiu is gut-loaded mealworms. Mealworms will be placed into Repashy gut-loading formula (<http://www.rainbowmealworms.net/repashy-superload/>) and allowed to remain for up to 48 hours. Prior to feeding the mealworms to Kiwikiu, they will be sifted out of the mix and then distributed to feeding containers. The mealworms will be weighed to ensure feeding consistency and the ability to compare across birds and feeding bouts.

General Management: Birds will be managed starting at 6:00 am and ending at 6:00pm. The bird room staff will look at each bird and determine its basic status. Once all birds have been accounted for, then the weights for each bird will be collected using the remote weighing system. Once weights are complete, food prep will begin. A double set of feed and water bowls will be used to allow one set to be cleaned while the other is filled and offered to the birds. Feed and water bowls will be placed on a table and food items will be distributed among the bowls. When all food and water bowls have been prepped, then preparations for cleaning and feeding will begin. Paper for the cage floors will be precut. Papers will be numbered sequentially with a magic marker and stacked in order. When everything is ready then feeding and cleaning will begin.

To remove the service tray from the cage, the front door will be lifted up off of the service tray by no more than $\frac{1}{2}$ " , and the tray slowly pulled out. We will be using 4" bowls that are $\frac{1}{2}$ " high for some of the food items. When the bowl hits the back of the front door, we will lift the door just enough so the tray and feed bowl are able to pass under the bottom of the door. We will always lower the door so there is about $\frac{1}{4}$ " of space between the bottom of the door and the object on the service tray we are trying to remove. Two 3" D cups will be hung on the back plate of the service tray, when these hit the back of the front door, we will lift the door just enough so the last bowls can fit under the door and the lower the door as soon as possible.

When the service tray is removed from the cage, the paper will be placed onto a table. The food bowls will be placed on the paper. The cage's service tray will be cleaned as necessary, fresh paper placed on the service tray, and the food and water containers on the tray. The service tray will be placed on the bottom front edge of the cage and the tray will be inserted back into the cage.

When all birds have been fed, each bird will be directly observed again and its location, activity, and posture noted. Birds are creatures of habit, and differences or changes from each individual's baseline behavior are critical in early detection of problems. Anything out of the ordinary may indicate a concern, requiring further observation.

Once all behavioral observations are made, the food consumption and fecal output will be documented.

All unconsumed food and tray paper will be placed into a trash bag. The food and water bowls will be placed into a cleaning bucket and then taken to the field camp. All food prep and cleaning will be done away from the bird room so as to minimize disturbances.

Feeding will occur three times per day; 7:00am, 11:00am and 3:00pm. Cage cleaning will only occur during the first feeding. During the lunch and afternoon feeding the tray will be pulled out and food will be checked. Food will be added as needed.

Removing birds from holding cages: At any time a bird needs to be removed from the holding cage, the cage will be taken off of the shelf and placed onto the table. Two people will be needed to remove the bird from the cage. One person will stand next to the right side of the cage and place a small hand net over the trap door opening. This person will hold the net bag so it extends out from the cage providing the bird with an area that it can easily enter. Once the net is properly located and secure, the other person who is stationed at the front of the cage will pull up the sliding door on the trap door. They will then pull up the front service door just enough so they can fit their fingers under the door. This is usually enough to encourage the bird to enter the net. Once the bird has entered the net, the first person will grab the net and contain the bird.

Weight management: All birds will be weighed twice daily. The top plate to the weighing perch will be lifted and an Ohaus HH120 scale will be placed under it so the scale is sitting on the top of the cage with the top plate on top of the scale. The scale will be positioned so it is centered between the two opposing perch support dowels. The perch support dowels need to project out of the box and attach to the top plate are centered in the holes in the top of the cage and are not touching the sides. We will tare the scale so it reads 0. Once everything is ready, we will place one hand over the cage

and gently tap the back window. This will usually result in the bird hopping to the weighing perch. When the bird settles and the scale gets a reading, we will document the weight on the weight log and proceed to the next bird. All weights will be carefully monitored and the first morning weight will be our target weight to maintain and used to assess the bird's condition.

Monitoring status of birds: The birds will be evaluated using weight data, activity patterns, posture, body condition, food consumption, and fecal output.

The best time to monitor birds is after their first morning feeding. The birds should be hungry and spend much of their time acquiring food. Viewing can be made from the rear of the cage where there is a large screened wall. Depending on the type of structure we use for the Bird Holding area we may be able to set it up so the birds are placed in the structure so they can be viewed from the back of the holding structure. We may consider using a remote camera to monitor the birds between feedings.

Decision on status of bird: A bird will be determined to be suitable to be moved to, and released at Wailaulau based on the flow chart in the "Capture" section on page 52. This flow chart includes consultation with husbandry experts and veterinarians.

Intensive care: There will be a veterinarian at the capture and release sites and provide immediate care for any unforeseen medical issues and to evaluate whether a bird can be translocated or released.

