Kawailoa Wind Project Habitat Conservation Plan
FY 2023 Annual Report

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Incidental Take License ITL-14 Amended/ Incidental Take Permit TE59861A-1

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EXECUTIVE SUMMARY

This report summarizes work performed by Kawailoa Wind, LLC (Kawailoa Wind), owner of Kawailoa Wind Project (Project) during the State of Hawaiʻi fiscal year 2023 (FY 2023; July 1, 2022 to June 30, 2023) under the terms of the approved Habitat Conservation Plan (HCP) dated October 2011 and the approved HCP Amendment dated September 2019, and pursuant to the obligations in the Project's state Incidental Take License (ITL; ITL-14 Amended) and federal Incidental Take Permit (ITP; TE-59861A-1). The Project was constructed in 2011 and 2012 and commissioned to begin operating on November 2, 2012. Species covered under the HCP and HCP Amendment include seven state and federally listed threatened or endangered species, as well as one state listed endangered species.

Fatality monitoring at the Project continued throughout FY 2023 at all wind turbine generators (WTG). In FY 2023, search areas consisted of 55-meter-radius circles centered on each turbine and roads out to 75 meters from each turbine. For the two unguyed meteorological towers, the search area consisted of a 50-meter-radius circle centered on each tower. The mean search interval for both turbines and the meteorological towers in FY 2023 was 7.0 days.

Four 28-day carcass persistence trials were conducted in FY 2023 using 60 bat surrogates and 12 medium-sized bird carcasses. For FY 2023, the probability and 95% confidence interval that a bat surrogate carcass persisted until the next search was 0.70 (0.61 to 0.78). The probability that a medium-size bird carcass persisted until the next search was 0.98 (0.90 to 1.00). Scavenger trapping occurred at the Project throughout FY 2023.

Searcher efficiency trials were conducted over 23 trial days with 77 trial carcasses in FY 2023. The overall searcher efficiency in FY 2023 for bat surrogates (N = 65) was 0.95 (0.88 to 0.99). For medium-sized birds (N = 12) searcher efficiency was 1.00 (0.82 to 1.00).

No HCP Covered Species fatalities were observed at the Project in FY 2023. The Project's total observed Hawaiian hoary bat/ ʻopeʻapeʻa (*Lasiurus cinereus semotus*) take from operations through FY 2023 is 42 bats. The fatality estimate for non-incidental observed bats using the Evidence of Absence estimator (Dalthorp et al. 2017) at the upper 80 percent credibility level is 92 bats, and the total indirect take for this estimate is 9 adult bat equivalents. Combining these values, there is an approximately 80 percent chance that actual take of Hawaiian hoary bats at the Project is less than or equal to 101 adult bats. This total is estimated using no adjustment to the annual rho value for years when deterrents were operational, despite a demonstrated 95 percent confidence that risk to bats has been significantly reduced through the installation of bat deterrents at the Project. The unbiased estimated benefit of deterrents indicates that risk to the Hawaiian hoary bat has been reduced by 88.3 percent. Kawailoa Wind is currently working with USFWS and DOFAW to ensure that demonstrated benefits from the deployment of bat deterrents can appropriately be incorporated into the Project take estimate. While USFWS conditionally accepted using a highly conservative adjusted rho value incorporating the benefits of deterrents in June 2023, Kawailoa Wind is actively working with the agencies to identify when an appropriate adjusted rho can be applied. The current estimate falls within the Tier 4 bat take request (which is up to 115 bats). Mitigation for Tier 4 take was completed in 2018.

Twenty-two fatalities representing 10 non-listed species were found at the Project in FY 2023. This includes the following birds that are protected by the Migratory Bird Treaty Act: three white-tailed tropic birds/koaʻe kea (*Phaethon lepturus*), two house finches (*Haemorhous mexicanus*), and one Pacific golden plover/kolea (*Pluvialis fulva*).

Tier 1 mitigation for the Hawaiian hoary bat continued in FY 2023. Four permanent ground-based ultrasonic bat detectors were managed at the Project at WTGs 1, 10, 21, and 25. Hawaiian hoary bats were detected on 248 of 1,451 (17.1 percent) detector-nights sampled throughout the 2023 Bat Sampling Period. The ʻUkoʻa Wetland mitigation program for Tier 1 mitigation continued for waterbirds and bats through FY 2023 including invasive vegetation control, predator control and monitoring, fence monitoring and maintenance, bat acoustic monitoring, bat lane maintenance, and insect assessment. During the 2023 Bat Sampling Period, Hawaiian hoary bats were detected at ʻUkoʻa Wetland on 534 of 2,708 detector-nights sampled (19.7 percent). The ʻUkoʻa Wetland Insect Assessment Report was completed in FY 2023, summarizing the insect sampling that occurred in 2014, 2015, and 2021.

Mitigation for Tiers 2 through 4 is complete. Final invoices for the Hawaiian hoary bat research projects conducted by the U.S. Geological Survey and Western EcoSystems Technology, Inc. for Tiers 2 and 3 were paid in FY 2022. The remainder of Tier 3 bat mitigation was completed in FY 2019 with the acquisition of the Waimea Native Forest. Tier 4 bat mitigation was completed in FY 2019 with the acquisition of the Helemano Wilderness Area. Kawailoa Wind continues to plan for Tier 5 bat mitigation, should it be needed.

Mitigation for waterbirds continued at ʻUkoʻa Wetland, despite no observed take of these species at the facility. In total, 14 Hawaiian common gallinule/ʻalae ʻula (*Gallinula chloropus sandvicensis*) fledglings have been recorded at ʻUkoʻa since monitoring began following management. No evidence of Hawaiian stilt/aeʻo (*Himantopus mexicanus knudseni*) or Hawaiian coot/ʻalae keʻokeʻo (*Fulica alai*) breeding has been observed at ʻUkoʻa Wetland despite years of ongoing management. Kawailoa Wind is having ongoing discussions with the agencies regarding adaptive management of waterbird mitigation.

No Hawaiian petrel/ʻuaʻu (*Pterodroma sandwichensis*) fatalities were observed in FY 2023. The estimated cumulative Project take is below the authorized take limit. Mitigation for the take of Hawaiian petrel was completed in FY 2021. Pacific Rim Conservation's research related to Hawaiian petrels on Oʻahu continued in FY 2023 using funds provided by Kawailoa Wind.

Mitigation for Newell's shearwater/aʻo (*Puffinus newelli*) was completed in FY 2015. Pueo/Hawaiian short-eared owl (*Asio flammeus sandwichensis*) mitigation was completed in FY 2017.

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1.0 Introduction

The Habitat Conservation Plan (HCP) for the Kawailoa Wind Project (Project) was approved by the Hawaiʻi Division of Forestry and Wildlife (DOFAW) in 2012 (SWCA 2011; the 2011 HCP). On December 8, 2011, the U.S. Fish and Wildlife Service (USFWS) issued Kawailoa Wind, LLC (Kawailoa Wind) a federal incidental take permit (ITP) for the Project, and DOFAW issued a state incidental take license (ITL) on January 6, 2012. The original ITP and ITL cover the incidental take of six state and federally listed threatened or endangered species, as well as one state listed endangered species (referred to as the Covered Species) over a 20-year permit term.

In September 2019, Kawailoa Wind submitted a final HCP Amendment to USFWS and DOFAW to request an increase in the amount of Hawaiian hoary bat/ʻopeʻapeʻa (*Lasiurus cinereus semotus*) take and add the state and federally listed endangered Hawaiian petrel/ʻuaʻu (*Pterodroma sandwichensis*) as a Covered Species (Tetra Tech 2019). Kawailoa Wind received an amended ITP from USFWS on September 4, 2019. An amended ITL was issued by DOFAW on February 26, 2021, and signed by Kawailoa Wind on March 30, 2021. The Project's Covered Species are listed in Table 1.

