NĀ PUA MAKANI WIND ENERGY PROJECT

Habitat Conservation Plan

FY 2022 Annual Report

(July 1, 2021 – June 30, 2022)

Prepared for:

Nā Pua Makani Power Partners, LLC

Prepared by:

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July 2022

Incidental Take License: ITL-21/Incidental Take Permit: TE63452B-0

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1.0 Introduction

Nā Pua Makani Power Partners, LLC (NPMPP) developed a Habitat Conservation Plan (HCP; Tetra Tech 2016) for the Nā Pua Makani Wind Energy Project (Project) and received a U.S. Fish and Wildlife Service (USFWS) incidental take permit on September 7, 2018 (ITP; TE63452B-0) and the Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) incidental take license on April 30, 2019 (ITL; ITL-21). Covered Species include:

- Hawaiian hoary bat (*Lasiurus cinereus semotus*) or ʻōpeʻapeʻa,
- Newell's shearwater (*Puffinus newelli*) or ʻaʼo,
- Hawaiian goose (*Branta sandvicensis*) or nēnē,
- Hawaiian duck (*Anas wyvilliana*) or koloa maoli,
- Hawaiian coot (*Fulica alai*) or ʻalae keʻokeʻo,
- Hawaiian gallinule (*Gallinula chloropus sandvicensis*) or ʻalae ʻula,
- Hawaiian stilt (*Himantopus mexicanus knudseni*) or ae'o, and
- Hawaiian short-eared owl (*Asio flammeus sandwichensis*) or pueo.

Project construction began in FY 2019 and continued into FY 2021. Concrete pouring for the first turbine foundation began on April 30, 2019 and coincides with the effective start date of the ITL. Project commissioning began on August 16, 2020, and commercial operations began on December 11, 2020. During commissioning Project components and the interconnection and transmission capabilities of the system are tested before the initiation of full commercial operation.

On behalf of NPMPP, Tetra Tech, Inc. (Tetra Tech) has prepared this report to describe activities relating to the Project HCP for the State of Hawaii fiscal year (FY) 2022,[1] from July 1, 2021, through June 30, 2022, pursuant to the terms and obligations of the approved HCP, ITL, and ITP. The Project has previously submitted annual HCP progress reports to DOFAW and USFWS for FY 2019 through FY 2021 (Tetra Tech 2019a, Tetra Tech 2020a, Tetra Tech 2021).

2.0 On-Site HCP-Related Management

2.1 Avoidance and Minimization

NPMPP has worked to minimize risk to wildlife through avoidance and minimization measures outlined in the HCP. In addition, NPMPP has implemented monitoring approaches to document potential impacts to wildlife.

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[1] Fiscal year references in this report refer to the State of Hawaii fiscal year, which begins every July 1st and ends every June 30th.

To minimize potential impacts to wildlife, on-site lighting at the O&M building and substation is shielded and/or directed downward, triggered by a motion detector, and fitted with non-white light bulbs. Lighting is only used when workers are at the site at night. No night work requiring lights that could attract wildlife occurred in FY 2022.

NPMPP implements low wind speed curtailment to reduce potential impacts to Hawaiian hoary bats. Implementation included increasing manufacturer's recommended cut-in speeds to 16 feet per second (ft/s; 5 meter per second [m/s]) and feathering turbine blades into the wind below 16 ft/s (5 m/s). Low wind speed curtailment is instituted March – November between sunset and sunrise; in FY 2022 this included implementation July – November 2021 and March – June 2022. In addition to the intended benefit of reducing bat fatalities, low wind speed curtailment reduced risk to Covered Species such as the Newell's shearwaters and Hawaiian short-eared owl, which could transit the Project at night.

NPMPP installed an NRG ultrasonic acoustic bat deterrent system on turbines 2, 3, 4, and 6 prior to the initiation of commercial operations to further reduce the collision risk to the Hawaiian hoary bat. These turbines were selected due to their proximity to forest edge and gulch habitat, which have been correlated with increased bat activity.

2.2 Downed Wildlife Monitoring

On August 26, 2020, the Project initiated standardized carcass searches according to the Project's Post-construction Mortality Monitoring (PCMM) Implementation Plan (Tetra Tech 2020b), concurrent with the beginning of periodic turbine testing during the Project commissioning phase (August 16, 2020). While input had not yet been received from USFWS or DOFAW on the PCMM Implementation Plan, there was a need to implement a standardized monitoring approach suitable for yielding robust statistical estimates of take.

NPMPP and Tetra Tech conducted a site visit with the USFWS and DOFAW on April 16, 2021, and the agencies provided input on the PCMM Implementation Plan in May and June 2021. A revised plan was submitted in October 2021, followed by additional input from the agencies and a meeting to discuss input and presentation of a proposed approach to addressing agency concerns on December 13, 2021. Over the remainder of FY 2022, NPMPP and Tetra Tech worked to incorporate additional information and commitments to address agency questions and concerns. These steps included hiring an additional canine search team and identifying ways to incorporate supplemental (agricultural) search areas into the standardized analysis. Field testing for these supplemental area searches began in June 2022. Once these methods have been refined, the PCMM Implementation Plan will be updated and submitted to USFWS and DOFAW for review.

For the majority of FY 2022 downed wildlife monitoring at the Project consisted of standardized fatality monitoring according to the Project's PCMM Implementation Plan (Tetra Tech 2020b). The PCMM Implementation Plan describes how the Project implements the PCMM program provided in the HCP based on the Project construction footprint, current land use patterns, and topography. The elements of the PCMM program used to estimate fatality rates of Covered Species include:

- The specific delineation of systematic search areas,
- Search frequency,
- Bias correction testing protocols (see sections 2.3 – 2.4 below),
- Methods and results for the calculation of the proportion of the carcass distributions planned for searching, and,
- A commitment to perform supplemental searches (not used in the statistical analysis for estimating take of Covered Species) within agricultural areas in the vicinity of turbines 6 – 9.

Based on recommendations from DOFAW and USFWS to increase the search areas around the turbines, NPMPP and Tetra Tech began field testing protocols in FY 2022 that will allow for the evaluation of bias correction data within supplemental search areas and incorporating search results from supplemental search areas where consistent and effective searching can take place into the statistical analyses. This process included extensive outreach to the farmers working adjacent to the Project turbines, hiring of an additional canine handler, and significant logistical and methodological adjustments to ensure that health and safety requirements are met, landowner and farmer relationships are maintained, and quality data can be collected. Supplemental searches and associated bias correction trials in these areas were initiated in June 2022 and incorporated into the results provided in this report (sections 2.2, 2.3, and 2.7).

Under the PCMM Implementation Plan as performed in FY 2022, NPMPP conducted weekly searches with trained canine search teams within systematic search areas (Figure 1). These systematic search areas consist of areas that were cleared and graded during Project construction at each of the Project's eight turbines and can be practicably maintained in low-growing vegetation through mowing. Cleared and maintained areas include roads and pads and additional areas cleared during construction on low or moderate slopes that can be practicably maintained. In addition, as site conditions allowed, a canine search team performed supplemental searches within active agricultural areas. With the addition of associated bias correction trials (see sections 2.3 – 2.4) in June of 2022, any such areas that can be searched consistently during any quarter will be incorporated into future fatality estimate(s); for FY 2022 we performed associated bias correction trials and searches in June and incorporated consistently searched supplemental search area results into the analysis of the take estimate (Section 2.7).

Figure 1. Project Infrastructure and HCP Implementation Components

Supplemental areas are not always searchable,[2] can be highly variable in terms of the vegetative growth, evolve quickly, and are relatively small. These challenges mean that it is likely that not all supplemental search areas will be used in the statistical analyses. Nevertheless, such supplemental search areas will continue to be evaluated and considered for incorporation in future analyses and are likely to provide opportunities for an improved understanding of the carcass distribution at the site and may facilitate the establishment of more robust lower bounds of fatality estimates.

2.3 Carcass Persistence Trials

Within the systematic search areas, eighty, 28-day carcass persistence trials were conducted in FY 2022 using black rats (*Rattus rattus*) for Hawaiian hoary bat surrogates, and chukars (*Alectoris chukar*) or wedge-tailed shearwater (*Ardenna pacifica*) carcasses collected or procured under the Project's Special Purpose Utility Permit (MB79835D-0) and Hawaii Protected Wildlife Permit (WL20-18) as surrogates for the avian Covered Species. Within supplemental search areas, an additional twelve, 28-day carcass persistence trials were conducted in Quarter 4 of FY 2022. The probability that a carcass persisted until the next search is reported in Table 1.

Table 1. Cumulative Searcher Efficiency and Carcass Persistence Trial Results FY 2022

Size	Search Area	Total Trials		Mean (95% Confidence Interval)	
		Searcher Efficiency[1]	Carcass Persistence	Searcher Efficiency (Proportion Detected)[2]	Probability of Persistence to the Next Search (r)[3]
Bat Surrogate	Systematic	50	40	0.96 (0.88 – 0.99)	0.83 (0.73 – 0.90)
Medium Bird	Systematic	45	40	1.00 (0.95 – 1.00)	0.99 (0.97 – 1.00)
Bat Surrogate	Supplemental	7	6	1.00 (0.71 – 1.00)	0.59 (0.24 – 0.89)
Medium Bird	Supplemental	4	6	1.00 (0.56 – 1.00)	0.86 (0.61 – 0.96)

1. Available for detection.
2. Estimates and 95 percent confidence interval calculated using Dalthorp et al. (2017) single year module.
3. The estimate of *r* is reported in lieu of carcass persistence time, as *r* provides a more informative portrayal of the effect of carcass persistence on fatality estimates, incorporating information from the carcass persistence distribution and the search interval in a single variable. Estimates and confidence interval for *r* calculated using Dalthorp et al. (2017) single year module.

2.4 Searcher Efficiency Trials

Within systematic search areas, a total of 99 searcher efficiency trials over 12 trial days were administered during FY 2022. Similar to the carcass persistence trials, black rats were used as surrogates for bats, and chukars, wedge-tailed shearwaters, or cattle egrets (*Bulbulcus ibis*) were

[2] Some supplemental search areas regularly or occasionally have loose dogs which threaten the safety of the canine search team. Similarly, other conditions, such as the periodic application of herbicide or other chemicals, may make searching a supplemental search area unsafe or impractical during a particular week.

used as surrogates for avian Covered Species. Searcher efficiency trials occurred approximately monthly throughout the year. All trials tested canine search teams in FY 2022, as no un-aided human searches occurred in FY 2022. Of the 99 trials placed, 4 bat surrogates were not available for detection.[3] Within supplemental search areas, an additional 12 searcher efficiency trial carcasses were placed in Quarter 4 of FY 2022. Of these, one avian Covered Species surrogate was unavailable for detection. The probability that an available carcass would be detected is reported in Table 1.