Holding at Release Site

SDZG will supervise the care and maintenance of the Kiwikiu in the field aviaries for staging in Nakula NAR, while the release cohort of 12 birds is captured. The reintroduction site will have ten paired release aviaries with dimensions of approximately 2.5 m long × 2.5 m wide × 2.25 m tall (8.2 ft long × 8.2 ft wide × 7.4 ft) tall, and made of PVC and wire mesh, with a wood platform (Figure 13). These dimensions have been determined based on observations of Kiwikiu behavior within aviaries used by SDZG's conservation breeding program. At each release aviary site, two paired aviaries will be placed side-by-side allowing two individual birds to see and hear each other, but not physically interact prior to release. There will be a removable visual barrier if it is deemed necessary for the birds not to be able to see each other due to aggressive behaviors. The barrier between the aviaries will also have doors that can allow physical interaction between individuals. A minimum of ¼ of

each aviary will be covered by a roof and shade cloth to allow birds to get out of the sun. Each aviary will be covered in mosquito netting.

Aviary prototypes have been built in Olinda and will be placed in the field in September, 2019. The wooden platforms have been built and are completed in Nakula NAR (Figure 13). The wooden platforms are 2.5 × 2.5 m, constructed with pressure-treated wood, and suspended on 6 cm diameter square steel posts.

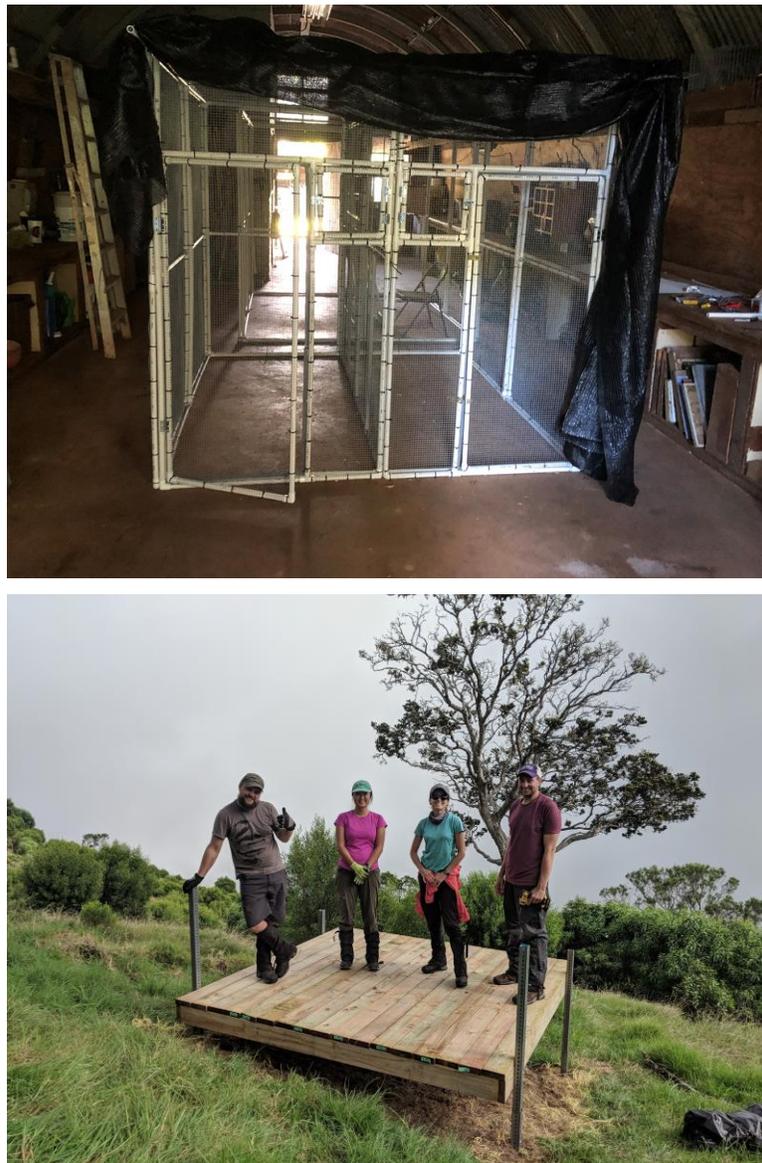


Figure 13. Release aviary prototype (Top) and release aviary platform in Nakula (Bottom).

Release aviary sites were selected based on close proximity to intact forest sections (e.g., gulches; **Error! Reference source not found.**, ≤ 150 m from another aviary (so birds can hear other Kiwikiu), within 10-15 minutes hike from Camp Release, and in areas where construction of aviary will result in minimal disturbance to native plants (Figure 9). Aviaries will be constructed in a way that they can be easily broken down and removed following the final releases. Two supplemental feeders will be placed in each aviary (one for each bird).