Table 1. Covered Species

Common and Hawaiian Names	Scientific Names	Listing Status[1]
Hawaiian coot, ʻalae keʻokeʻo	*Fulica alai*	FE/SE
Hawaiian duck, koloa maoli	*Anas wyvilliana*	FE/SE
Hawaiian common gallinule, ʻalae ʻula	*Gallinula chloropus sandvicensis*	FE/SE
Hawaiian stilt, aeʻo	*Himantopus mexicanus knudseni*	FE/SE
Hawaiian petrel, ʻuaʻu	*Pterodroma sandwichensis*	FE/SE
Newell's shearwater, ʻaʻo	*Puffinus newelli*	FT/ST
Hawaiian hoary bat, ʻopeʻapeʻa	*Lasiurus cinereus semotus*	FE/SE
Hawaiian short-eared owl, pueo	*Asio flammeus sandwichensis*	SE
1. FE = Federally endangered; SE = State endangered; FT = Federally threatened; ST = State threatened.		

The Project was constructed in 2011 and 2012 and was commissioned to begin operating in November 2012. The Project is owned and operated by Kawailoa Wind, a wholly owned subsidiary of DESRI IV, LLC, which is an investment fund managed by D.E. Shaw Renewable Investments, LLC.

This report summarizes work performed for the Project during the State of Hawaiʻi 2023 fiscal year (FY 2023; July 1, 2022 to June 30, 2023) pursuant to the terms and obligations of the 2011 HCP (SWCA 2011), HCP Amendment (Tetra Tech 2019), and amended ITL and ITP.

2.0 Fatality Monitoring

All 30 wind turbine generators (WTGs) and the two meteorological (met) towers were searched for fatalities once per week throughout FY 2023. Search plots for each WTG in FY 2023 consisted of a 55-meter-radius circle centered on the WTG and roads surrounding the WTG out to 75 meters. Search plots for each unguyed met tower were 50-meter-radius circles centered on the met towers. The FY 2023 mean search interval for WTGs was 7.0 days (standard deviation [SD] = 0.1 days). The mean search interval for unguyed met towers in FY 2023 was 7.0 days (SD = 1.8 days).

Due to safety issues or physical constraints, small portions of the 55-meter-radius search plots at 13 of the turbines have unsearchable areas. Combined, the inability to search these areas reduces the propoportion of the carcass distribution searched by 0.012 for birds and 0.035 for bats compared to 55-meter-radius search plots without these constraints. There were no unsearchable areas within the unguyed met tower search plots.

In FY 2023, the search areas were searched by trained dogs accompanied by their handlers. In previous years when conditions limited the use of dogs (e.g., weather, injury, availability of canine search teams), search plots were visually surveyed by Project staff; however, canine teams conducted 100 percent of the WTG searches in FY 2023. Vegetation within the search areas is managed to maximize searcher efficiency (SEEF) (see Section 4.0).

3.0 Bias Correction

3.1 Carcass Persistence Trials

Four 28-day carcass persistence trials (CPT) were conducted in FY 2023 using bat surrogates (black rat; *Rattus rattus*) and wedge-tailed shearwater (*Ardenna pacifica*) carcasses. Wedge-tailed shearwaters are medium-sized birds that are suitable surrogates for the listed bird species covered in the 2011 HCP and the HCP Amendment (see Table 1). Trials results for FY 2023 are provided in Table 2, including results by vegetation class.

3.2 Searcher Efficiency Trials

Tetra Tech personnel (non-searchers) administered 77 searcher efficiency trials on 23 trial days during FY 2023. Similar to the carcass persistence trials, wedge-tailed shearwaters were used as surrogates for listed bird species, and black rats were used as surrogates for the Hawaiian hoary bat. SEEF trials occurred throughout FY 2023. Vegetation category (short vs. medium) of the search plot was documented at the time the carcasses were placed and when they were found. Results for the FY 2023 SEEF trials are provided in Table 2, including results by vegetation class.

Table 2. Carcass Persistence and Searcher Efficiency Trial Results in FY 2023

Size	Vegetation Class	Total Trials		Mean (95% Confidence Interval)	
		SEEF[1]	CPT[1]	SEEF (Proportion Detected)[2]	Probability of Persistence to the Next Search (*r*)[2, 3]
Rat Surrogate	Short	50	46	0.98 (0.91 – 1.00)	0.70 (0.60 – 0.80)
	Medium	15	14	0.87 (0.64 – 0.97)	0.69 (0.49 – 0.86)
	Combined	65	60	0.95 (0.88 – 0.99)	0.70 (0.61 – 0.78)
Medium Bird	Short	10	9	1.00 (0.78 – 1.00)	0.97 (0.85 – 0.99)
	Medium	12	3	1.00 (0.33 – 1.00)	0.97 (0.91 – 1.00)
	Combined	12	12	1.00 (0.82 – 1.00)	0.98 (0.90 – 1.00)

1. SEEF = Searcher efficiency; CPT = Carcass Persistence Trials.
2. Estimates and 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 than carcass persistence time, incorporating information from the carcass persistence distribution and the search interval in a single variable. Estimates and confidence interval for r were calculated using Dalthorp et al. (2017) single-year module.

4.0 Vegetation Management

Vegetation in the search plots consists mainly of Guinea grass (*Megathyrsus maximus*), Bermuda grass (*Cynodon dactylon*), and a mixture of common, low-growing weedy plants. All search plots around the WTGs and unguyed met towers are mowed regularly to increase visibility during fatality searches. Plots are mowed to a height of 3 to 4 inches, depending on the type of mower used. Plots are mowed roughly every 2 to 4 weeks. Herbicides were also used in FY 2023 to control vegetation in some portions of the search areas. The frequency of vegetation management varies depending on rainfall, time of year, type of vegetation cover, and cattle presence.

The landowner, Kamehameha Schools, has managed cattle on their property since before the Project was constructed. Domestic cattle are rotated periodically throughout portions of the Project and graze vegetation under several of the turbines. Cattle periodically graze at WTGs 1 – 3 and WTGs 16 – 26. The specific locations and number of cows present throughout the year depends on several factors including forage and water availability, and landowner operations. No cattle are present at WTGs 4 – 15 and 27 – 30. Because Kawailoa Wind is not the landowner, the Project does not have control over cattle use in the area.

5.0 Scavenger Trapping

Scavenger trapping is responsive to Project needs, and carcass persistence is monitored quarterly throughout the fiscal year. Scavenger trapping continued throughout FY 2023. Mongoose and cats were targeted by deploying 30 DOC 250 series traps and 10 Timms lethal traps. In FY 2023, a total of 89 mongoose, 2 rats, and 1 cat were trapped at the Project.

6.0 Documented Fatalities and Take Estimates

No HCP Covered Species or other listed species fatalities were observed in FY 2023. All non-listed fatalities observed at the Project during FY 2023 are listed in Appendix 1.

6.1 Hawaiian Hoary Bat

No Hawaiian hoary bat fatalities were documented during FY 2023 (Appendix 1). The total take estimate for the Hawaiian hoary bat is based on fatality monitoring data and bias correction data from the start of Project operation (November 2012) through the end of FY 2023 (June 2023). An upper credible limit (UCL) of take is estimated from three components: (1) observed direct take (ODT) during protocol (standardized) surveys, (2) unobserved direct take (UDT), and (3) indirect take. The Evidence of Absence software program (EoA; Dalthorp et al. 2017), which is the agency-approved analysis tool for analyzing direct take, uses results from bias correction trials and ODT to generate UCL of direct take (i.e., ODT + UDT). The USFWS and DOFAW have requested that these calculations be reported at the 80 percent UCL. Values from this analysis can be interpreted as meaning 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 observations of the temporal distribution of Covered Species fatalities at the Project and agency guidance regarding life history characteristics of the associated Covered Species.