2.5 Vegetation Management

Mowing within each of the eight search plots is currently occurring on an as-needed basis[4]; staff evaluate and perform necessary vegetation management around turbines weekly following the completion of scheduled fatality monitoring searches. This effort maintains vegetation at heights below approximately 8 inches within the systematic search areas at each turbine.

2.6 Scavenger Trapping

Nā Pua Makani Power Partners has contracted scavenger control for the site. Traps are checked approximately every two weeks. Active trapping occurred at all eight turbines and throughout the Project area using 90 DOC250 and 10 Steve Allan traps. The scavenger control program documented the removal of 384 mongooses (*Herpestes auropunctatus*), 90 rats (*Rattus* spp.), 20 feral cats (*Felis cattus*), one mouse (*Mus musculus*), and 33 non-target species (spotted dove [*Spilopelia chinensis*], common myna [*Acridotheres tristis*], cane toad [*Rhinella marina*]) in FY 2022. Trapping rates were relatively stable over time and are reported in Table 2.

Table 2. Scavenger Trapping Results at the Project in FY 2022

Trap Check Date	Mongooses per Trap	Rats per Trap	Cats per Trap	Non-Target Species per Trap	Active Traps per Check[1]
7/9/2021	0.25	0.01	0.00	0.03	97
7/23/2021	0.22	0.05	0.00	0.03	96
8/6/2021	0.18	0.04	0.01	0.01	99
8/20/2021	0.25	0.00	0.03	0.01	99
9/3/2021	0.10	0.03	0.01	0.00	97
9/17/2021	0.22	0.09	0.01	0.01	97
10/1/2021	0.14	0.07	0.00	0.00	95
10/15/2021	0.14	0.05	0.00	0.00	98
10/29/2021	0.11	0.02	0.02	0.02	95

[3] Carcasses not available for detection are those that were not detected by the search team, and upon investigation by the testing proctor, could not be found, indicating the carcass had likely been scavenged prior to the search.

[4] On average the systematic search areas are mowed every other week.

Trap Check Date	Mongooses per Trap	Rats per Trap	Cats per Trap	Non-Target Species per Trap	Active Traps per Check[1]
11/12/2021	0.13	0.01	0.00	0.01	96
11/19/2021	0.08	0.03	0.00	0.00	95
12/11/2021	0.23	0.05	0.00	0.01	95
12/17/2021	0.13	0.02	0.02	0.00	91
1/7/2022	0.16	0.06	0.01	0.00	95
1/21/2022	0.13	0.06	0.00	0.00	88
2/4/2022	0.14	0.04	0.01	0.04	97
2/18/2022	0.12	0.01	0.01	0.00	85
3/5/2022	0.13	0.06	0.01	0.02	93
3/18/2022	0.10	0.02	0.00	0.05	88
4/1/2022	0.16	0.03	0.00	0.00	96
4/14/2022	0.09	0.01	0.01	0.00	90
4/29/2022	0.19	0.04	0.00	0.02	89
5/13/2022	0.22	0.07	0.00	0.00	85
5/27/2022	0.13	0.03	0.02	0.01	93
6/11/2022	0.06	0.01	0.00	0.01	94
6/25/2022	0.14	0.01	0.01	0.00	88
Mean (SD)	0.15 (0.05)	0.04 (0.02)	0.01 (0.01)	0.01 (0.01)	93.5 (4.1)
1. Traps were less than 100 when trap(s) were damaged, lost, or malfunctioned.					

2.7 Documented Fatalities and Monitoring Results

All observed downed wildlife were handled and reported in accordance with the USFWS and DOFAW Downed Wildlife Protocol (DOFAW and USFWS 2020). NPMPP documented 38 wildlife incidents in FY 2022 (Appendix 1). One Covered Species, a Hawaiian hoary bat, was found in FY 2022 (Quarter 1). Five Migratory Bird Treaty Act (MBTA) species fatalities were documented, two house finches (*Haemorhous mexicanus*), one cattle egret, one red-tailed tropicbird (*Phaethon rubricauda*), and one wedge-tailed shearwater. The other wildlife incidents included 26 spotted doves, three zebra doves (*Geopelia striata),* two red-whiskered bulbuls *(Pycnonotus jocosus*), and one warbling white-eye (*Zosterops japonicus*).

Various factors affect how the number of observed fatalities is scaled to estimate the direct take of Covered Species at the Project. Unobserved fatalities are due to three primary factors:

- Carcasses may be scavenged before searchers can find them,
- Carcasses may be present and not detected by searchers, and
- Carcasses may fall outside of the search area.

Sections 2.3 and 2.4 describe methods that are used to estimate the effect of the first two factors. To evaluate the contribution of the proportion of the search area searched to the estimate, we used an agency recommended ballistics model (Hull and Muir 2010) and GIS-delineated search area spatial data to estimate the proportion of the carcass distribution searched.

2.7.1 Hawaiian Hoary Bat

Estimated Take

One Hawaiian hoary bat fatality has been observed at the Project since the Project began testing turbine operations (commissioning) in August 2020. The single documented Hawaiian hoary bat fatality was found on September 22, 2021, during a regular search. The carcass was detected 14 meters from the base of Turbine 6 and was collected and transferred to the U.S. Geological Survey (USGS) for genetic sexing. The results of the testing identified the individual as a female (Pinzari and Bonaccorso 2018). The observed Hawaiian hoary bat fatalities by fiscal year are listed in Table 3.

Table 3. Observed Hawaiian Hoary Bat Fatalities at the Project through FY 2022

Fiscal Year	Hawaiian Hoary Bat Observed Direct Take	Hawaiian Hoary Bat Incidental Fatality Observations	Total
2021	0	0	0
2022	1	0	1
Total	**1**	**0**	**1**

Cumulative take is estimated from three components: (1) observed direct take (ODT) during protocol (standardized) fatality monitoring, (2) unobserved direct take (UDT), and (3) indirect take. The Evidence of Absence software program (EoA; Dalthorp et al. 2017), an agency-approved analysis tool for analyzing direct take, uses results from bias correction trials and ODT to generate an upper credible limit (UCL) of direct take (i.e., ODT + UDT). USFWS and DOFAW have requested that estimates of direct take be reported at the 80 percent UCL. Direct take values from this analysis can be interpreted as: there is an 80 percent probability that actual direct take at the Project over the analysis period was less than or equal to the 80 percent UCL. Associated indirect take is estimated based on the sex and age characteristics of bat fatalities found at the Project, and the life history characteristics of (assumed to be representative of) the Hawaiian hoary bat, as described in the Project's approved HCP and current agency guidance (USFWS 2016).

The total cumulative estimated bat take (including indirect take) from the start of Project commissioning (when periodic turbine operation began) through FY 2022 is summarized in Table 4. Input values used in the EoA multi-year analysis are provided in Table 5.

Table 4. Cumulative Take Estimation for Hawaiian Hoary Bat through FY 2022

A: Observed Direct Take Used in Analysis	B: Incidental Observed Take	C: 80% Upper Credible Limit of Estimated Direct Take[1]	D: UDT (C – A – B)	E: Estimated Indirect Take (Adult Equivalents)[2],	Total Estimated Adult Take (C + E)
1	0	3	2	1	4

1. Multi-year EoA analysis (Dalthorp et al. 2017) based on FY 2021 –FY 2022 data.
2. Overall indirect take for the Project is the rounded-up value calculated using the USFWS (2016) methodology as described in the text.

Table 5. Input Values for Multi-Year Analysis of Hawaiian Hoary Bat Take

Modelling Period	Weight	Search Fatalities	Ba[1]	Bb[1]	$\hat{g}$	$\hat{g}$ 95% CI
FY 2021	0.87	0	81.18	74.92	0.520	0.442–0.598
FY 2022[2]	1.00	1	144.3	115.2	0.556	0.492–0.616

1. EoA stores the parameters of the beta distribution to 4 significant digits; however, model imprecision suggests these results should be reported to a maximum of 3 digits (Dan Dalthorp, USGS, pers. comm. January 2020).
2. Results from FY 2022 include results from searches within the systematic search areas and nine consistently searched supplemental search areas combined into a single estimate through the multi-class module in EoA (Dalthorp et al. 2017).

The estimated direct take (ODT + UDT) for the one Hawaiian hoary bat fatality found between the start of operation and end of FY 2022 (June 30, 2022) is less than or equal to 3 bats (80 percent UCL). Details of the estimated direct take parameters are in Appendix 2.

Indirect take is estimated to account for the potential loss of future individuals (offspring) that may occur as the result of the loss of an adult female through direct take during the breeding period when females may be pregnant or supporting dependent young. Indirect take for the Project is calculated using the USFWS (2016) guidance as follows:

- **Total Juvenile Take Calculated from Observed Female Take (April 1 – September 15)**
  - 0 (observed females) * 1.8 (pups per female) = 0 juveniles[5]
- **Total Juvenile Take Calculated from Observed Unknown Sex Take (April 1 – September 15)**
  - 0 (observed unknown sex) * 0.5 (assumed sex ratio) * 1.8 (pups per female) = 0 juveniles
- **Total Juvenile Take Calculated from Unobserved Take**

[5] As the observed fatality in FY 2022 occurred outside the period when females have dependent young, no indirect take is associated with that individual.

  - 2 (unobserved direct take) * 0.5 (assumed sex ratio) * 0.25 (proportion of calendar year females could be pregnant or have dependent pups) * 1.8 (pups per female) = 0.45 juveniles

- **Total Calculated Juvenile Indirect Take** = 0.45
- **Total Adult Equivalent Indirect Take =** 0.3 (juvenile to adult conversion factor) * 0.45 = 0.135

The UCL for cumulative Project take of the Hawaiian hoary bat at the 80 percent credibility level is 4 adult bats (3 [estimated direct take] + 1 [estimated indirect take]). That is, there is an approximately 80 percent probability that actual take at the Project at the end of FY 2022 is less than or equal to 4 bats.

Projected Take

Evidence of Absence (EoA) includes a module that allows users to project future estimates of mortality based on results of past fatality monitoring. Due to the inherent uncertainty of these projections (including the potential future contribution of indirect take) and the amplification of this uncertainty resulting from the use of the 80 percent UCL as the estimate of take for regulatory compliance, long term projections have limited utility. Nevertheless, they do help gauge the likelihood of permitted take exceedance, and may help operators in their mitigation planning, assuming future management and monitoring conditions can be reasonably estimated.