Supplemental feeders will be placed within the aviaries and these feeders will remain accessible to the birds within each habitat area following the release (Figure 15). Captive birds will already be accustomed to the feeders. The food within each feeder will consist primarily of dry pellet food and/or live mealworms. Dried insects or other items may also be added to the supplemental food (pending ongoing nutritional analysis). The feeders will be similar to (or modified) commercially purchased feeders raised above ground on a metal pole within a PVC pole and/or aluminum flashing to repel rodents. Timing of food replenishment will be dictated by how long it takes for the feeders to be emptied. Each release aviary will be surrounded by five rodent traps to protect the birds from any potential predators while in the aviaries or near the feeders.



Figure 14. Release aviary Site D (Top) and a nearby gulch providing good habitat (Bottom).



Figure 15. Prototype supplemental feeding dispenser designs to be placed inside each aviary cell and outside of the release aviary. The exact feeder used will be slightly different modification designed as a hybrid of the two pictured.

Transport

The captive-bred birds will be moved to the release site at the beginning of the reintroduction process, and before any capture attempts are made for the wild birds. Prior to being moved to the release site, all captive-bred birds will undergo an examination by a SDZG veterinarian. A helicopter will land at a landing zone near or above the Maui Bird Conservation Center to pick up the captive-bred birds and transport them to the field. These individuals will be held at the release site for approximately one week prior to when wild captured birds will be moved to the release site (see below). A portion of the release team will arrive at Camp Release in Nakula NAR, before these birds to open the camp, prepare release aviaries, and care for the birds once they arrive.

After being captured, the wild Kiwikiu will be hand-carried in transfer cages to a central field aviary near the capture site. Once the 12 bird cohort is assembled, the birds will be helicoptered to Camp Release on the next morning with safe flying conditions. Once the birds arrive at Wailaulau, the wild Kiwikiu will be immediately placed into release aviaries. If the full cohort of 12 birds is not captured within ten (10) days of the first capture, a smaller cohort may be moved to Wailaulau, followed by additional cohorts (no wild bird will be held in capture site field aviaries for > 10 days). Wild birds may be housed in paired aviaries (separate compartments) with captive birds, so that the captive bird can tutor the wild bird on how to use the supplemental feeders. Another priority will be to maintain pairs of wild-wild birds that are believed to be an existing pair based upon their capture behavior and history. There will likely be more wild birds than captive birds being released, so it is unlikely all wild birds will have captive tutor. This is not a great concern due to past SDZG observations of wild Kiwikiu acclimating to feeders relatively quickly.

Release

We will use a soft-release technique for all 20 Kiwikiu. The birds will be held in separate, but paired aviaries (with removable visual barriers), at the ten locations shown in Figure 9. As stated previously, these aviaries will be 2.5 m maximum in its longest dimension (approximately 2.5 m long × 2.5 m wide × 2 m tall), and constructed with PVC with wire mesh. The aviaries will not be permanent structures, and will have no long-term impact on the NAR landscape. The release aviaries will be removed following the final release.

The captive birds will be held for approximately one week prior to when the wild birds are transferred and placed into the release aviaries. This one-week duration will allow the captive birds

to acclimate to the release site prior to a wild bird being placed in an adjacent chamber. Once the wild birds are placed in the adjacent chamber, both the captive and wild birds will be held for approximately 1-2 weeks prior to release. This duration is the expected period of time it will take for wild birds to become comfortable eating out of the supplemental feeders and acclimate to both the conspecific and the release site. In total, captive birds will be held at the release site for approximately 2-3 weeks. Behavioral observations, including food consumption monitoring, will be conducted to inform factors that may affect post-release survival and settlement for future Kiwikiu releases. It is not known which specific behaviors, as well as the intensity and frequency of the behaviors, are associated with post-release survival and settlement for Kiwikiu.

Food will be provided to each bird while in the release aviaries and the same diet will continue to be provided after the birds are released into the wild. This diet will consist primarily of dry pelleted food, and may also include dried insects (pending ongoing nutritional analysis) and live prey items. Following the acclimation period, the aviary doors will be opened. The door can be closed at a later date to re-capture birds, if necessary. Supplemental food will continue to be offered from within or in the vicinity of the release aviary for as long as the Kiwikiu are returning and game cameras will be used to determine the frequency that the birds (Kiwikiu or other species) are feeding from the trays.

The release will be conducted incrementally in order to help anchor birds to the release site, and to ensure that post-release monitoring is manageable. On the first day of the release, one pair being held in a centrally located release aviary will be released. Then, on each subsequent day, one additional pair from an adjacent aviary will be released. If there are no post-release difficulties, the releases will be conducted over a period of ten days, since there will be ten release aviaries.