A total of 42 Hawaiian hoary bat fatalities have been observed at the Project since operations began on November 2, 2012. The highest number of annual bat fatalities (nine) was observed in FY 2014 and FY 2015. Two of the total 42 observed bats were found outside of fatality search plots and classified as incidental observations.

Table 3 presents the cumulative take estimates (direct take + indirect take) by FY since operations began. Direct take is estimated using the EoA estimator at the 80 percent UCL (Dalthorp et al. 2017). Indirect take is calculated using USFWS (2016) guidance.

The estimated direct take (ODT + UDT) for the 42 Hawaiian hoary bat fatalities found between the start of operation (November 2, 2012) and end of FY 2023 is less than or equal to 92 bats (80 percent UCL; Appendix 2). Because two of the 42 observed bat fatalities were found outside of the search areas (i.e., were incidental observations), 40 fatalities were used in the direct take analysis, and the two incidental observations are accounted for in the estimated value of UDT. The two incidental observations were found in FY 2013 and FY 2016. UDT is estimated at 50 (92 bats, 80 percent UCL–42 bats ODT).

Table 3. Hawaiian Hoary Bat Fatalities by Fiscal Year and Cumulative Take Estimates

Fiscal Year	Number of Observed Fatalities[1]	Cumulative Take Estimate[2]
2013	4	11
2014	9	26
2015	9	38
2016	4	49
2017	2	60
2018	5	73
2019	5	89
2020	0	94[3]
2021	0	97[3]
2022	2	102[3]
2023	0	101[3]
Total	**40**	**101[3]**

1. Does not include bat fatalities found outside of the search areas (i.e., two incidental observations).

2. Cumulative take represents the 80 percent UCL of cumulative direct take estimated from the Evidence of Absence estimator (Dalthorp et al. 2017) plus the associated indirect take calculated using USFWS (USFWS 2016) guidance.

3. The installation of acoustic deterrents represents an inflection point in the bat fatality rate, reducing the risk to bats. Based on results from 4 years of monitoring, there is a 95 percent probability that the risk to bats of operating with deterrents is reduced by at least 65.0 percent of operating without deterrents under similar low wind speed curtailment regimes. The unbiased estimate of deterrent effectiveness estimates a reduced risk to bats of 88.3 percent. While USFWS conditionally accepted using a highly conservative adjusted rho value incorporating the benefits of deterrents in June 2023, Kawailoa Wind is actively working with the agencies to identify when an appropriate adjusted rho can be applied.

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

- The average number of pups attributed to a female that survives to weaning is assumed to be 1.8.
- The sex ratio of bats taken through UDT is assumed to be 45 percent female based on the 42 bats assessed by USGS from the Project.
- The assessment of indirect take to a modeled UDT accounts for the fact that it is not known when the unobserved fatality may have occurred. The period of time from pregnancy to end of pup dependency for any individual bat is estimated to be 3 months. Thus, the probability of taking a female bat that is pregnant or has dependent young is 25 percent.
- The conversion of juveniles to adults is one juvenile to 0.3 adults.

Based on the USFWS methodology (2016), the estimate of cumulative indirect take in FY 2023 is calculated as:

- **Total juvenile take calculated from observed female take (April 1 to September 15)**
  - 10 (observed females) * 1.8 (pups per female) = 18 juveniles
- **Total juvenile take calculated from observed unknown sex take (April 1 to September 15)**
  - 0 (observed unknown sex) * 0.45 (sex ratio observed at Kawailoa Wind) * 1.8 (pups per female) = 0 juveniles
- **Total juvenile take calculated from unobserved take**
  - 50 (unobserved direct take) * 0.45 (sex ratio observed at Kawailoa Wind) * 0.25 (proportion of calendar year females could be pregnant or have dependent pups) * 1.8 (pups per female) = 10.2 juveniles
- **Total Calculated Juvenile Indirect Take** = 28.2 (18 + 0 + 10.2)
- **Total Adult Equivalent Indirect Take =** 0.3 (juvenile to adult conversion factor) * 28.2 = 8.5

Therefore, the estimated indirect take based on the UCL of Hawaiian hoary bat direct take at the Project is nine adult bats (rounded up from 8.5).

The UCL for Project take of the Hawaiian hoary bat at the 80 percent credibility level is 101 adult bats (92 estimated direct take + 9 estimated indirect take)[1]. That is, there is an approximately 80 percent probability that actual take at the end of FY 2023 is less than or equal to 101 bats. This estimate falls within the Tier 4 bat take authorization detailed in the HCP Amendment, which has a total take request of 115 bats. The HCP Amendment addressed the exceedance of the previously authorized bat take limit (Tiers 1 through 3) through the identification of additional avoidance and minimization measures, as well as additional compensatory bat mitigation (Tetra Tech 2019).

Kawailoa Wind described methods for determining an estimate of a conservative rho value in the FY 2020, 2021, and 2022 annual reports (Tetra Tech 2020, Tetra Tech 2021, Tetra Tech 2022) and continued discussions with the agencies in FY 2023 to incorporate a modified rho into the take analyses. The minimization measures associated with the HCP Amendment demonstrate a statistically significant reduction in the fatality rate. This reduction warrants the application of an appropriate rho value in the EoA model. A comparison of the fatality rates before and after the application of minimization measures associated with the HCP Amendment shows the fatality rate is reduced from an average of 11.15 bats per year from FY 2013 to 2019, estimated by EoA, to an average of 1.49 bats per year in FY 2020 to 2023 (Figure 1). A test for misspecification of rho in EoA demonstrates that application of a rho value of 1 from FY 2020 to 2023 is overestimated (p value = 0.00002). Using an annual rho value of 0.35, the test for misspecification exceeds the threshold of

[1] This total is estimated using no adjustment to the annual rho value of 1.0 for years when deterrents were operational.