NPMPP projected take through the end of the permit term using the fatality monitoring data collected through FY 2022. The objective of this analysis was to evaluate the potential for the Project to exceed the permitted take limit at the 80 percent UCL prior to the end of the permit term (Appendix 2).For this analysis, the detection probability for future years is assumed to be constant at 0.556 (95 percent CI = [0.495, 0.616]). As future indirect take is unknown and will potentially vary based on the timing of ODT, we assumed total indirect take for the Project over the permit term would be a maximum of 3 adult equivalents (10 juveniles based on assumed Hawaiian hoary bat survival rates; USFWS 2016), or 5.8 percent of the permitted take. Currently, the proportion of total take that is attributable to indirect take is 4.3 percent. Assuming 3 adult bat equivalents are attributed to the Project as indirect take, the permitted direct take under the Project's ITP and ITL would be 48 bats (i.e., 51 permitted take – 3 indirect take = 48 direct take).

Based on the analysis described above and presented in Appendix 2, there is a 79.0 percent chance that the 80 percent UCL of cumulative take will not be exceeded during the permit term. The probability of permit exceedance at the Project may be overestimated given that the estimate of indirect take is high.

2.8 Invasive Species Management Surveys

In FY 2019 NPMPP developed an invasive species management plan to limit the potential impacts of invasive species (Tetra Tech 2019b). Consistent with HCP requirements, NPMPP coordinated with the O'ahu Invasive Species Committee to identify and implement measures to minimize the risk of introducing devil weed (*Chromolaena odorata*) to the Project area. Approaches to minimize risk include periodic site inspections by qualified personnel to search for the presence of plants and cleaning of equipment used in the Project area.

During an invasive plant species survey of the Project in Quarter 2 FY 2022, biologists detected devil weed in the same distribution as the Quarter2 FY 2021 surveys (turbines 3, 6, and 7, as well as near Kamehameha Highway and along the road between the Mālaekahana- and Department of Land and Natural Resources-owned portions of the Project), with one additional systematic search area impacted (Turbine 4). Some mature plants were found at locations previously identified during the Quarter 2 FY 2021 surveys and outside of the systematic search areas. Following initial detection of devil weed at the site, NPMPP coordinated with the Oʻahu Invasive Species Committee (OISC) to verify appropriate control measures for this species within the Project's disturbance footprint and has continued to implement this approach in FY 2022.

Field observations suggest devil weed is established beyond the Project's disturbance footprint. The OISC has reported the presence of a known infestation in the vicinity of the Project prior to Project construction. Based on current data, OISC does not believe eradication of devil weed is possible and requested that NPMPP manage the species to the extent practicable, using best practices identified in the Project's invasive species management plan. NPMPP manages the devil weed within the Project footprint through a combination of hand removal, herbicide, and mowing. Herbicide cannot be used within the systematic search areas to protect the health and safety of the canine search team. Hand pulled specimens are bagged and incinerated. NPMPP continues to monitor and manage known infestations and monitor for the presence of devil weed in new locations. The canine search team and project biologist follow decontamination protocols to clean field gear following potential exposure to devil weed seed sources. This approach should reduce the risk of further expansion of the colony. To date regular mowing of affected areas within the systematic search areas have kept the plants from forming flowers or seeds.

2.9 Wildlife Education and Incidental Reporting System

NPMPP implemented a Wildlife Education and Incidental Reporting Program for Project staff working at the Project. This training enables staff to identify the Covered Species that may occur at the Project site by providing staff with printed reference materials that include photographs of each of the Covered Species, information on their biology and habitat requirements, threats to the species onsite, and avoidance and minimization measures of the HCP. Project staff are responsible for awareness of wildlife activity onsite, responding to and treating wildlife appropriately, documenting any Project-related wildlife incidents, and reporting any downed wildlife to the on-site manager.

Seven Project personnel or subcontractors were trained through this program in FY 2022. Downed wildlife observations found during standardized searches were supplemented by 17 incidental downed wildlife observations reported in FY 2022 by Project personnel trained through the Wildlife Education and Incidental Reporting Program (Table 6).

Table 6. Wildlife Education and Incidental Reporting Program Trainings

Date	Affiliation	Number of Trainees
10/4/2021	Tetra Tech	1
11/6/2021	AWS	1
11/16/2021	ERSG	2
11/19/2021	Vestas	1
3/3/2022	Tetra Tech	1
5/10/2022	Vestas	1

3.0 Mitigation and Related Activities

The Project's mitigation requirements are described in Section 6.0 of the HCP (Tetra Tech 2016).

3.1 Hawaiian Hoary Bat

3.1.1 Poamoho Management Area Research and Management Plans

The mitigation plan for the Hawaiian hoary bat in the HCP includes preparation of research and management plans targeting actions that will improve and protect bat habitat in the Poamoho Management Area and study the effectiveness of habitat restoration activities on improving the availability of bat food resources, increasing bat activity, or other appropriate variables. The associated research and management plans have been submitted and reviewed by DOFAW and USFWS. NPMPP and Tetra Tech are working with the Ko'olau Mountain Watershed to address agency comments and submit revised versions for approval by USFWS, DOFAW, and the Endangered Species Recovery Committee (ESRC).

3.1.2 Bat Deterrent Research Plan

The ITL includes a special condition requiring NPMPP to perform research focused on bat deterrence measures with the goal of reducing the bat take at wind turbines. NPMPP and Tetra Tech have consulted with DOFAW on their priorities for this research, potential challenges, and possible research approaches. Based on this input, NPMPP and Tetra Tech are preparing a research plan for review and approval by DOFAW. Results of this research will be reported in the HCP annual reports for the duration of the approved research project.

3.1.3 On-Site Acoustic Surveys

The Project commenced commercial operation on December 11, 2020. As part of the HCP the Project commits to performing acoustic monitoring for Hawaiian hoary bat activity for an undefined period during operation (Section 4.2.2 of the HCP, Tetra Tech 2016). Post construction monitoring for bat activity began in September 2020 and is currently in the second monitoring year. Monitoring was conducted at four locations (turbines 1, 4, 6, and 9; Figure 2) using ground-based recording units. Recording units consisted of a Song Meter SM4BAT-FS ultrasonic acoustic recorder equipped with high frequency microphones (SMM-U2; Wildlife Acoustics, Inc., Maynard, Massachusetts), elevated 3 meters above the ground on poles and powered by 12 v/36 amp-h batteries connected to 30 w/12 v Sun Saver Solar Panels (Morningstar Corp, Newton, Pennsylvania). All units were set to record nightly bat activity beginning 1 hour before sunset and end 1 hour after sunrise. Monitoring site locations were selected to provide the best spatial distribution across the Project and representation of the habitats (e.g., mature forest, agriculture, and gulch).

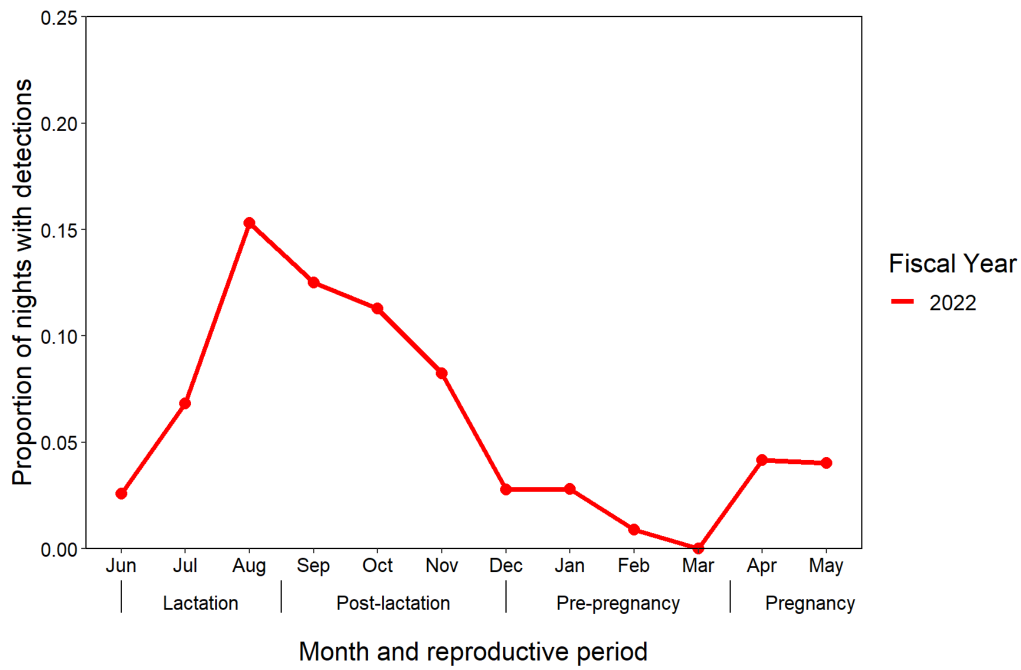

Figure 2. Monthly Bat Acoustic Activity at Nā Pua Makani for FY 2022 with Corresponding Reproductive Periods

The objective of acoustic monitoring is to better understand the annual, seasonal, and site variation in bat activity at the Project. A linear model (LM) was used to test for a difference in monthly sampling periods between years as well as a difference in the annual detection rate during the FY2021 and FY2022. Analysis of Variance (ANOVA) was used to test for differences in mean detection rates between sites. Data were normalized using an Ordered Quantile Normalization transformation (ORQ). The distribution of residuals from the LM were examined to check for violations of model assumptions. All tests were 2-tailed, employed an alpha value of 0.05, and were conducted in the program R version 4.1.2 (R Core Team 2022).

Bat activity at the Project was generally low. Across the four turbines monitored during FY 2022 (June 2021 to May 2022), Hawaiian hoary bats were detected on 83 nights out of the 1,357 (6.12

percent) detector-nights sampled.[6] Detection rates were highest from July through November during the lactation and post-lactation reproductive periods, with a peak occurring in the month of August (Figure 3). Following November, bat activity continued to decline throughout the pre-pregnancy reproductive period, with no detections observed in the month of March. Detection rates increased again in April and May of the pregnancy reproductive period (Figure 3).