Each bird will have four bands (three colors, one USGS/USFWS steel band) that will be applied prior to movement into the release aviaries (at capture site for translocated birds and at MBCC for the captive birds). Every bird will also have a radio transmitter to allow for monitoring the individual birds' behavior and movements. It will be critical to follow the birds if they go onto the adjacent parcels or move across the many drainages within Nakula. Transmitters will also provide the ability to locate deceased birds to determine sources of mortality. The radio transmitter will be attached a few days before the birds are released to monitor how the birds are interacting with the transmitter. Although not perfect surrogates for the wild birds, we will attach dummy transmitters

to captive birds at MBCC prior to the move to Wailaulau to allow for extended observations of how the birds may interact with the transmitters and harnesses. Of particular concern is if Kiwikiu bend the antennae, as Palila (*Loxioides bailleui*) have done, or are able to cut the harness with their sharp mandibles. Depending on the size of the transmitter (determined by the size of the bird), the transmitter batteries should last between 50 and 88 days after activation. If possible, the birds will be recaptured in the field before the transmitter battery dies, and the transmitter will be replaced.

Veterinary Care

All reasonable efforts will be made to have a veterinarian on site during captures and releases. These individuals are not available locally and will likely need to be brought in from the mainland for one to two weeks at a time.

Death and Necropsy

This reintroduction is a significant management action that will have large benefits to the long-term conservation of Kiwikiu. However, translocations involve lots of capture, handling, and movement of the birds, and unfortunate events can happen and mortality can result. If this occurs, the bird's carcass will be retrieved as soon as possible, and stored on ice (being careful for the carcass to not touch the ice directly, and only for the carcass to be kept cool by the ice) until it can be transferred to a qualified veterinarian for a necropsy. SDZG will conduct the necropsies for all the captive and wild birds. The project leads from all involved agencies will be notified of the necropsy results as soon as the results become available.

3. Post-Release Monitoring and Assessment

3.1 Protocols and data collection

Short term (50-88 days)

We will attempt to resight each bird every day (or at least every other day) while the transmitters are active. Although this will be very demanding on the monitoring personnel, because there is so much uncertainty in the birds' behaviors we must maximize our data collection while the transmitters are active. This intensive monitoring will allow us to detect an individual's absence and potential emigration or attempt to return to the source population. It will also allow us to determine the home ranges and pair status of all the birds. The home range data is especially

critical because it is unclear how the translocated and released Kiwikiu will perceive the recovering forest, and the actual habitat suitability is critical for evaluating the carrying capacity of the Wailaulau unit and greater Nakula area. Similarly, it will provide important data on foraging and behavior to help assess the bird's health and ability of the habitat to support Kiwikiu and future translocations.

This intensive data will allow us to determine the survival of the birds and detect any mortality caused by the capture, transport, and release process. Intensive monitoring while the transmitters are active will assist in determining the timing of mortalities and timely retrieval of carcasses. This will increase the likelihood of determining causes of mortality and ultimately methods to mitigate these factors during subsequent translocations. We will also conduct focal behavioral observations of each bird during the resighting period. These short observations will allow us to determine foraging behaviors, habitat preferences, and possible social interactions. The length of these focal observations will depend on how long the bird remains within close distance to the observer. This information will be critical in assessing possible difficulties (e.g., insufficient food plants available) with the reintroduction. Beyond survival and foraging behaviors, every effort will be made to determine if any pairing, territorial, or breeding behaviors are being exhibited. In the marked wild populations in Waikamoi and Hanawi, establishing pairing and breeding status often took multiple encounters with individuals over an extended period. The transmitters will greatly enhance our ability to determine the status of each bird during the life of the transmitter battery.

Extended term (89-365 days)

We will monitor all the movements during the first 50-88 days (depending on sex and size of bird due to battery life) while the radio transmitters are active. This will allow us to track any short-term movements. We will use our daily resights to determine each bird's home range and the habitat they are using.

Monitoring after the radio transmitters' batteries are no longer active is still important, but much more difficult. The Kiwikiu's territoriality should make it easier to locate birds that remain within the Wailaulau unit. However, some birds will presumably continue to slowly leave the release area, into the adjacent habitat or searching for their previous territory. Additionally, the remote nature of Wailaulau means that field teams cannot always be present. The most important data to collect is the survival and continued persistence of birds at the translocation site, as well as maintaining

supplemental food resources if the birds are still observed using them. As stated above, this is an experimental release into an area with different habitat than either the Hanawi or Waikamoi sites. Evaluation of the success, or potential success, of the translocation depends on determining the survival and persistence of the Kiwikiu in this restored forest.