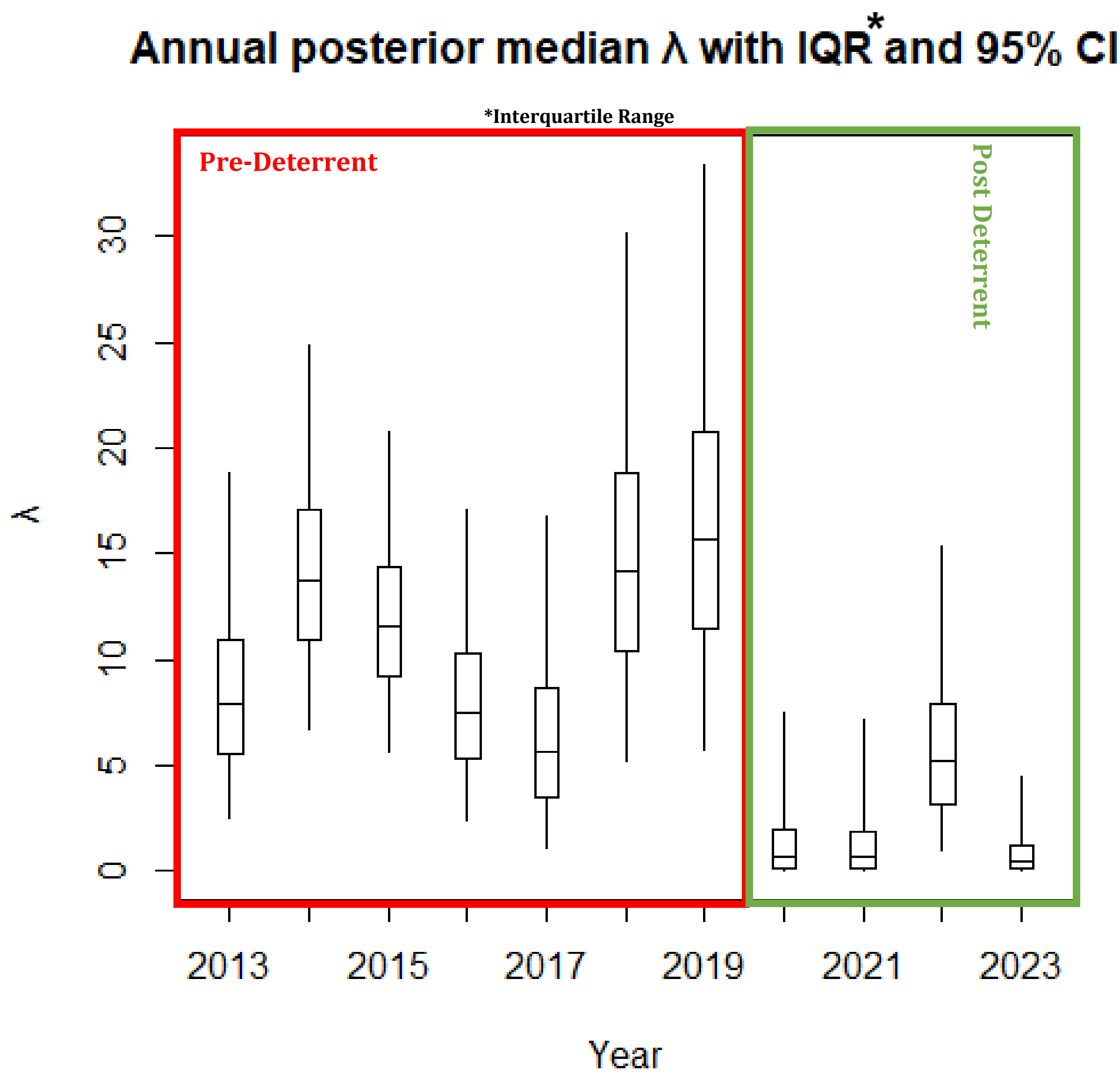
0.05 (p value = 0.053). The estimate of a rho of 0.35 is statistically supported as a maximum value by EoA ($\alpha = 0.05$) and is highly conservative (assumes lower deterrent effectiveness than suggested by available data) because of the use of a 95 percent confidence level. This demonstration of deterrent effectiveness was measurable in the first year of deployment (Tetra Tech 2020), has been sustained over four years, and is robust enough to demonstrate benefits despite the observation of two bat fatalities in FY 2022. Based on the strength and resilience of these measured benefits, the use of an adjusted rho is appropriate. Kawailoa Wind is currently working with USFWS and DOFAW to ensure that the measurable benefits from deployment of these minimization measures are appropriately accounted for in the take analyses. The details of the rho analysis demonstrating the effectiveness of deterrents with data through FY 2023 are provided in Appendix 3.

In FY 2023, Kawailoa Wind worked with DAPPER Stats to develop a statistical analysis to produce an unbiased estimate of the benefit of the deterrents (Appendix 4; DAPPER Stats 2023). The analysis presented in Appendix 4 provides results through FY 2022. Updated results through FY 2023 are shown in Appendix 5; these results indicate the unbiased estimate rho to account for deterrent effectiveness is 0.117 (0.022 – 364), an 88.3 percent reduction of risk (Appendix 5) compared to 82.4 percent (Appendix 4). Ultimately, the assessment of rho in the post-UAD installation period is expected to incorporate ongoing fatality monitoring results in the post-UAD period and an unbiased estimate of the deterrent benefit. The inclusion of additional years will continue to increase statistical rigor to accurately assess changes in rho. The rho value applied for periods with the current minimization measures will be re-evaluated annually to incorporate new data. While USFWS conditionally accepted using a highly conservative adjusted rho value incorporating the benefits of deterrents in June 2023, Kawailoa Wind is actively working with the agencies to identify when an appropriate adjusted rho can be applied.

A take projection can be generated with EoA and with methods outlined in the HCP Amendment to estimate the likelihood of staying within the permitted take. The take projection is strongly influenced by the rho value as outlined in the preceding paragraphs. If no adjustment to rho is used, the median take projection at the end of the ITP term (December 2031) is 159 bats (Interquartile Range [IQR]: 149, 171). This value would be well below the total take authorization of 220 bats. However, this method of projection is likely to overestimate Project impacts because the take rate prior to deterrent installation heavily impacts the projection. Given the use of an unbiased estimate of the rho value of 0.117 post-UAD, the median take projection at the end of the ITP term (December 2031) is 97 bats (Interquartile Range [IQR]: 93, 101). Alternatively, using EoA with a selected estimate of relative risk of post-UAD versus pre-UAD periods, the HCP Amendment specifies a comparison of the current take estimate and the current take rate to total authorized take over the permit term to determine if adaptive management is warranted. This method can also be used to evaluate take rates on an ongoing basis. EoA estimated the take rate at the Project between FYs 2020 and 2023 as 1.49 bats per year; extrapolating from the current direct take estimate (using a rho of 1) and the current take rate the Project estimates a direct take total of 104.7 bats at the end of the ITP term (92 bats estimated by EoA in FY 2023 + 1.49 bats per year * 8.5 years remaining in the permit term). However, note that this methodology ignores the benefits of deterrents during four years of Project operation (FY 2020 – FY 2023).

The Project's current ratio of indirect take to direct take indicates the estimated indirect take is 9.2 percent of the direct take estimate (8.50 adult bat equivalents estimated in FY 2023/92 bats estimated from direct take). When an estimate of indirect take of 9.7 adult bat equivalents (9.2 percent * 104.7 bats estimated from direct take) is added to the direct take estimate, the estimated take is 114.4 adult bat equivalents (104.7 bats estimated through direct take + 9.7 bats estimated through indirect take) in December 2031. This indicates that while the Project may stay below the Tier 4 maximum of 115 bats through the permit term, it is also possible that it will surpass this value. Nevertheless, both the EoA and HCP methods of generating take projections indicate the Project will stay below the total HCP Amendment take estimates (up to Tier 6) through the permit term.

Figure 1. EoA Estimated Hawaiian Hoary Bat Fatality Rates by Year at the Project



6.2 Hawaiian Petrel

Although no Hawaiian petrel fatalities were observed in FY 2023, this is the only other HCP Covered Species previously observed as a fatality at the Project; thus, a take estimate is calculated. The Hawaiian petrel was added as an HCP Covered Species through an amendment to the HCP and issuance of amended permits in 2019 (ITP in September 2019 and ITL in February 2021).[2] Therefore, there is a distinction between the Project estimated take and the level of take occurring under the authorized permits and the amended HCP. To address this issue, estimated take over the period of Project operations was analyzed first. Following this analysis, a ratio was applied of the portion of the Project's operations under which the Hawaiian petrel was an HCP Covered Species to identify the estimated take for the purposes of tracking take with respect to the applicable regulatory permits.

Table 4 summarizes the total estimated Hawaiian petrel take through FY 2023. Input values for the multi-year analysis are provided in Table 5. Inputs and output from EoA are provided in Appendix 6.

Table 4. Eighty Percent Upper Credible Limit (UCL) Estimate of Cumulative Hawaiian Petrel Take through FY 2023

A: Observed Direct Take[1]	B: Incidental Observed Take[2]	C: 80% UCL of Estimated Direct Take[3]	D: UDT (C –A – B)	E: Estimated Indirect Take (Chicks/Eggs)[4]
0	2	1	NA	2

1. Observed direct take used in Evidence of Absence analysis based on FY 2013 to FY 2023 data.
2. Fatalities occurred outside of the defined search area and were not used in Evidence of Absence analysis.
3. Multi-year Evidence of Absence analysis (Dalthorp et al. 2017) based on FY 2013 to FY 2023 data.
4. Overall indirect take for the Project is calculated based on parameters described in Appendix 16 of the HCP Amendment and rounded up to the nearest integer (Tetra Tech 2019).