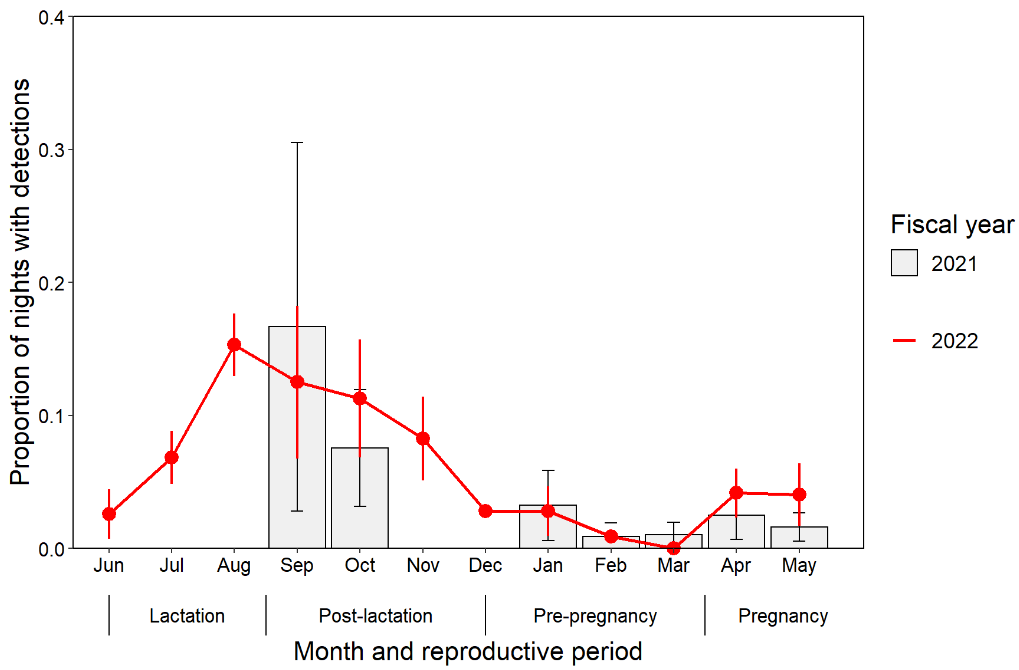

Figure 3. Monthly Bat Acoustic Activity at Na Pua Makani for FY 2021 and FY2022 with Corresponding Reproductive Periods

The annual detection rate during the FY 2022 monitoring period (6.12 percent) was higher than the observed annual detection rate (2.68 percent) for the previous FY 2021 monitoring period (Table 7), although not significantly different (LM: $t_{3,84} = 0.00$, $P > 0.997$). The seasonal trend observed in FY 2022 was similar to the seasonal trend observed in FY 2021 (Figure 4), and there was no significant difference in detection rates among similar month-long monitoring periods sampled in FY2021 and FY2022 (LM: $t_{3,84} = 0.62$, $P > 0.536$). The higher annual detection rate observed during the FY 2022 monitoring period was likely caused by the inclusion of the months June, July, and

[6] USFWS and DOFAW approved the reporting of bat acoustic monitoring results on a June 1 – May 31 annual cycle to allow for adequate data review and analysis prior to the annual report submittal deadline of August 1.

August, that were not sampled in FY 2021[7], as these months are known to have higher rates of detections.

Table 7. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections at Four Ground-based Detectors Sampled from FY 2021 through FY 2022.

Sampling Period	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2021 (September 2020 — May 2021)	969	26	0.027
FY2022 (June 2021 - May 2022)	1,357	83	0.061

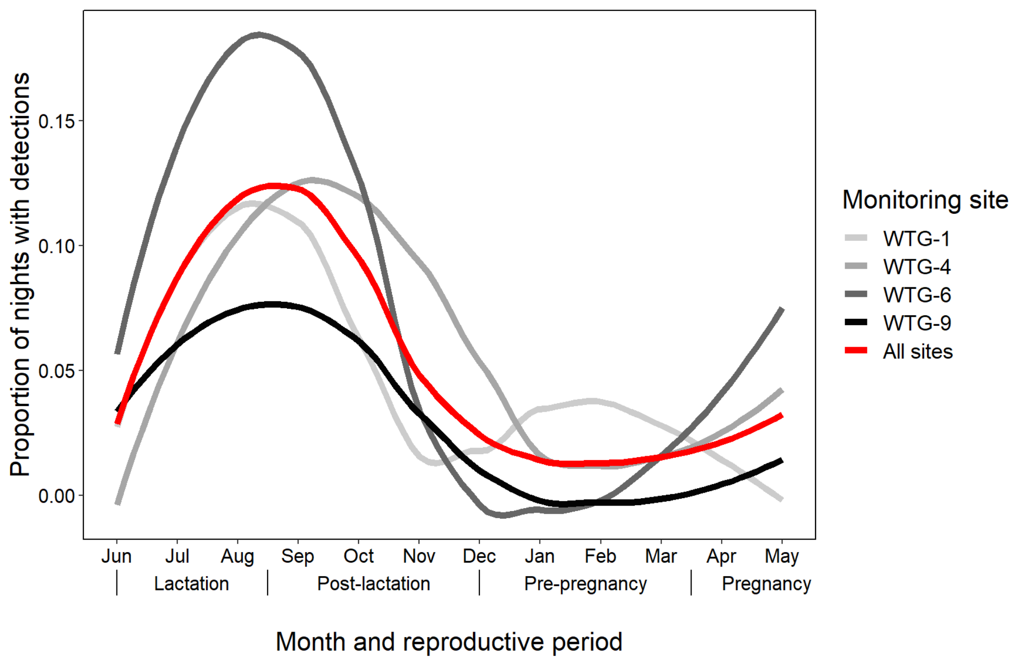

Figure 4. Site-Specific Variation in Mean Detection Rates for Each Month with Corresponding Reproductive Periods. Trend Lines are fitted with a Loess Smoothing Curve.

Note: Trend Lines are fitted with Loess smoothing curve; see Figure 2 for spatial context.

Variation in mean detection rates between the four monitoring locations was minimal and not significant (ANOVA: $F_{3,80} = 0.95$, $P = 0.42$). During the lactation and post-lactation reproductive periods mean detection rates were highest at turbines 6, 4, and 1. In October detections rates increased at Turbine 4, while decreasing at all of the other sites (Figure 5). Throughout the pre-

[7] Acoustic recording units were deployed as soon as practicable following construction and prior to commercial operation

pregnancy period bat activity primarily occurred at Turbine 1 with low levels of activity at Turbine 4. No activity was observed at Turbine 6 and 9 during pre-pregnancy reproductive period. During the pregnancy reproductive period activity decreased at Turbine 1 while increasing at all of the other sites (Figure 5).

3.2 Newell's Shearwater

NPMPP provided required mitigation funds to the National Fish and Wildlife Foundation (NFWF) on September 22, 2020. USFWS has reported that NFWF has not funded programs with these funds yet, but the funds are intended to be used in combination with other funds for a larger project on Kaua'i (pers. comm. Adrienne Ouellette, July 2022). NPMPP will report results from the Newell's shearwater mitigation efforts once NFWF identifies and funds an appropriate mitigation project.

3.3 Hawaiian Goose

Based on NPMPP's consultation with DOFAW and USFWS regarding the extirpation of the Hawaiian goose from O'ahu prior to the construction and operation of the Project, NPMPP will address updates to the mitigation framework for this species in the HCP major amendment (see Section 4.0).

3.4 Hawaiian Waterbirds

Adaptive management of the Hawaiian waterbird mitigation program is required (see Section 4.0). Based on this need, NPMPP has submitted and received agency comments on an updated Hawaiian waterbird mitigation plan. NPMPP and Tech are working with the DOFAW to address agency comments and submit a revised version for approval by USFWS and DOFAW.

3.5 Hawaiian Short-eared Owl

NPMPP provided required mitigation funds to the Endangered Species Trust Fund on September 18, 2020, and an MOU for use of the funds and reporting requirements was finalized with DOFAW on February 18, 2021. DOFAW used the funds provided by NPMPP to fund a graduate research project on Hawaiian short-eared owl breeding ecology. An interim report summarizing the research effort is provided as Appendix 3.

4.0 Adaptive Management

NPMPP has identified several adaptive management actions for the Project and has coordinated closely with USFWS and DOFAW to document needs and ensure agency support for the identified actions. Adaptive management actions identified by NPMPP include:

- Limited deployment of ultrasonic acoustic bat deterrents to test their efficacy at the Project;
- Modifications to the waterbird mitigation plan described in the HCP to address changed conditions at Hāmākua Marsh (the proposed mitigation site); and

- Adjustments to the Hawaiian goose mitigation framework to address changed conditions relating to the status of the Hawaiian goose on O'ahu.

In consultation with USFWS and DOFAW, NPMPP voluntarily installed ultrasonic acoustic bat deterrents on four Project turbines based on available scientific research and preliminary results from the Kawailoa Wind Farm on Oʻahu (Tetra Tech 2019c, Weaver et al. 2019). Deterrents became operational between September 17 and 28, 2020.

The deterrent system is monitored to ensure components are operating according to the manufacturer's recommendations. The effective area covered by each of the 6 deterrent units overlap, ensuring redundancy in the system in the event of a component failure. Components are replaced as soon as they fall below the manufacturer's standards, and replacement components are stored on site to ensure availability. During FY 2022, the deterrent units operated within manufacturer's recommendations 96.0 percent of the time.

USFWS and DOFAW have agreed that a modified waterbird mitigation program implemented at Hāmākua Marsh that reduces fatalities and/or increases productivity of the resident waterbird species is appropriate, as the fencing, public outreach, and staffing program identified in the HCP is no longer viable due to changed site conditions and development plans.

USFWS, DOFAW, and NPMPP have agreed that because the Hawaiian goose was extirpated from O'ahu prior to the construction and operation of the Project, the Project currently poses no risk to the Hawaiian goose. Based on input from USFWS and DOFAW, NPMPP will modify the mitigation framework for the Hawaiian goose in the HCP major amendment to clarify that if the Hawaiian goose is not at risk from the Project during the permit term, no mitigation will be required.

5.0 Agency Meetings, Consultations, and Site Visits

NPMPP and Tetra Tech communicated actively with USFWS, and DOFAW throughout FY 2022 through in-person meetings, conference calls, and e-mail communications related to the Project's HCP. The purposes of these communications included required semi-annual meetings, and planning associated with avoidance and minimization measures, monitoring, and mitigation. A summary of agency coordination is provided in Table 8.

Table 8. Summary of Key Agency Coordination and Communication in FY 2022

Date	Description	Participants/Recipients
09/28/2021	HCP Amendment planning[1]	DOFAW, USFWS, NPMPP, Tetra Tech
10/22/2021	Semi-annual HCP Implementation Review	DOFAW, USFWS, NPMPP, Tetra Tech
12/13/2021	PCMM Plan Discussion	DOFAW, USFWS, NPMPP, Tetra Tech
02/03/2022	HCP Implementation ESRC Annual Review	DOFAW, USFWS, NPMPP, Tetra Tech
06/02/2022	HCP Amendment Meeting[1]	DOFAW, USFWS, NPMPP, Tetra Tech
06/08/2022	HCP Implementation Meeting	DOFAW, USFWS, NPMPP, Tetra Tech

1. Based on initial consultation with USFWS and DOFAW, the HCP Amendment is anticipated to include two primary changes: adding the Hawaiian petrel (*Pterodroma sandwichensis*) as a Covered Species and modifying the mitigation framework for the Hawaiian goose due to the changed circumstances regarding the species' presence on O'ahu (see Section 4.0).