Monitoring the persistence, home range size, and foraging behavior over the first year will provide the data to evaluate whether subsequent translocations can occur. To reach our short- and long-term objectives, the Kiwikiu must persist at the site, which requires them finding sufficient food in the recovering forest. Estimating home range area is important because it determines how many Kiwikiu the area can support, i.e., carrying capacity. Given the differences in habitat between the current and reintroduced range, predicting carrying capacity in Nakula is very difficult. Through their intensive monitoring efforts, MFBRP found 24 pairs per km² in Waikamoi and 52 pairs per km² in Hanawi on average (0.23-0.52/ha) (MFBRP unpublished data) and pair home range size was estimated to be 14.5 ha (Warren *et al.* 2015). Based on the home range densities seen in Waikamoi and Hanawi we may expect that an area of equivalent habitat quality the size of Wailaulau (170 ha) could support between 40 and 88 pairs. Given the current state of the habitat in Nakula, we expect the current carrying capacity to be much lower than this. Based on non-overlapping home ranges, Wailaulau may hold 11 pairs (170 ha/14.5 ha pair home range). However, pairs often overlap home ranges with neighboring pairs on the windward slope thereby increasing density (more overlap = higher pair density) and we expect similar behavior at the release site. Thus, comparing home range size and overlap in the released birds to those estimated in Waikamoi and Hanawi may give us an idea of the eventual densities we can expect (i.e., carrying capacity) and the number of birds to release over three years. The habitat is unlikely to be saturated in the first year, even if all 20 birds survive, but comparing the home range size to currently occupied habitat will also provide an index of the habitat quality.

Breeding

The long-term objective is for the established population to be self-sustaining, which requires local breeding and recruitment. During the first spring after the translocation (e.g., April-June 2020), there will be additional effort dedicated to find and monitor the remaining birds, and detect any nesting that occurs.

Longer Term (>1 yr)

MFBRP and the project partners will continue to resight and collect foraging and behavioral data on the translocated birds on their subsequent trips to the site. Continuous monitoring will be done until January 2020 and intermittent monitoring will be conducted at least until November 2020, one full year following the release. Annual point counts will be conducted in Nakula in April and May 2020. MFBRP will continue to visit Nakula monthly for predator control and monitoring through the fall. These data will be used to determine long-term persistence and ability of the Wailaulau area to support Kiwikiu and continue additional releases. If MFBRP and partners decide to move forward with additional releases, preparation will be made to capture wild birds from TNC Waikamoi Preserve in year 2 (captures to occur sometime between November 2020-January 2021). At this time, no releasable birds will be available from SDZG and cohort will be made up of all wild birds.

3.2 Alternatives and future actions

Guidelines for determining releases

In the first year, we will be released or translocating 20 or fewer birds from one wild source (Hanawi NAR) so we will not be capturing all the genetic diversity necessary. We know that multiple translocations will be necessary to create a healthy, self-sustaining population in Nakula. However, one translocation from a single source population will meet the short term goals of the reintroduction and will be a more efficient use of resources. If the birds persist into the summer and appear to be doing well, then planning for a second translocation operating from a different source (e.g., Waikamoi) can begin. If the birds fail to persist, the first priority will be to determine why and how to correct this, and immediately work on resolving these reasons for emigration or mortality (if possible), before conducting subsequent and future translocations.

Any subsequent translocation will not occur until the second year, i.e., October 2020 – January 2021. If possible, factors that reduced the first year survival or persistence will be addressed and mitigated. However, it is important to keep in mind that 20 birds is a relatively small number to release, and that post-release mortality and dispersal is inevitable due to the stressful translocation and reintroduction process. Therefore, the plan is to release birds each year for at least three consecutive years, keeping in mind that the reintroduction protocols will change based on data collected during post-release monitoring and necropsy analysis. Due to the logistical difficulties in capture, transport, release, and monitoring, it is not feasible to attempt more than one release each

year. Due to the release of nearly the entire captive flock, subsequent releases will be entirely wild translocated birds.

4. Resources Needed

4.1 People and Roles

Staff Needed

Installing Release Aviary Team (MFBRP/SDZG): Building release aviaries will involve up to 10 people at camp and within the area for up to 10 days per trip.

Capture team (MFBRP/ABC/DOFAW): Three teams of three people (9 total). These staff will work in the capture site, and then shift to Wailaulau. Some of these could be short-term experienced volunteers and/or partners that would not stay at Wailaulau for the entire monitoring rotation.

Holding Team (MFBRP/SDZG/Pacific Bird Conservation): Two teams of 2-3 (4-6 total). One team will be stationed at the capture site and the second team will be at Wailaulau. The holding team at the capture site could get assistance from SDZG staff, Pacific Bird Conservation, or the capture team. Once the wild birds are moved to Wailaulau, a second team would not be needed.

Release & Monitoring Team (MFBRP/ABC/DOFAW): 4-6 people. Initially, this team will only be two people to open Camp Release and prep it for birds, open and run the predator grid, and assist the Holding Team that is caring for the captive-bred birds in the aviaries. Once the birds are released, the team will need to increase to four to six people to monitor all the birds and collect the necessary behavioral data to assess the translocation. The number of staff needed for monitoring will depend on the difficulty in locating and observing all released birds. Constant staff presence will be required during the four to eight-week period of soft release, and then three to four months for initial monitoring. Team members will be rotated to maintain constant presence at the site for monitoring and maintenance of supplemental feeders. It is possible that only two people will be required for the latter part of the monitoring period. MFBRP has a field staff usually consisting of three to four people. We plan to hire three temporary field assistants in addition to our 1-2 interns.