Table 5. Input Values for Multi-Year Analysis of Hawaiian Petrel Take through FY 2023

Year[1]	Weight	Search Fatalities[2]	Ba	Bb	$\hat{g}$	$\hat{g}$ 95% Confidence Interval
FY 2013	0.67	0	347.5	34.45	0.910	0.879 – 0.936
FY 2014	1	0	126.3	23.51	0.843	0.781 – 0.897
FY 2015	1	0	398.7	221.4	0.643	0.605 – 0.680
FY 2016a	0.33	0	393.4	209.6	0.652	0.614 – 0.690
FY 2016b	0.67	0	1437	4968	0.224	0.214 – 0.235
FY 2017	1	0	496.6	1734	0.223	0.206 – 0.240

[2] Based on input from the agencies and species experts, take of the Hawaiian petrel was not anticipated during the development of the original HCP.

Year[1]	Weight	Search Fatalities[2]	Ba	Bb	$\hat{g}$	$\hat{g}$ 95% Confidence Interval
FY 2018	1	0	5.721	22.19	0.205	0.080 – 0.370
FY 2019	1	0	140.0	426.5	0.247	0.213 – 0.283
FY 2020	1	0	978.7	3056	0.243	0.229 – 0.256
FY 2021	1	0	1698	5298	0.243	0.233 – 0.253
FY 2022	1	0	201.2	448.2	0.310	0.275 – 0.346
FY 2023	1	0	775.1	1029	0.430	0.407 – 0.453

1. Year data for FY 2013 to 2017 are taken from Appendix 16 in the HCP Amendment (Tetra Tech 2019).
2. Two Hawaiian petrel fatalities have been found at the Project (July 21, 2017, and August 20, 2018), both occurred outside of the systematic search areas and therefore were not included in the Evidence of Absence analysis.

Based on biological parameters presented in Appendix 16 of the HCP Amendment (Tetra Tech 2019), the estimate of cumulative indirect take through FY 2023 is calculated as follows:

- **Estimate of direct adult take:**
  - Greater of observed adult direct take (2) and estimated direct take using Evidence of Absence (1) = **2 adults**
- **Proportion of adults that breed:**
  - Both observed fatalities occurred from May to August. The estimate of the percent of adults breeding in the colony = **0.89**
- **Parental contribution:**
  - Breeding adults produce 1 chick/pair and are dependent on both adults during May through August = **100 percent**
- **Reproductive success:**
  - Average reproductive success = **0.63**
- **Total chick/egg indirect take**
  - Calculated as (2 * 0.89 * 1.00 * 0.63) **= 1.12**

Therefore, the estimated indirect take based on the estimate of Hawaiian petrel direct take at the Project is **2 chicks/eggs** (rounded up from 1.12).

The UCL for cumulative Project take of the Hawaiian petrel over the period of Project operations is **2 adults and 2 chicks/eggs**.

As noted above, from a regulatory perspective, take of the Hawaiian petrel has only been permitted for a portion of the Project's operations. To measure take against the authorized take limit, a proportion of the time the Project has operated with permits authorizing incidental take of the

Hawaiian petrel is applied to the estimate for the entire period of Project operation. For FY 2023, the Project has operated from November 2012 through June 2023 (10.67 years) and the Project has authorized incidental take of the Hawaiian petrel from September 2019 to June 2023 (3.83 years).

- **Estimated adult Hawaiian petrel take** under permit = (3.83/10.67) * 2 = **0.72**
- **Estimated chick/fledging Hawaiian petrel take** under permit = (3.83/10.67) * 1.12 = **0.40**

Rounding up, the cumulative Project take of Hawaiian petrels as measured against the authorized take limit is **1 adult and 1 chick/egg**. This estimate is below the authorized take limit of 19 adults and 5 chicks/eggs.

6.3 Non-listed Species

Twenty-two bird fatalities representing 10 different non-listed species were documented at WTGs at the Project in FY 2023 (see Table 6). No fatalities have been observed at either of the two met towers. Three of the bird species observed in FY 2023 are protected by the Migratory Bird Treaty Act. Appendix 1 provides a complete list of fatalities for FY 2023.

Table 6. Non-listed Bird Fatalities Documented at the Project in FY 2023

Species	Common/ Hawaiian Names	No. of Observed Fatalities in FY 2023
Acridotheres tristis	Common Myna	2
Estrilda astrild	Common Waxbill	3
Francolinus francolinus	Black Francolin	3
Francolinus pondicerianus	Gray Francolin	1
Geopelia striata	Zebra Dove	2
Haemorhous mexicanus[1]	House Finch	2
Phaethon lepturus[1]	White-tailed Tropicbird; koaʻe kea	3
Pluvialis fulva[1]	Pacific Golden-Plover; kolea	1
Spilopelia chinensis	Spotted Dove	4
Zosterops japonicus	Warbling White-eye	1
1. Species protected by the Migratory Bird Treaty Act.		

7.0 Wildlife Education and Observation Program

Wildlife Education and Observation Program (WEOP) trainings continue to be conducted on an as-needed basis to provide on-site personnel and visitors with the information they need to be able to respond appropriately in the event they observe a listed species or encounter a fatality while on site. Twenty WEOP trainings were conducted in FY 2023.

8.0 Mitigation

The Project's current mitigation requirements are described in Section 7.6 of the 2011 HCP (SWCA 2011) and Section 7 of the HCP Amendment (Tetra Tech 2019).

8.1 Hawaiian Hoary Bats

For the Hawaiian hoary bat, mitigation is required based on where the estimated Project take falls with respect to tiers identified in the HCP and HCP Amendment. As stated above, the Project is currently in Tier 4 take.

During FY 2023, acoustic bat surveys continued at the Project (see Section 8.1.1) and management activities and acoustic bat surveys for Tier 1 mitigation continued at ʻUkoʻa Wetland (see Section 8.1.2). Mitigation for Tiers 2 through 4 is complete. USFWS- and DOFAW-approved bat research projects for Tiers 2/3 mitigation were completed in FY 2022 (see Section 8.1.3), and funds were previously provided toward the acquisition of Waimea Native Forest to fulfill remaining obligations for Tier 3 (see Section 8.1.4). Tier 4 mitigation was completed in FY 2019 with the acquisition and long-term protection of Helemano Wilderness Area (see Section 8.1.5). Kawailoa Wind is continuing planning for Tier 5 bat mitigation should it be required during the Project's permit term (see Section 8.1.6).

8.1.1 On-site Acoustic Surveys

Following commitments outlined in the HCP (SWCA 2011), bat activity was intensively monitored at 42 sites (30 WTGs at ground and nacelle, and 12 gulch detectors) across the Project during the first 3 years of systematic fatality monitoring (beginning in August 2013, FY 2014). Having identified no significant correlation with acoustic bat activity that could inform curtailment during the required intensive acoustic monitoring period (April 2012 to November 2015), Kawailoa Wind reduced the acoustic monitoring effort at the Project in the second quarter of FY 2017 to four permanent, ground-based units located at WTGs 1, 10, 21, and 25 (Figure 2). These locations were randomly chosen after eliminating detectors with high or low detection rates. Currently, each monitoring site consists of one song meter SM2BAT+ ultrasonic recorder (hereafter referred to as SM2) equipped with one SMX-U1 ultrasonic microphone (Wildlife Acoustics, Maynard, MA, USA) positioned 6.5 meters above ground level.