6.0 Expenditures

Total HCP-related expenditures for the Project in FY 2022 were $268,352. A summary of expenditures by category is provided in Table 9.

Table 9. HCP-related Expenditures at the Project in FY 2022

Category	Amount
Permit Compliance	$21,209
Fatality Monitoring	$74,771
Acoustic Monitoring for Bats	$6,858
Vegetation Management	$81,000
Scavenger Trapping	$22,955
Bat Mitigation Planning	$22,537
Other Mitigation Planning and Coordination	$23,003
HCP Amendment Planning	$7,383
Miscellaneous Costs	$8,637
Total Cost for FY 2022	**$268,352**

7.0 FY 2023 HCP Implementation Work Plan

NPMPP's FY 2023 HCP implementation work plan is provided as Table 10.

Table 10. FY 2023 HCP Implementation Work Plan

Program	Component	FY 2023			
		Q1	Q2	**Q3**	**Q4**
PCMM	Fatality Searches	Weekly searches throughout FY			
	Bias Correction Trials	Searcher efficiency and carcass persistence trials	Searcher efficiency and carcass persistence trials	Searcher efficiency and carcass persistence trials	Searcher efficiency and carcass persistence trials
	Scavenger Control	Initial trap checks every ~2 weeks, quarterly evaluation to assess changes in schedule			
	Vegetation Management	Occurs shortly after completion of searches, search areas evaluated weekly and managed as needed			
	Invasive Species Surveys		Survey Project area		
		Manage devil weed consistent with protocols			
Bat Acoustic Monitoring	Data downloads and Equipment Checks	Download data and equipment check monthly			
Bat Deterrents	Maintenance	Maintain operational deterrents on 4 turbines			
	Research Study	Submit research plan for approval	Implementation		
Mitigation	Hawaiian Goose	Addressed in HCP major amendment			
	Waterbirds	Revise and submit mitigation plan for approval	Implementation		
	Newell's Shearwater	Coordinate with USFWS regarding mitigation progress and reporting			
	Hawaiian Hoary Bat	Revise and submit research and management plans for approval	Implementation		
	Hawaiian Short-eared Owl	Coordinate with DOFAW regarding mitigation progress and reporting			
Reporting	Wildlife Incidents	As required per DOFAW and USFWS 2020 protocol			
	Regular Reporting	FY 2023 annual report	Semi-annual agency meeting	ESRC annual review	Semi-annual agency meeting

8.0 References

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Tetra Tech. 2019b. Nā Pua Makani Wind Energy Project Invasive Species Prevention and Management Plan. Prepared for Nā Pua Makani Power Partners, LLC.

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Weaver, S., C. Hein, T. Simpson, and I. Castro-Arellano. 2019. Testing ultrasonic acoustic deterrents for reducing bat fatalities at wind turbines in south Texas. Proceedings of the National Wind Coordinating Collaborative, Wind-Wildlife Research Meeting, XII, 27–30 November2018, St. Paul, Minnesota, USA. National Wind Coordinating Collaborative, Washington, D.C., USA.

APPENDIX 1. OBSERVED FATALITIES, LOCATIONS, AND DETECTION METHOD IN FY 2022 AT THE PROJECT

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Species	Date	Turbine Number[1]	Distance to the Turbine (meters)	Detection Method[2]
Spilopelia chinensis (spotted dove)	07/07/2021	8	2	Search
Spilopelia chinensis (spotted dove)	07/24/2021	9	1	Incidental
Spilopelia chinensis (spotted dove)	07/28/2021	8	1	Search
Spilopelia chinensis (spotted dove)	08/07/2021	1	2	Incidental
Spilopelia chinensis (spotted dove)	09/06/2021	8	3	Incidental
Spilopelia chinensis (spotted dove)	09/22/2021	6	1	Search
Lasiurus cinereus semotus (Hawaiian hoary bat)	09/22/2021	6	14	Search
Zosterops japonicus (warbling white-eye)	11/03/2021	6	37.5	Search
Spilopelia chinensis (spotted dove)	11/17/2021	9	1	Search
Spilopelia chinensis (spotted dove)	11/17/2021	8	2	Incidental
Geopelia striata (zebra dove)	11/24/2021	2	1	Search
Bulbulcus ibis (cattle egret)	12/05/2021	7	30	Incidental
Spilopelia chinensis (spotted dove)	12/15/2021	8	1	Search
Spilopelia chinensis (spotted dove)	12/21/2021	7	3	Incidental
Spilopelia chinensis (spotted dove)	01/12/2022	4	4	Search
Haemorhous mexicanus (house finch)	01/26/2022	3	5	Search
Spilopelia chinensis (spotted dove)	02/22/2022	9	3	Incidental
Spilopelia chinensis (spotted dove)	02/28/2022	9	1	Incidental
Spilopelia chinensis (spotted dove)	03/16/2022	2	2	Search
Spilopelia chinensis (spotted dove)	03/16/2022	2	2	Search
Spilopelia chinensis (spotted dove)	03/18/2022	7	1	Incidental
Pycnonotus jocosus (red-whiskered bulbul)	04/06/2022	6	4	Search
Spilopelia chinensis (spotted dove)	04/06/2022	9	1	Search
Spilopelia chinensis (spotted dove)	04/06/2022	9	2	Search
Spilopelia chinensis (spotted dove)	04/12/2022	3	2	Incidental
Spilopelia chinensis (spotted dove)	04/12/2022	3	2	Incidental
Geopelia striata (zebra dove)	04/12/2022	2	2	Incidental
Spilopelia chinensis (spotted dove)	04/12/2022	2	1	Incidental
Spilopelia chinensis (spotted dove)	04/16/2022	8	3	Incidental
Spilopelia chinensis (spotted dove)	05/04/2022	2	3	Incidental
Geopelia striata (zebra dove)	05/14/2022	2	2	Search
Haemorhous mexicanus (house finch)	05/18/2022	3	46	Search
Spilopelia chinensis (spotted dove)	05/18/2022	2	1	Incidental

Species	Date	Turbine Number[1]	Distance to the Turbine (meters)	Detection Method[2]
Phaethon rubricauda (red-tailed tropicbird)	06/17/2022	7	78 – 84	Search
Spilopelia chinensis (spotted dove)	06/22/2022	7	97	Search
Spilopelia chinensis (spotted dove)	06/29/2022	9	4	Search
Ardenna pacifica (wedge-tailed shearwater)	06/29/2022	9	34.5	Search
Pycnonotus jocosus (red-whiskered bulbul))	06/29/2022	4	4	Search

1. Weekly systematic searches by a trained canine search team were conducted throughout FY 2022. Incidental detections are downed wildlife incidents detected outside of the systematic search effort, including detections outside of the defined search areas used in the statistical estimation of take but found during a search effort.
2. Turbines 2, 3, 4, and 6 are outfitted with an NRG ultrasonic acoustic bat deterrent system. The bat deterrent system was confirmed as operational during the two week period preceding the September 22, 2021 bat fatality observation.

APPENDIX 2. DALTHORP ET AL. (2017) FATALITY ESTIMATION DATA FOR HAWAIIAN HOARY BATS THROUGH FY 2022 AT THE PROJECT

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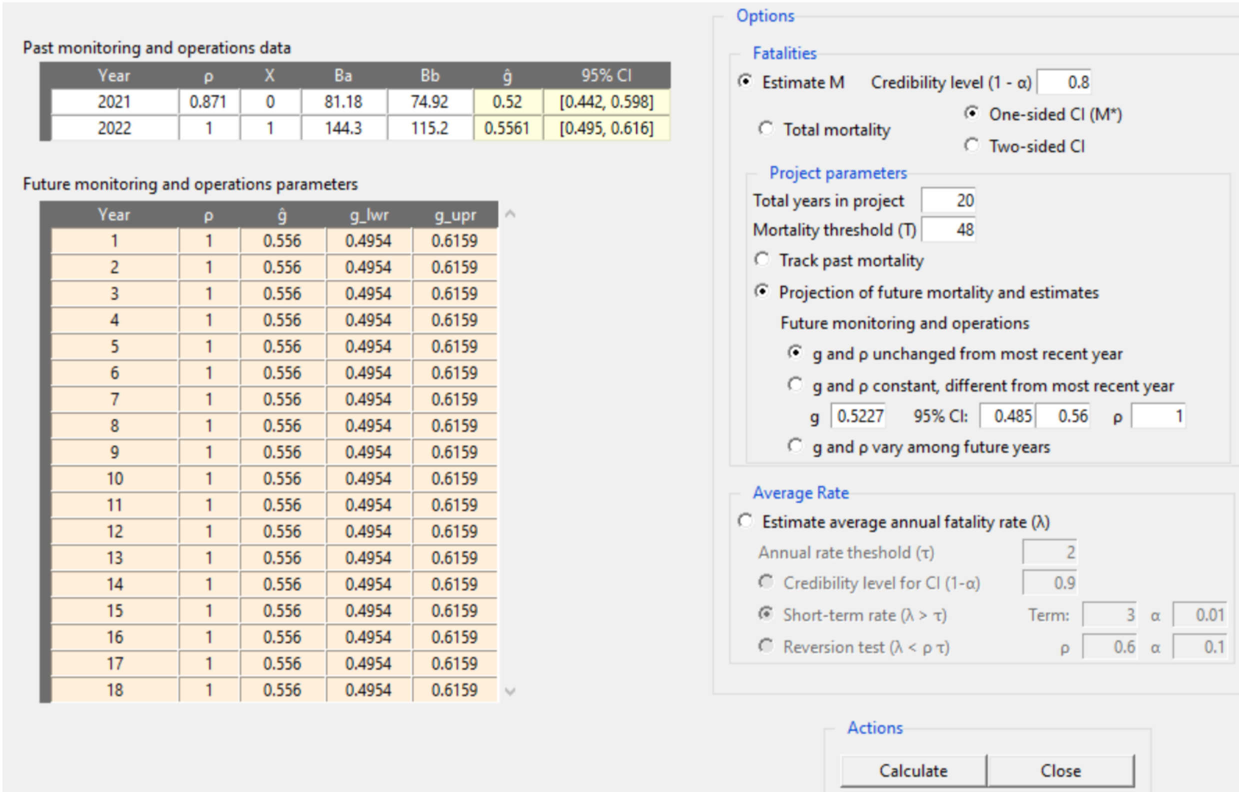
Figure 1. Dalthorp et al. (2017) Multi-year Analysis Input