Community volunteers and staff from partner organizations have been instrumental in the success that MFBRP has had conducting restoration work in Nakula NAR in the last five years. With the help

of volunteers, MFBRP have been able to increase their effectiveness on the ground. MFBRP plans to continue using volunteers throughout the Kiwikiu reintroduction and for future restoration work. Volunteers during the release are likely to be longer-term, skilled persons given the specialized and sensitive nature of the work. Four to six volunteers will be involved with the aviary construction and continued predator control while one to two skilled volunteers will be recruited for monitoring.

Partners and collaborators

Maui Forest Bird Recovery Project – translocation from capture site to release site, release of cohort, post-release monitoring of cohort to collect behavioral data, predator control and rodent traps, future mosquito control.

Pacific Bird Conservation – advise design and construction of field aviaries and care of translocated birds in temporary field aviaries at capture and release sites.

San Diego Zoo Global – design and construct release aviaries at Wailaulau, transport captive birds from the Maui Bird Conservation Center to Wailaulau, care of captive and wild birds in release aviaries at Wailaulau, conduct necropsies on dead birds

American Bird Conservancy – continued funding and advise adaptive reintroduction plan informed by success and mortalities of released birds, support and assist with initial capture and monitoring.

DOFAW-NEPM – continued funding, and continued restoration in Wailaulau and West Pahihi Nakula NAR units. Access to NARs.

DOFAW-Wildlife – continued funding, and organizational support

DOFAW-Forestry – continued restoration in Kahikinui FR and access to Forest Reserve lands for monitoring if needed

USFWS – continued funding, possible personnel support

The Nature Conservancy – organizational support and access to TNC Waikamoi Preserve as a source for translocated Kiwikiu

Haleakalā National Park – access to Nu‘u unit during post-release monitoring and the Kīpahulu and Manawainui areas are possible future source of translocated Kiwikiu

LHWRP – coordinate access to Department of Hawaiian Home Lands with community leaders during post-release monitoring, continued restoration across the leeward slope

5. Literature Cited

- Atkinson, C.T., J.K. Lease, R.J. Dusek, and M.D. Samuel. 2005. Prevalence of pox-like lesions and malaria in forest bird communities on leeward Mauna Loa Volcano, Hawaii. *Condor* 107:537-546.
- Atkinson, C.T. and D.A. LaPointe. 2009. Introduced avian diseases, climate change, and the future of Hawaiian honeycreepers. *Journal of Avian Medicine and Surgery* 23:53-63.
- Atkinson, C.T. and M.D. Samuel. 2010. Avian malaria *Plasmodium relictum* in native Hawaiian forest birds: epizootiology and demographic impacts on 'Apapane *Himatione sanguinea*. *Journal of Avian Biology* 41:357-366.
- Banko, W. 1971. Preservation of Maui's endangered forest birds. *Condor* 73:120-121.
- Brinck, K.W., R.J. Camp, P.M. Gorresen, D.L. Leonard, H.L. Mounce, K.J. Iknayan, and E.H. Paxton. 2012. 2011 Kiwikiu (Maui Parrotbill) and Maui 'Alauahio abundance estimates and the effect of sampling effort on power to detect a trend. Hawai'i Cooperative Studies Unit, Technical Report HCSU-035, University of Hawai'i, Hilo.
- Camp, R.J., P.M. Gorresen, T.K. Pratt, and B.L. Woodworth. 2009. Population trends of native Hawaiian forest birds: 1976-2008: the data and statistical analyses. Hawai'i Cooperative Studies Unit Technical Report HCSU-012, University of Hawai'i, Hilo.
- Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436:686-688.
- IUCN/SSC. 2013. Guidelines for reintroductions and other conservation translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission.
- James, H.F., and S.L. Olson. 1991. Descriptions of thirty-two new species of birds from the Hawaiian Islands: Part II. Passeriformes. *Ornithological Monographs* 46:1-88.

- James, H.F., T.W. Stafford, Jr, D.W. Steadman, S.L. Olson, and P.S. Martin. 1987. Radiocarbon dates on bones of extinct birds from Hawaii. *Proceedings of the National Academy of Sciences of the USA* 84:2350-2354.
- Judge, S.W., R.J. Camp, and P.J. Hart. 2013. Pacific Island landbird monitoring annual report, Haleakalā National Park, 2012. Natural Resource Technical Report NPS/PACN/NRT-2013/740. National Park Service, Fort Collins, Colorado.
- Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A.K. Srivastava, and M. Sugi. 2010. Tropical cyclones and climate change. *Nature Geoscience* 3:157-163.
- LaPointe, D.A. 2000. Avian malaria in Hawai'i: Distribution, ecology, and vector potential of forest-dwelling mosquitoes. PhD Dissertation, University of Hawai'i - Mānoa.
- Masuda, B.M. and Jamieson, I.G., 2012. Age-specific differences in settlement rates of saddlebacks (*Philesturnus carunculatus*) reintroduced to a fenced mainland sanctuary. *New Zealand Journal of Ecology* 36:123-130.
- Motyka, P.J. 2016. Non-native trees provide habitat for native Hawaiian forest birds. MS Thesis, Northern Arizona University, Flagstaff.
- Maui Forest Bird Recovery Project. 2013. Nakula Field Reports: May 28-30; July 10-15; October 8-11; October 17-22; November 8-12; December 2-6; December 12-16.
- Mounce, H.L., C.R. Kohley, C. Rutt, and D.L. Leonard. 2012. Maui's protected areas shelter long-lived Hawaiian honeycreepers. Presentation, Hawaiian Conservation Conference, Honolulu, USA.
- Mounce, H.L., C. Raisin, D.L. Leonard, H. Wickenden, K.J. Swinnerton, and J.J. Groombridge. 2015. Spatial genetic architecture of the critically-endangered Maui Parrotbill (*Pseudonestor xanthophrys*): management considerations for reintroduction strategies. *Conservation Genetics* 16:71-84.