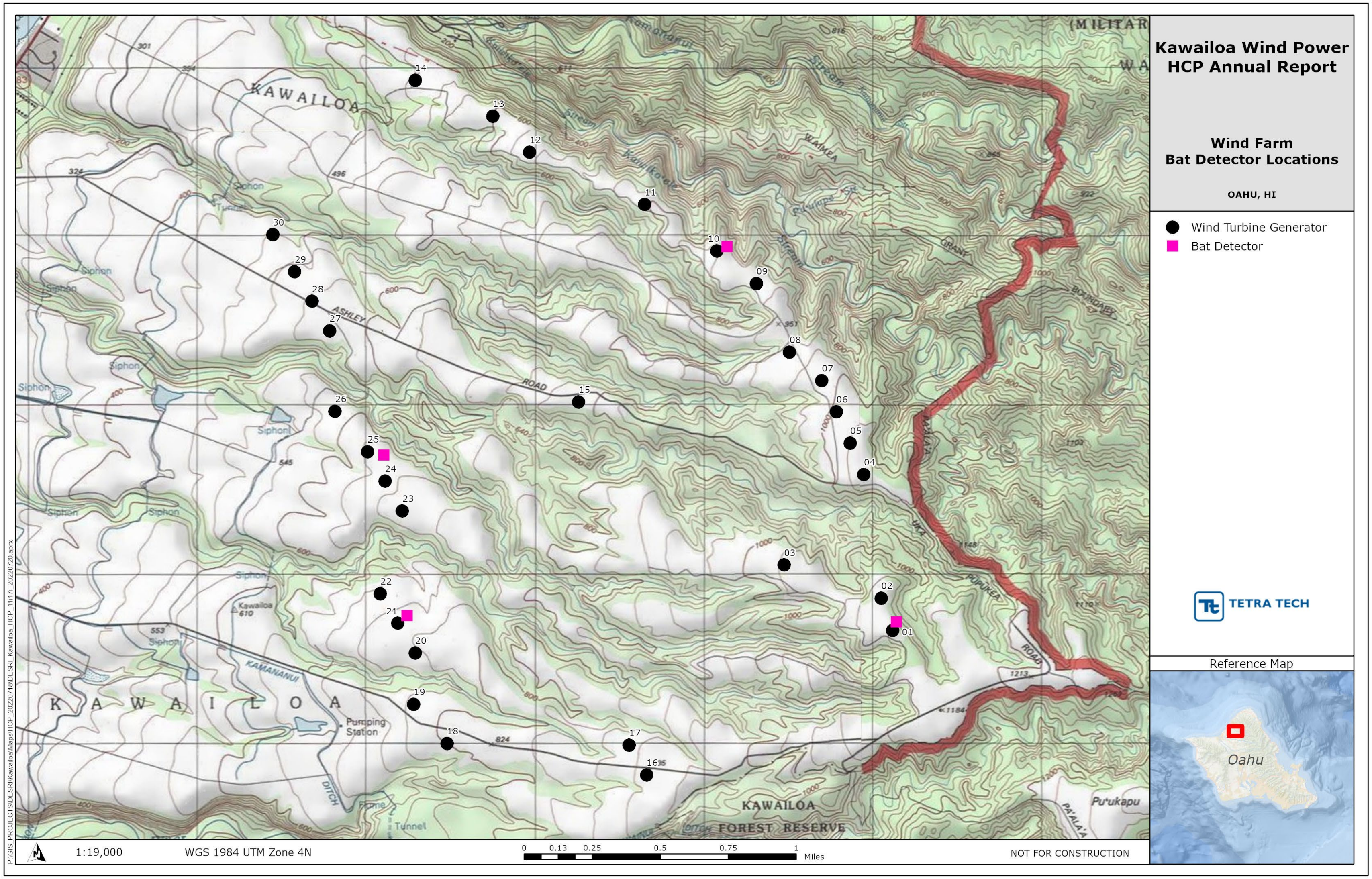


Figure 2. Four Permanent Bat Acoustic Detector Locations at the Project in FY 2023

The objective of acoustic monitoring is to better understand the annual and seasonal variations in bat activity at the Project. Analysis of variance (ANOVA) and Tukey's honest significance difference (Tukey's HSD) were used to test for differences in detection rates between the 2014 and 2023 Bat Sampling Periods.[3] A linear model (LM) was used to test for a change in detection rates across all monitoring years. Data were normalized using an Ordered Quantile Normalization transformation (ORQ) using the 'bestNormalize' package in R (Peterson 2021). The distribution of residuals from the LM were examined to check for violations of model assumptions. All tests were two-tailed, employed an alpha value of 0.05, and were conducted in R version 4.2.3 (R Core Team 2023). The characterization of Hawaiian hoary bat seasons corresponds approximately to Gorresen et al. (2013).

Hawaiian hoary bats were detected on 248 of 1451 (17.1 percent) detector-nights sampled throughout the 2023 Bat Sampling Period. The annual detection rate during the 2023 Bat Sampling Period was marginally lower than the annual detection rate during the 2022 Bat Sampling Period (21.9 percent; Table 7), although not significant (Tukey's HSD: $P = 1.00$). Annual detection rates varied between all years (Table 7); however, only differences between 2014 and 2018, 2014 and 2019, 2014 and 2021, and 2014 and 2022 were significant (ANOVA: $F_{9,108} = 2.7$, $P < 0.007$; Tukey's HSD: 2014-2018, $P < 0.045$; 2014-2019, $P < 0.017$; 2014-2021, $P < 0.028$; 2014-2022, $P < 0.019$).

Table 7. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections at Permanent Detectors from June 2013 through May 2023

Bat Sampling Period	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2014 (June 2013 – May 2014)	1,211	82	0.068
FY 2015 (June 2014 – May 2015)	1,021	144	0.141
FY 2016 (June 2015 – May 2016)	1,321	213	0.161
FY 2017 (June 2016 – May 2017)	1,355	180	0.133
FY 2018 (June 2017 – May 2018)	1,451	280	0.193
FY 2019 (June 2018 – May 2019)	1,249	300	0.240
FY 2020 (June 2019 – May 2020)	1,272	169	0.133
FY 2021 (June 2020 – May 2021)	1,437	298	0.207
FY 2022 (June 2021 – May 2022)	1,217	266	0.219
FY 2023 (June 2022 – May 2023)	1,451	248	0.171
Note: FY 2013 not included due to minimal number of detector-nights compared to other years.			

[3] The analysis and reporting period for bat acoustic data (referred to as the Bat Sampling Period) differs slightly from the FY to allow adequate time for data review and analysis. The Bat Sampling Period stretches from June 1 to May 31.

Across all years (2014 to 2023), there is a significant increasing trend in the annual detection rates (LM: R^2 = 8.91 percent; $F_{1,116}$ = 11.34, $P < 0.001$; Figure 3). If the 2014 Bat Sampling Period is removed, there is still an increasing trend in the annual detection rates, although not significant (LM: R^2 = 2.86 percent; $F_{1,104}$ = 3.06, $P > 0.083$). The low r-squared value of this trend suggests that little of the variation is explained by the linear model (i.e., year). This could be an indication of inherent inter-annual variation or the importance of variables not included in the model.