Past monitoring and operations data

Year	ρ	X	Ba	Bb	ĝ	95% CI
2021	0.871	0	81.18	74.92	0.52	[0.442, 0.598]
2022	1	1	144.3	115.2	0.5561	[0.495, 0.616]

Future monitoring and operations parameters

Year	ρ	ĝ	g_lwr	g_upr
1	1	0.556	0.4954	0.6159
2	1	0.556	0.4954	0.6159
3	1	0.556	0.4954	0.6159
4	1	0.556	0.4954	0.6159
5	1	0.556	0.4954	0.6159
6	1	0.556	0.4954	0.6159
7	1	0.556	0.4954	0.6159
8	1	0.556	0.4954	0.6159
9	1	0.556	0.4954	0.6159
10	1	0.556	0.4954	0.6159
11	1	0.556	0.4954	0.6159
12	1	0.556	0.4954	0.6159
13	1	0.556	0.4954	0.6159
14	1	0.556	0.4954	0.6159
15	1	0.556	0.4954	0.6159
16	1	0.556	0.4954	0.6159
17	1	0.556	0.4954	0.6159
18	1	0.556	0.4954	0.6159

Figure 2. Dalthorp et al. (2017) Projection Results Figure Output

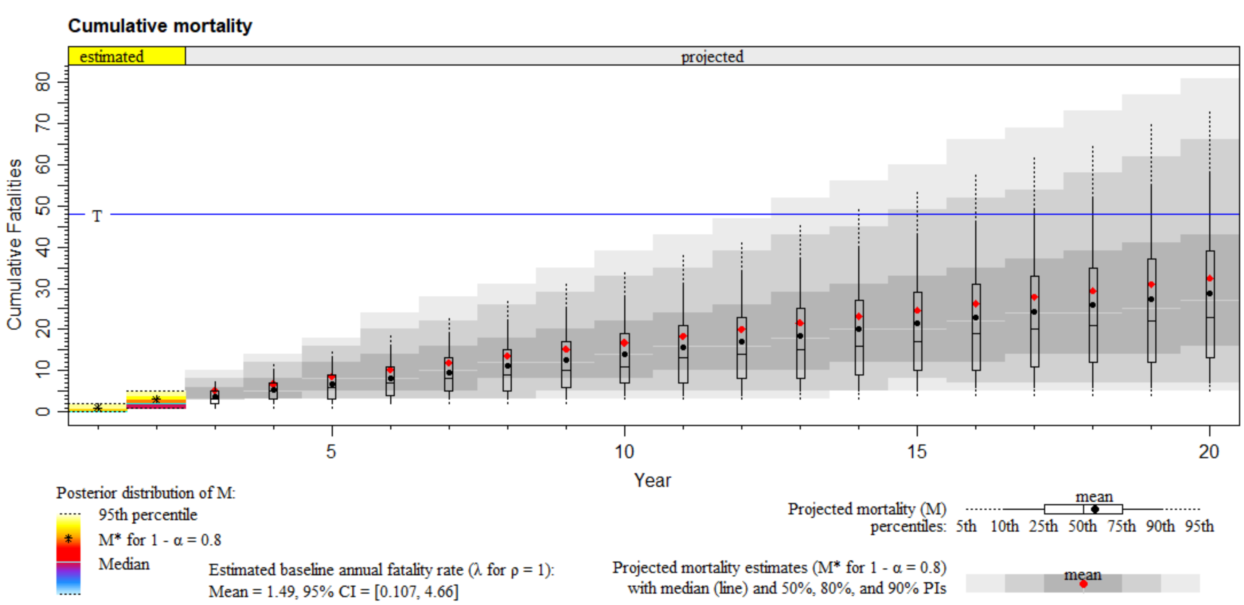


Figure 3. Dalthorp et al. (2017) Projection Text Results Output Page 1 of 2

```
================================================================================
Summary statistics from posterior predictive distributions for 10000 simulated projects
------------------------------------
Estimated annual baseline fatality rate (lambda for rho = 1): mean = 1.49, 95% CI = [0.107, 4.66]

Projected fatalities and fatality estimates...
p(M > Tau within 20 years) = 0.1615  [exceedance]
p(M* > Tau within 20 years) = 0.2103  [triggering]
M* based on credibility level 1 - alpha = 0.8

Among projects with triggering (21.03%), mean(M) = 43.81 at time of triggering, with median = 43 and IQR = [40, 47]
Among projects with no triggering (78.97%), mean(M) = 19.81 at end of 20 years, with median = 18 and IQR = [11, 28]

Years of operations without triggering:
 Mean = 18.98, with median =  20 and IQR = [20, 20]

----------------------------------------
Summary statistics for projection years
----------------------------------------------------------------------------------------------
```

Yr	Mean M	M*	quantiles of M 0.05	0.10	0.25	0.50	0.75	0.90	0.95	quantiles of M* 0.05	0.10	0.25	0.50	0.75	0.90	0.95
1	3.8	5.1	1	1	2	3	5	7	8	3	3	3	3	6	8	10
2	5.2	6.7	1	2	3	5	7	10	12	3	3	3	5	8	12	14
3	6.7	8.5	1	2	3	6	9	13	15	3	3	5	8	12	16	18
4	8.2	10.2	2	2	4	7	11	16	19	3	3	5	8	14	20	24
5	9.6	11.9	2	3	5	8	13	19	23	3	3	5	10	16	22	28
6	11.1	13.6	2	3	5	9	15	22	27	3	3	8	12	18	26	31
7	12.6	15.2	2	3	6	10	17	25	31	3	5	8	12	20	29	35
8	14.1	16.8	3	4	7	11	19	28	34	3	5	8	14	22	33	39
9	15.5	18.4	3	4	7	13	21	31	38	3	5	10	16	24	35	43
10	17.0	20.0	3	4	8	14	23	34	42	3	5	10	16	26	39	47
11	18.5	21.6	3	5	8	15	25	37	46	3	5	10	18	29	43	52
12	20.0	23.1	3	5	9	16	27	40	50	5	5	12	20	31	45	56
13	21.4	24.7	4	5	10	17	29	43	54	5	8	12	20	33	49	60
14	22.9	26.3	4	6	10	19	31	46	58	5	7	12	22	35	52	66
15	24.4	27.8	4	6	11	20	33	49	62	5	7	14	24	37	54	69
16	25.9	29.4	4	6	12	21	35	52	65	5	7	14	24	39	58	73
17	27.3	30.9	4	6	12	22	37	55	70	5	7	14	25	41	62	77
18	28.8	32.5	5	7	13	23	39	58	73	5	7	16	27	43	66	81

```
================================================================================

Governing parameters: Tau = 48, alpha = 0.2
```

Figure 3 (continued). Dalthorp et al. (2017) Projection Text Results Output Page 2 of 2

```
Data for 2 years of monitoring:
            yr    x    g    glwr   gupr  rho  M*
          2021   0 0.5201 0.4403 0.5998  0.871   1
          2022   1 0.5561 0.4945 0.6176  1   3

Parameters for future monitoring and operations:
  Number of years:  18
  g = 0.5561, 95% CI  [0.4945, 0.6176]
  Relative weight (rho): 1
*************************************************************************************
Summary statistics for mortality estimates through 2 years
------------------------------------
Results
Totals through 2 years

M* = 3 for 1 - alpha = 0.8, i.e., P(M <= 3) >= 80%
Estimated overall detection probability: g = 0.539, 95% CI = [0.491, 0.588]
    Ba = 217.33, Bb = 185.65
Estimated baseline fatality rate (for rho = 1): lambda = 1.491, 95% CI = [0.107, 4.66]

Cumulative Mortality Estimates
Year        M*   median   95% CI   mean(lambda) 95% CI
2021         1     0      [0, 2]  0.9699   [0.0009283,  4.888]
2022         3     2      [1, 5]  2.7900   [0.2002,  8.714]

Annual Mortality Estimates
Year        M*   median   95% CI   mean(lambda) 95% CI
2021         1     0      [0, 2]  0.9699   [0.0009283,  4.888]
2022         3     2      [1, 5]  2.7100   [0.1942,  8.473]


Test of assumed relative weights (rho) and potential bias              Fitted rho
Assumed rho     95% CI
  0.871     [0.002, 1.592]
      1     [0.273, 1.868]

p = 0.27535 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.013

================================================================================
Input
Year (or period) rel_wt  X    Ba     Bb   ghat    95% CI
2021             0.871   0  81.18  74.92 0.520 [0.442, 0.598]
2022             1.000   1  144.3  115.2 0.556 [0.495, 0.616]
```

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APPENDIX 3. BREEDING ECOLOGY OF HAWAIIAN SHORT-EARED OWLS (*ASIO FLAMMEUS SANDWICHENSIS*) INTERIM REPORT

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Breeding Ecology of Hawaiian Short-eared Owls (*Asio flammeus sandwichensis*)

Interim Report

July 2022

Project dates: May 1, 2021 – December 31 2022

Submitted by

Dr. Melissa R. Price, Assistant Professor

Olivia Wang, M.S. Student

Department of Natural Resources & Environmental Management

University of Hawaiʻi at Mānoa

Scope of Work and Overview of Progress

In this study we will address two research objectives:

1. Describe the breeding ecology of the Hawaiian Short-eared Owl, including nest-site selection characteristics and nesting success; and
2. Describe the timing of courtship and nesting, based on all confirmed nesting records for Pueo.

This information will inform Best Management Practices to support nesting success for Pueo.

To address these objectives, to date we:

1. Collected breeding parameters, nesting pueo diet, and nest site selection data at 11 nests on Oʻahu
    a. Completed analysis of nest site selection data
    b. Began analysis of breeding parameters and nesting pueo diet
2. Collected incidental breeding observations from 12 additional nests across the Hawaiian islands and Johnston Atoll
    a. Began analysis of incidental breeding observations

Unresolved Issues and Future Directions

Data collection has been completed, and all analyses and final report writing will be completed in the following months.