- Mounce, H.L., K.J. Iknayan, D.L. Leonard, K.J. Swinnerton, and J.J. Groombridge. 2014. Management implications derived from long term re-sight data: annual survival of the Maui Parrotbill *Pseudonestor xanthophrys*. *Bird Conservation International* 24:316-326.
- Mounce, H.L., D.L. Leonard, K.J. Swinnerton, C.D. Becker, L.K. Berthold, K.J. Iknayan, and J.J. Groombridge. 2013. Determining productivity of Maui Parrotbills, an endangered Hawaiian honeycreeper. *Journal of Field Ornithology* 84: 32-39.
- Mounce, H.L., C.C. Warren, C. Farmer, J.P. Vetter, L.K. Berthold, P. Landon, and S. Fretz. 2015. Planning for Kiwikiu reintroduction: Habitat restoration in Nakula Natural Area Reserve, Maui. Presentation Hawai'i Conservation Conference, Hilo, HI.
- Munro, G.C. 1944. *Birds of Hawai'i*. Tong Publishing Co., Honolulu.
- Mountainspring, S. 1987. Ecology, behavior, and conservation of the Maui Parrotbill. *Condor* 89: 24-39.
- Peck, R.W., P.C. Banko, J. Cappadonna, C. Steele, D.L. Leonard, H.L. Mounce, D. Becker, and K. Swinnerton. 2015. An assessment of arthropod prey resources at Nakula Natural Area Reserve, a potential site of reintroduction for Kiwikiu (*Pseudonestor xanthophrys*) and Maui 'Alauahio (*Paroreomyza montana*). Hawai'i Cooperative Studies Unit, Technical Report HCSU-059, University of Hawai'i, Hilo.
- Perkins, R.C.L. 1903. Vertebrata. *In: Fauna Hawaiiensis* (D. Sharp, ed.). Cambridge University Press, UK. pp. 365-466.
- Pratt, L.W., and J.D. Jacobi. 2009. Loss, degradation, and persistence of habitats. *In: Conservation biology of Hawaiian forest birds: implications for island avifauna* (T.K. Pratt, C.T. Atkinson, P.C. Banko, J.D. Jacobi, B.L. Woodworth, eds.). Yale University Press, New Haven, USA. pp 137-158.
- Richards, L. P. and P. H. Baldwin. 1953. Recent records of some Hawaiian honeycreepers. *Condor* 55:221-222.

- Samuel, M.D., B.L. Woodworth, C.T. Atkinson, P.J. Hart, and D.A. LaPointe. 2015. Avian malaria in Hawaiian forest birds: Infection and population impacts across species and elevations. *Ecosphere* 6:2-21.
- Scott, J.M., and J.L. Sincock. 1977. Recent observations on the birds of the Koolau Forest Reserve. *Western Birds* 8:113-116.
- 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:i-xii.
- Seddon, P.J. 1999. Persistence without intervention: assessing success in wildlife re-introductions. *Trends in Ecology & Evolution* 14:503.
- Simon, J.C., P.E Baker, and H. Baker. 1997. Maui Parrotbill (*Pseudonestor xanthophrys*). In *The Birds of North America*, no. 311 (A. Poole and F. Gill, eds.). Academy of Natural Science, Philadelphia, and American Ornithologists Union, Washington DC, USA. pp 1-16.
- Simon, J.C., T.K. Pratt, K E. Berlin, and J.R. Kowalsky. 2000. Reproductive ecology of the Maui Parrotbill. *Wilson Bulletin* 112:482-490.
- Stein V. 2007. Critical assessment of habitat for release of Maui Parrotbill. Honolulu (HI): Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Department of Botany. Honolulu, HI. Technical Report, 146.
- U.S. Fish and Wildlife Service. 2006. Revised recovery plan for Hawaiian forest birds. USFWS Region 1, Portland, OR, 622 pp.
- van Riper, C. III, S.G. van Riper, M.L. Goff, and M. Laird. 1986. The epizootiology and ecological significance of malaria in Hawaiian land birds. *Ecological Monographs* 56:327-344.