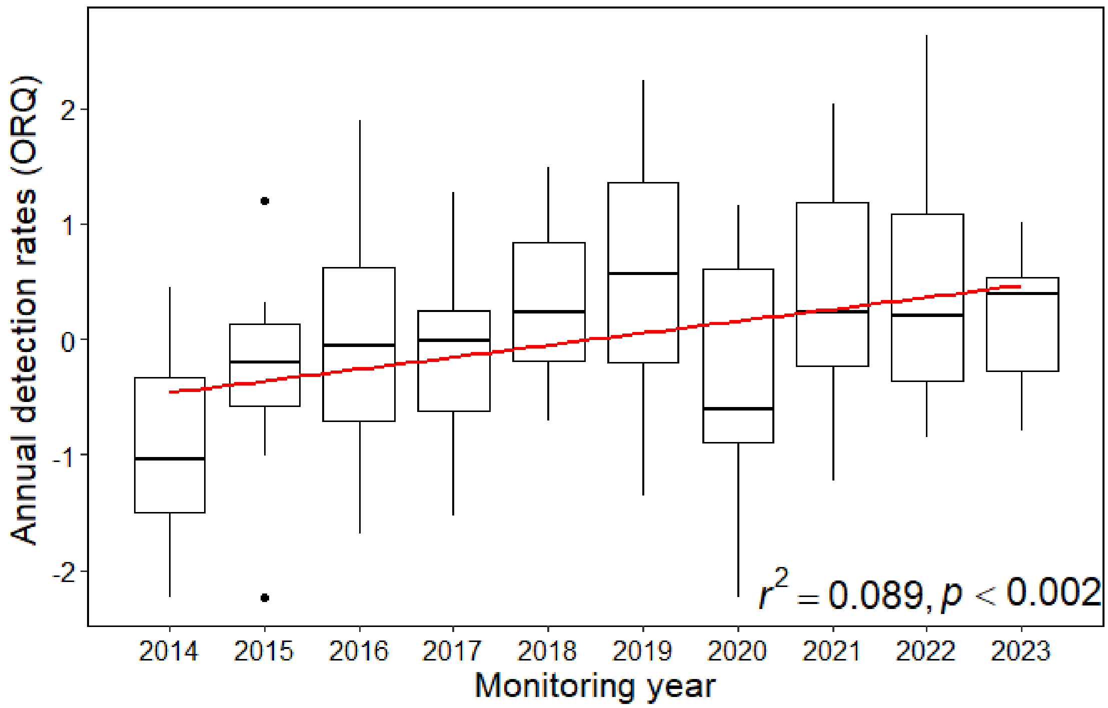


Figure 3. Box-plot Fitted with a Linear Regression Showing the Increasing Trend in the Annual Detection Rate at the Project between FY 2014 and FY 2023.

Note: Annual Detection Rates were Transformed using an Ordered Quantile Normalization Transformation (ORQ).

During the 2023 Bat Sampling Period, elevated detection rates were observed during the lactation reproductive period (mid-June through August), reaching an initial peak during the early post-lactation (September) reproductive period. A decline in detection rates occurred following the initial peak in September and the transition to the post-lactation (September to mid-December) reproductive period. Lower detection rates were observed from October of the post-lactation reproductive period to January of the pre-pregnancy reproductive period (mid-December to mid-March). Detections rates increased in February followed by a second smaller peak in March during the transition between the pre-pregnancy and pregnancy (mid-March to mid-June) reproductive periods. Detection rates declined in April followed by an increase in May, which was the largest peak in detection rates throughout the year (Figure 4).

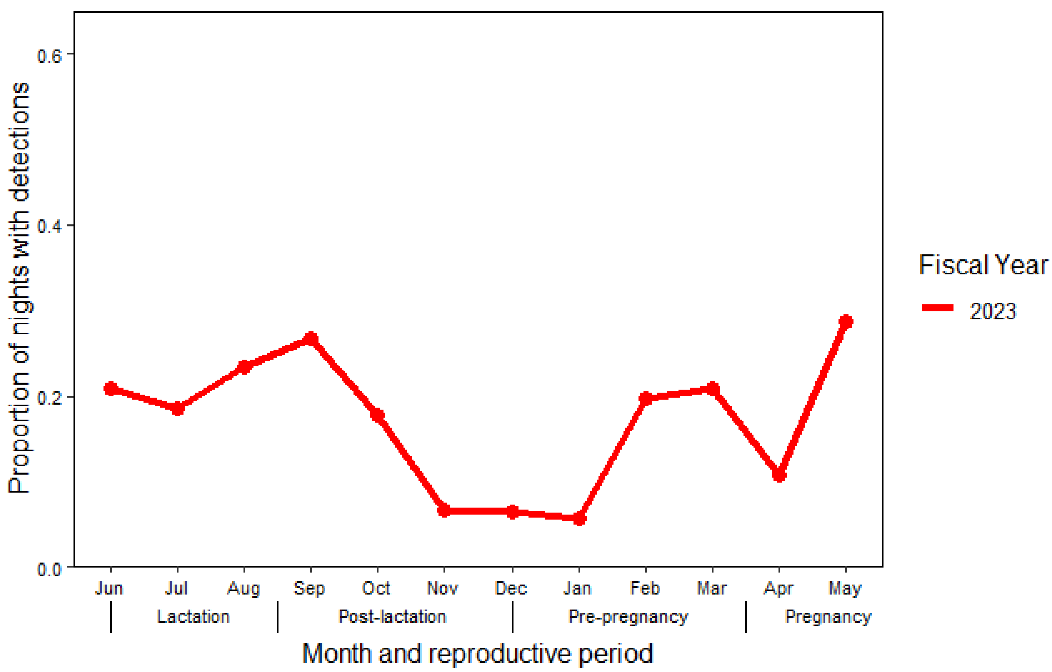


Figure 4. Monthly Detection Rates at Kawailoa in FY 2023 with Corresponding Reproductive Periods.

The temporal patterns in detection rates during the 2023 Bat Sampling Period were relatively similar to detection rates observed in previous sampling years (Figure 5). The general temporal pattern in the detection rates observed at the Project has also been reported in other acoustic monitoring studies at other low-elevation sites on Oʻahu (Thompson and Starcevich 2022) and Hawaiʻi Island (Todd 2012).

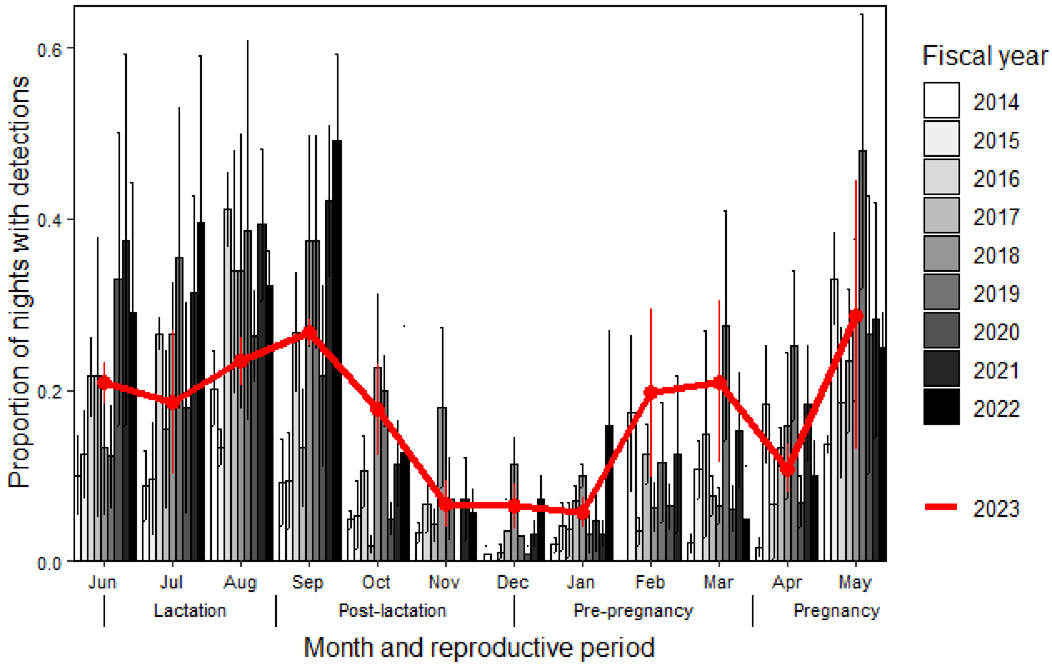


Figure 5. Monthly Bat Detection Rates at Kawailoa for FY 2014 to FY 2023 with Corresponding Reproductive Periods.

The variation in detection rates across the four permanent detector sites is shown in Figure 6. In general, WTG-25 recorded higher detection rates on average throughout the year than the other sites, most notably during the lactation reproductive period and from October to February of the post-lactation and pre-pregnancy reproductive periods. The seasonal patterns in observed detection rates were relatively similar among all sites during the lactation and post-lactation reproductive periods. Greater variation in detection rates were observed between sites during the pre-pregnancy and pregnancy reproductive periods. At sites WTG-25 and 1, detection rates increased earlier in the pre-pregnancy reproductive period and then declined in the pregnancy reproductive period, while detection rates at sites WTG-10 and 21 increased later in the pre-pregnancy reproductive period and continued to increase throughout the pregnancy reproductive period (Figure 6).