Background

The Pueo, or Hawaiian short-eared owl (*Asio flammeus sandwichensis*), is an endemic subspecies of Short-eared owl that holds cultural and ecological importance in the Hawaiian Islands (DLNR 2005). In native Hawaiian culture this species is a common ʻaumakua, or incarnation of an ancestor, and its presence is valued by Hawaiians and other Hawaiʻi residents alike. Pueo are the only native raptor that breeds on all of the islands, playing an important role in top-down ecological regulation. Despite their cultural and ecological importance relatively little information is known about the biology of Pueo, and Short-eared Owls in general, with most information originating from research on the North American continent (Booms et al. 2014). Current population trends are difficult to ascertain; however, recent studies suggest Short-eared Owls populations are declining across the globe. Pueo survival is likely impacted by a combination of factors, including predation by invasive mammals, disease, and anthropogenic causes such as rodenticides, heavy machinery, car strikes, or barbed-wire fences (Lockie 1955, Clark 1975, Bluhm and Ward 1979, Holt 1992, Work and Hale 1996, Wiggins et al. 2006, Weir 2008, Booms et al. 2014, Keyes et al. 2016). Currently the subspecies is state-listed as endangered on Oʻahu, and population declines highlight the need to increase our understanding of Pueo biology to improve management efforts to reduce extinction risk (DLNR 2005).

Methods

Data collection:

Nest discovery. Surveys occurred at study sites (Figure 1a) on Oʻahu from November–July during the expected breeding season. Pueo breeding behaviors include courtship and territorial displays and prey carrying. If a breeding behavior was observed, the specific area was revisited at least twice a week to confirm establishment of a nesting territory and whether a female had begun incubating. Within a month of observing breeding behaviors and identifying an area suspected of containing a nest, the exact location of the nest was found either by observing prey deliveries to the nest or by searching the area by walking transects (Larson and Holt, 2018; Leasure and Holt, 1991). Once a nest was located and confirmed to be active (contains either eggs or chicks), we took the GPS coordinates of the nest and then retreated to a distance and observed the nest from afar until the female returns to the nest or either parent resume normal nesting behaviors.

Breeding parameters. Nests were checked directly on a weekly basis to determine clutch size, nesting success (success being at least one chick reaching the dispersal stage), and productivity (number of nestlings reaching the fledgling stage). Incubation period for Short-eared Owls ranges from 21-42 days, with most studies reporting an incubation period of 28 days (Wiggins 2020). Thus, lay dates will be estimated by subtracting 28 days from hatch date, which in turn will be estimated either when a nest is found with a hatching egg or indirectly from nestling age. Nestling age will be estimate either visually or from growth curve data from this species (Holt et al. 1992, Arroyo et al. 2002). We will not be able to determine lay date from nests that are abandoned before eggs have hatched; however, we can estimate an earliest possible lay date by backdating from the date of nest discovery.

Clutch size will be defined as the maximum number of eggs laid. Nest success will be defined as whether at least one young was raised to 14 days old, the approximate age of dispersal from the nest. While this is technically not fledgling age (27 days old) once the chicks disperse from the nest on foot they are extremely difficult to find and thus we will quantify nest success as survival of a chick to the dispersal stage (Clark 1975, Holt 1992). Nest success will be classified as "1" for nests where at least one young reaches 14 days old, or "0" if no young reach that age or eggs never hatch. Nest productivity will be classified as the number of chicks that reach dispersal age.

While nest cameras are a common way to collect data on avian breeding parameters as well as more accurately determine causes of nest failure (i.e. capturing predator visitation, parental behavior, provisioning rates), studies of Short-eared owls in North America have found nest failure associated with nest camera use (D. Holt, personal communication). Based on this, as well as the Pueo's state-listed status as endangered, we decided not to deploy nest cameras at the Pueo nests for these initial years of nest monitoring

Nesting pueo diet. Pellets and prey remains were collected from each nesting area as they were found. Each pellet and prey remain was dissected and cleaned, and all prey items were identified to lowest possible taxa by consulting reference collections and scientists at the Bishop Museum.

Nest site selection. Pueo nest site selection characteristics were determined using a paired design in which site data will be collected both for nests and for four randomly selected points within 100m of each nest site (Price et al. 2011, Keyes et al. 2016). All nest site characteristic data were collected at the first nest visit. At the nest site and the four random points, site characteristics such as dominant vegetation, percent vegetation cover, maximum vegetation height, and visual obstruction readings were collected.

Biometric measurements. Biometric measurements including mass, wing, tarsus, tail, and culmen lengths of nestlings were collected when nestlings were approximately 13-15 days old (Wiggins et al., 2020). At this age, nestlings can thermoregulate by themselves and will be large enough to be banded with metal U.S. Geological Survey Bird Banding Lab (USGS BBL) aluminum butt-end bands and VID aluminum rivet bands, which allows for future re-sightings of individuals and assist in understanding post-nest dispersal survival rates. Because the minimum age necessary for nestlings to be banded also lines up with the age they begin to disperse from the nest, not all nestlings could be found again after dispersal for banding.

Incidental breeding observations. To obtain a broader overview of Pueo phenology and nesting habitats across the Hawaiian Islands, we reached out to federal, state, non-profit, and private partners across the Hawaiian Islands and asked them to report any observations of Pueo breeding behaviors or nests that they encountered incidentally during their fieldwork. Along with this request for information was sent an informational document showing how to identify Pueo breeding behaviors, nests, and chicks; this information was also made available on our website, pueoproject.com. Data requested included the date of observation, location of observation (with guidance to be as detailed as possible, i.e. using GPS points), type of observation (breeding behavior or nest), and as much detail about the behavior, nest site characteristics, or chick as possible. An online form and physical datasheet was sent to help guide data collection. All reported observations were followed up on to confirm details and collect additional information.

Data analysis:

Pueo breeding parameters and nest site characteristics. All statistical analyses will be conducted using program R (version 3.6.2). Breeding parameters (lay date, clutch size, nesting success, and nest productivity) will be combined across all breeding seasons, and the means, standard deviations, and ranges of all parameters will be calculated. The mean, standard deviation, and range of dispersal distance of the fledged chicks will also be calculated. The means, standard deviations, and ranges of all the quantitative nest site characteristics will also be calculated, and the top three most abundant plant species across all nest sites summed.

Effect of nest site characteristics on breeding parameters. We will use logistic exposure models, a form of Generalized Linear Models (glm) to examine the relationship between lay date, clutch size, nest success, and nest productivity (fitted as response variables) with nest site characteristics (fitted to the model as predictor variables). Nest ID will be fitted as a random effect when appropriate. Stepwise backwards procedure for model selection (package "MuMIn") and AICc values will be used to select the best model and thus most important predictor variables. For the relationship between nest site characteristics and nest success, I will use a logistic exposure model with the same nest site characteristics fitted as predictor variables [1].

Nest site selection. We used a binomial logistic exposure model to the estimate relative probability of use of a site for nesting, with nest site characteristics (mean VOR high, mean VOR low, tallest vegetation height, and percent vegetation cover) fitted as predictor variables and use of site (1 for pueo nests, 0 for random points) as the response variable. AICc values will be used to select the best model and thus the most important predictor variables.

Nesting Pueo diet. To assess if there is a difference in diet between nests, we will test for the effect of nest as a predictor of presence of different prey items found in each sample (i.e. each pellet and prey remain). We will follow an approach that treats each sample as a multinomial vector of potential prey types, thus having a similar structure to data used in capture-mark-recapture studies (Lemons et al. 2010). We can then apply a close-capture model using package "marked" to see if individual nests serve as a predictor for the presence of different prey items. Prey items from pellets and prey remains were identified to the lowest possible taxa and then separated into one of four categories: Mouse (*Mus musculus*), Rattus species, bird species, and insect species. Mice and rats can be easily distinguished by teeth shape and patterns, but rat species (of which there are three in the Hawaiian islands: Pacific rat (*Rattus exulans*), Black rat (*Rattus rattus*), and Norway Rat (*Rattus norvegicus*)) can only be distinguished by looking at the entire skull, which are often not retained in pellets.

Preliminary results to date

Pueo breeding parameters and nest site characteristics. Table 1 is a rough summary of the breeding parameter data from 13 nests (Figure 1b and c) found at the main study sites on Oʻahu. Across the 2020-2022 breeding seasons, nests were found between mid-December and mid-June. The maximum clutch sizes observed ranged between 1 and 7, and maximum number of chicks observed ranged between 1 and 5. Six of the 13 nests had at least one nestling successfully disperse from the nest. Further analyses of this data is in progress.

Nest site selection. We collected vegetation characteristic data from 11 nests found between March 2020 and June 2022. The global model included tallest vegetation, percent cover, mean high VOR, and mean low VOR. The best fit model (determined using AICc model selection and Hosmer and Lemeshow goodness of fit test with R package "MuMin") included both mean low VOR and tallest vegetation as predictor variables; Table 2 summarizes the AICc values of the top 4 models. The top model (Figure 2a and b) indicates that as the mean low VOR and tallest vegetation at a given site increases, the probability of use of that site by a pueo for nesting also increases ($p=0.00298$).

Nesting Pueo diet. Table 3 summarizes the different prey items found in nesting Pueo pellets and prey remains. A total of 71 pellets and prey remains were collected from nesting Pueo. House Mice (*Mus musculus*) were the most frequently occurring prey type, occurring in 69% of the samples. Birds were the next most frequently occurring prey type, occurring in 38% of the samples, followed by *Rattus* species and Insect species occurring in 14% and 11% of samples, respectively (Figure 3). Further analyses of this data is in progress.

Incidental breeding observations. Twelve individual Pueo breeding observations have been reported to us through seven different observers thus far, ranging geographically from Hawai‘i Island, Kaho‘olawe, Lanai, Kaua‘i, and Johnston Atoll. Compilation of this data is still ongoing and will be summarized in the final report.

Preliminary discussion

This is the first study investigating Pueo nesting ecology, and our results so far suggest that pueo select areas with taller vegetation height and greater vegetation density for nesting; studies on North American Short-eared Owls indicate similar selection trends (Herkert et al. 1999, Swengel and Swengel 2014). Predicting where Pueo prefer to nest will be useful for future studies focused on Pueo breeding ecology, and will also help inform land managers and agricultural producers on how to minimize disturbance in likely pueo breeding areas. These results may also help predict how Pueo may respond to land use changes across the Hawaiian Islands, and inform best management practices to maximize pueo occupancy and nesting success.

Tables and Figures

Table 1: Summary of Pueo nest breeding parameters.