Warner, R.E. 1968. The role of introduced diseases in the extinction of the endemic Hawaiian avifauna. *Condor* 70:101-120.

Warren, C.C., P.J. Motyka, and H.L. Mounce. 2015. Home range sizes of two Hawaiian honeycreepers: implications for proposed translocation efforts. *Journal of Field Ornithology* 86:305-316. doi:10.1111/jofo.12123

Warren, C.C., L.K. Berthold, H.L. Mounce, J.T. Foster, and L.C. Sackett. *In prep.* Evaluating the risk of avian disease in reintroducing the endangered Kiwikiu (Maui Parrotbill: *Pseudonestor xanthophrys*) to Nakula NAR, Maui, Hawai'i. Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Department of Botany. Honolulu, HI. Technical Report.

Warren, C.C., H.L. Mounce, L.K. Berthold, C. Farmer, D.L. Leonard, and F. Duvall. 2019. Experimental restoration trials in Nakula Natural Area Reserve in preparation for reintroduction of Kiwikiu (*Pseudonestor xanthophrys*). Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Department of Botany. Honolulu, HI. Technical Report, 199.

Appendix I. Master timeline for Kiwikiu reintroduction

2018 Completed Tasks	NARS commission presentation. Secured funding. Finalized Reintroduction Plan. Conducted baseline tracking tunnel survey. Installed predator grid. Run predator traps (A24s are not set). Constructed prototype field aviary and feeder in Olinda. Finalized design and ordered materials. Constructed release platforms for aviaries in Nakula.
2019	Community Meeting/Communication with landowners. Construct telemetry towers when equipment becomes available, prior to October
January 2019	Finalize and order telemetry supplies.
2019 February	MFBWG conference call meeting
2019 March	Nakula predator control (all traps), tracking tunnels, planting Test harnesses and transmitters on captive-bred birds.
2019 April & May	Nakula point counts, banding, radio tracking HAAMs Filming/Production for Community Outreach.
2019 Summer	Nakula predator trapping, tracking tunnels, planting, possible mosquito control?
2019 September	Nakula predator trapping, planting, possible mosquito control? Install aviaries on the platforms in Nakula. Hanawi camp prep, trail work, scouting
2019 Oct	Nakula: predator trapping and quarterly tracking tunnels.

	<p>Move captive-bred birds to Nakula release sites. Provide supplemental food in release aviaries.</p> <p>Begin capturing wild birds in Hanawi.</p>
2019 November	<p>Move Hanawi wild birds to Nakula release sites.</p> <p>Staggered releases of pairs.</p> <p>Supplemental feeding.</p> <p>Radio tracking Kiwikiu.</p> <p>Predator Control.</p>
2019 Dec to 2020 Feb	<p>Monitoring and tracking released birds.</p> <p>Provide supplemental food as long as birds rely on it.</p> <p>Continue predator trapping and quarterly tracking tunnels.</p>
2020 March on	<p>Continue resighting and behavioral observations of Kiwikiu.</p> <p>Point-counts in Nakula NAR (April-May).</p> <p>Continue predator trapping and quarterly tracking tunnels.</p> <p>Evaluation of release and planning for future translocations.</p>

Appendix II. Equipment Needs for Capture Site

Equipment:

1 tent for Bird Holding area
13 collapsible holding cages
Brackets for the shelf, 1" EMT for shelf
2 folding field tables
55 3" D cups
26 4" plant saucers
2 hand nets for trapping birds out of holding cage
1 hand net for catching birds that escape into Bird Holding area.
2 plastic wash pans
2 Ohaus 120 scales
1 measuring spoon set
Pans for mealworms

Supplies

Mealworms
Bran meal
Repashy
Chlorox
Dawn dish soap
Scrub pads
Nekton I

Potential sources of equipment and supplies

<http://www.ezcorners.com/index.asp>
<https://www.homedepot.com/p/1-in-EMT-Conduit-101568/100400409>
<https://www.campmor.com/c/coleman-outdoor-compact-table>
https://www.backcountrygear.com/nrs-roll-a-table-blue-one-size.html?utm_keyword=NRS9R10490&utm_medium=cpc&utm_campaign=roi+plas+-+all+products
<https://www.outdoorgearlab.com/reviews/camping-and-hiking/camping-table/alps-mountaineering-dining-table-regular>
<http://www.avian.nl/EN/delikat-insectivores-di.html>
<http://www.wombaroo.com.au/birds/finch/insectivore-rearing-mix>
<http://www.mazuri.com/mazuriinsectivorediet5MK8.aspx>
<https://www.haiths.com/prosecto-insectivorous-wbsf01004/>
https://www.birdsupplynh.com/catalog/product_info.php?products_id=3271&osCsid=9ee52e164930e887715dac0f5f9d9f81

Appendix III. Equipment Needs for Release Site