Nest ID	Date discovered	Latitude	Longitude	Estimated hatch date[1]	Number of eggs[2]	Number of chicks[3]	Nest fate
01	12/18/2019	[redacted]	[redacted]	1/11/2020	2	0	Fail - Abandoned
02	1/7/2020	[redacted]	[redacted]	1/31/2020	5	0	Fail - predated
03	1/28/2020	[redacted]	[redacted]	2/21/2020	NA	1	Success
04	2/13/2020	[redacted]	[redacted]	3/8/2020	2	1	Fail - predated
05	2/14/2020	[redacted]	[redacted]	3/9/2020	4	0	Fail - abandoned
06	2/18/2020	[redacted]	[redacted]	3/13/2020	NA	NA	Fail - abandoned
07	3/25/2020	[redacted]	[redacted]	3/10/2020	NA	1	Success
08	6/3/2020	[redacted]	[redacted]	NA	2	0	Fail - abandoned
09	2/5/2021	[redacted]	[redacted]	3/6/2021	7	3	Success
10	2/16/2021	[redacted]	[redacted]	2/13/2021	NA	5	Success
11	3/31/2021	[redacted]	[redacted]	3/28/2021	NA	3	Success
12	6/8/2021	[redacted]	[redacted]	NA	1	0	Fail - abandoned
13	4/26/2022	[redacted]	[redacted]	4/13/2022	4	4	Success

[1]Based on status of nest at time of finding, using a 28-day incubation period, [2]Maximum number of eggs observed at the nest, [3]Maximum number of chicks observed at the nest

Table 2: Model selection table for relative probability of use of a site for nesting by a Pueo in response to vegetation characteristics.

Model Predictor Variables	AICc	ΔAICc
tallest	52.7	0.00
VOR low + tallest	53.0	0.33
VOR high	53.1	0.42
percent cover + tallest	53.6	0.88

Table 3: List of prey items found in nesting Pueo pellets and prey remains.

MAMMALS	
	Mus musculus
	Unidentified species of genus *Rattus*
BIRDS	
	Geopelia striata (Zebra Dove)
	Zosterops japonicus (Warbling White-eye)
	Estrilda astriid (Common Waxbill)
	Unidentified species of genus *Lonchura*
	Unidentified species of family Fringillidae
INSECTS	
	Unidentified species of family Carabidae
	Unidentified species of family Tenebridae
	Unidentified species of family Elateridae
	Unidentified species of family Curculonidae

Figure 1a: Map of the main study sites on Oʻahu. Red box shows the map extent of Figure 1b, yellow box shows the map extent of Figure 1c.

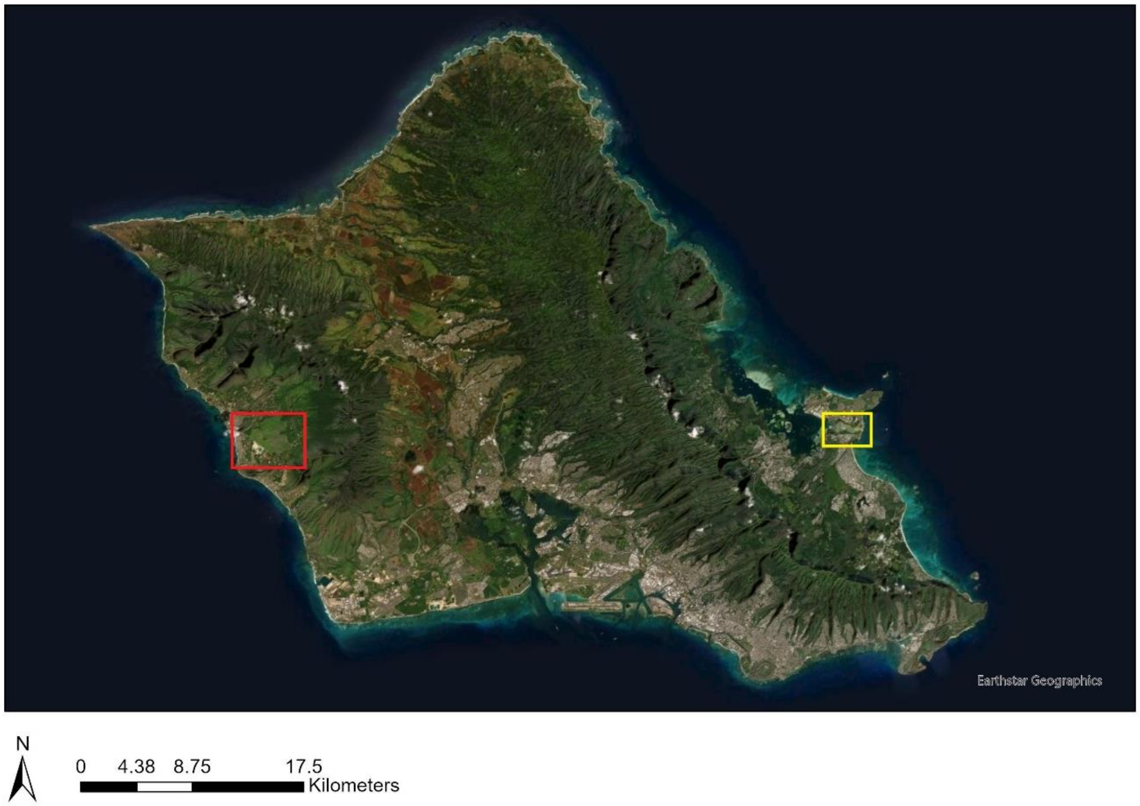


Figure 1b and c: Map of pueo nests found at main study sites on Oʻahu. Figure 1b (outlined in red) shows nests found at the Lualualei Naval Base in Waiʻanae, Oʻahu. Figure 1c (outlined in yellow) shows one nest found at the Marine Corps Base Hawaii in Kāneʻohe Bay, Oʻahu

[redacted]

[redacted]

Figure 2a (right) and b (left): Plot of the relative likelihood of use of a site for pueo nesting versus mean low Visual Obstruction Reading (cm) and tallest vegetation height (cm) at a given site. Gray dots are the tallest vegetation heigh at each site. Solid line indicates the predicted likelihood of use, dotted lines are the 95% confidence intervals.

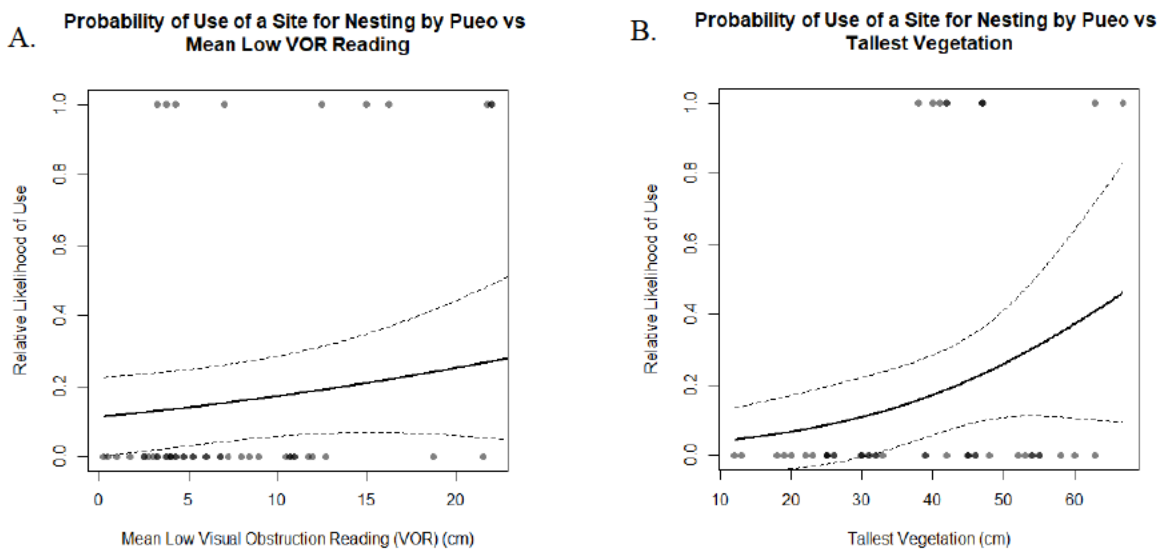
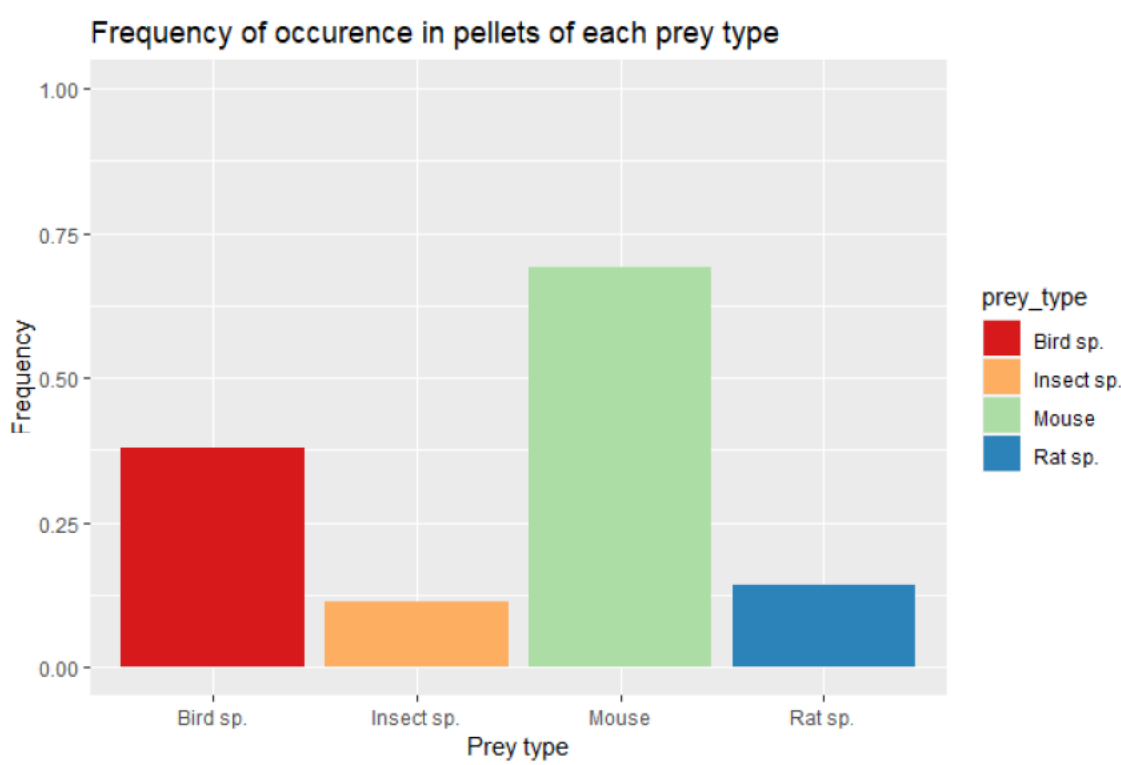


Figure 3: Frequency of occurrence of prey types in breeding Pueo pellets and prey remains.



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