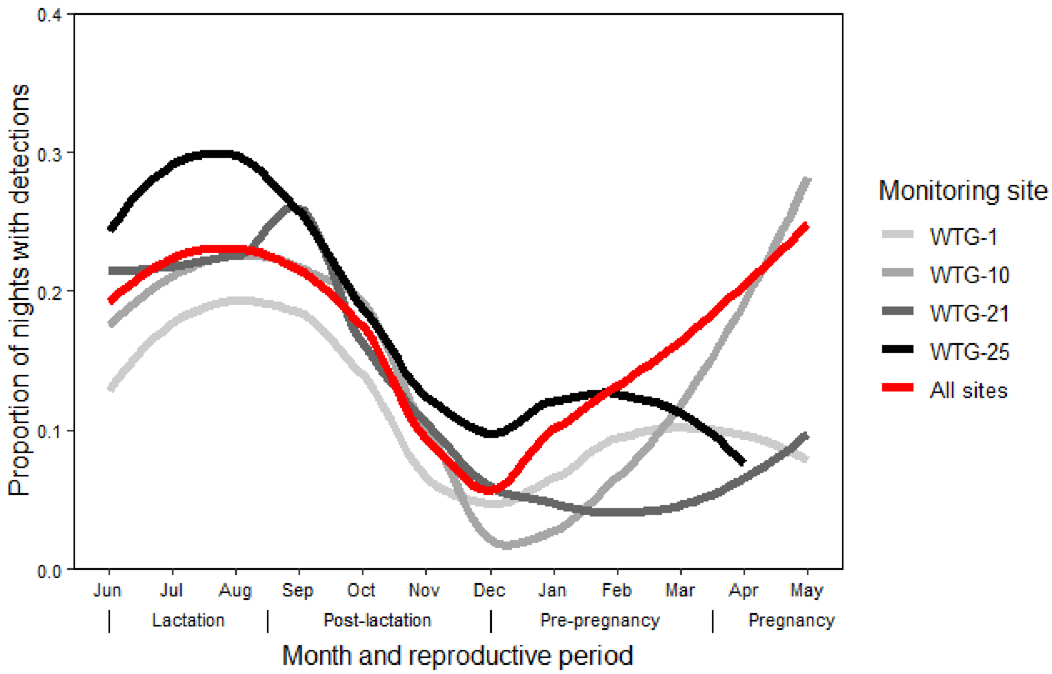


Figure 6. Site-Specific Variation in Detection Rates for Each Month of FY 2023 with Corresponding Reproductive Periods.

Note: Trend Lines are fitted with Loess smoothing curve

8.1.2 ʻUkoʻa Wetland (Tier 1)

Mitigation for bats and waterbirds continued at ʻUkoʻa Wetland during FY 2023. In FY 2016 (March 2016), USFWS and DOFAW provided written confirmation permitting adaptive management for the original bat and waterbird mitigation proposed at ʻUkoʻa Wetland. This included the following:

1. Reduction from 40 acres of vegetation removal to assumed open water areas, as outlined in Figure 2 of the approved ʻUkoʻa Wetland Hawaiian Hoary Bat Mitigation Management Plan (H. T. Harvey and SWCA 2014);
2. Omit replanting of natives with assumption of natural recruitment after invasive plant species are removed;
3. Omit mosquitofish removal component; and
4. Tie success criteria for bats to completion of all other management and monitoring components instead of increased bat activity.

In FY 2023, activities associated with Tier 1 bat mitigation at ʻUkoʻa Wetland included invasive vegetation removal, predator control, monitoring predator presence, fence monitoring and maintenance, bat acoustic monitoring, bat lane maintenance, and insect sampling analysis. Additional details for each are provided below.

8.1.2.1 Invasive Vegetation Removal

In FY 2023, Hapa Landscaping conducted maintenance visits to remove any areas of water hyacinth (*Eichhornia crassipes*) or other invasive vegetation that regenerated in the previously cleared, open water area including water lettuce (*Pistia stratiotes*) and California grass (*Urochloa mutica*). Quarterly scheduled visits were modified as needed to accommodate staff schedules and avoid disturbing Hawaiian common gallinule/ʻalae ʻula (*Gallinula chloropus sandvicensis*) nests and chicks in the area. Figure 7 shows a representative photograph of the open water that resulted from this ongoing maintenance.

Figure 7. Open Water Resulting from Ongoing Removal of Invasive Vegetation at ʻUkoʻa Wetland in FY 2023.

Note: Photo Taken in June 2023.

8.1.2.2 Predator Control and Monitoring Predator Presence

The Project contracts Grey Boar Wildlife Services, LLC (Grey Boar) to conduct predator and ungulate removal at ʻUkoʻa Wetland, as well as to monitor and repair the fence. Predator control first began at ʻUkoʻa Wetland in June 2014 (FY 2014). The number and type of predators trapped at ʻUkoʻa Wetland from FY 2014 to FY 2023 is shown in Table 8. In FY 2023, a total of 119 predators were removed from ʻUkoʻa Wetland including 23 pigs, 79 mongoose, 16 rats, and 1 cat (Grey Boar 2022a, Grey Boar 2022b, Grey Boar 2023a, Grey Boar 2023b). The following trap types are used throughout ʻUkoʻa Wetland in FY 2023: four pig corrals and two pig box traps, 100 GoodNature A24s, 12 live cages, and 50 Doc-250s. Pigs continue to move into the fenced area at ʻUkoʻa Wetland due to breaches in the fence caused by trespassers cutting the fence and occasionally tree fall.

Table 8. Predators Trapped at ʻUkoʻa Wetland from FY 2014 to FY 2023

	FY 2014[1]	**FY 2015**[2]	**FY 2016**[2]	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**	**FY 2021**	**FY 2022**	**FY 2023**
Rats	30	92	77	18	24	12	25	35	23	16
Cats	15	22	7	2	10	2	3	2	0	1
Mongoose	224	190	204	96	160	136	168	173	105	79
Mice	21	23	6	1	3	0	0	0	0	0
Pigs	51	56	20	103	29	42	7	9	48	23
Dogs	0	0	0	0	1	0	0	0	0	0
Total Removed	**341**	**383**	**314**	**220**	**227**	**192**	**203**	**219**	**176**	**119**

1. In FY 2014, trapping only occurred for 1 month (June 2014).

2. No trapping occurred at ʻUkoʻa Wetland from April 2016 to November 2016.

Tracking tunnels are generally set out quarterly to assess the presence of rodents, mongoose, and cats within the wetland. Overall, tracking tunnel data since 2014 (see Figure 8) shows a general reduction in predator presence, specifically mongoose and rats, since the predator program was initiated.

In FY 2023, tracking tunnels were set out in September 2022, December 2022, March 2023, and June 2023. Twenty-five tracking tunnels were used to detect predator presence in FY 2023. The cards were baited with peanut butter and collected one day after setting. Tracks were then counted and recorded. Percent activity (number of cards with tracks divided by total number of cards set out) during FY 2023 is shown in Table 9. Rat activity varied between 8.0 and 22.2 percent and showed the highest activity rates of the predators. Mice and cats were only detected during the September 2022 deployment.

Table 9. Percent Predator Activity Based on Tracking Tunnels at ‘Uko‘a Wetland during FY 2023

Date	Rats	Mongoose	Mice	Cats
September 17, 2022	8.0%	8.0%	8.0%	4.0%
December 11, 2022	22.2%	0.0%	0.0%	0.0%
March 4, 2023	11.1%	4.0%	0.0%	0.0%
June 11, 2023	14.8%	4.0%	0.0%	0.0%

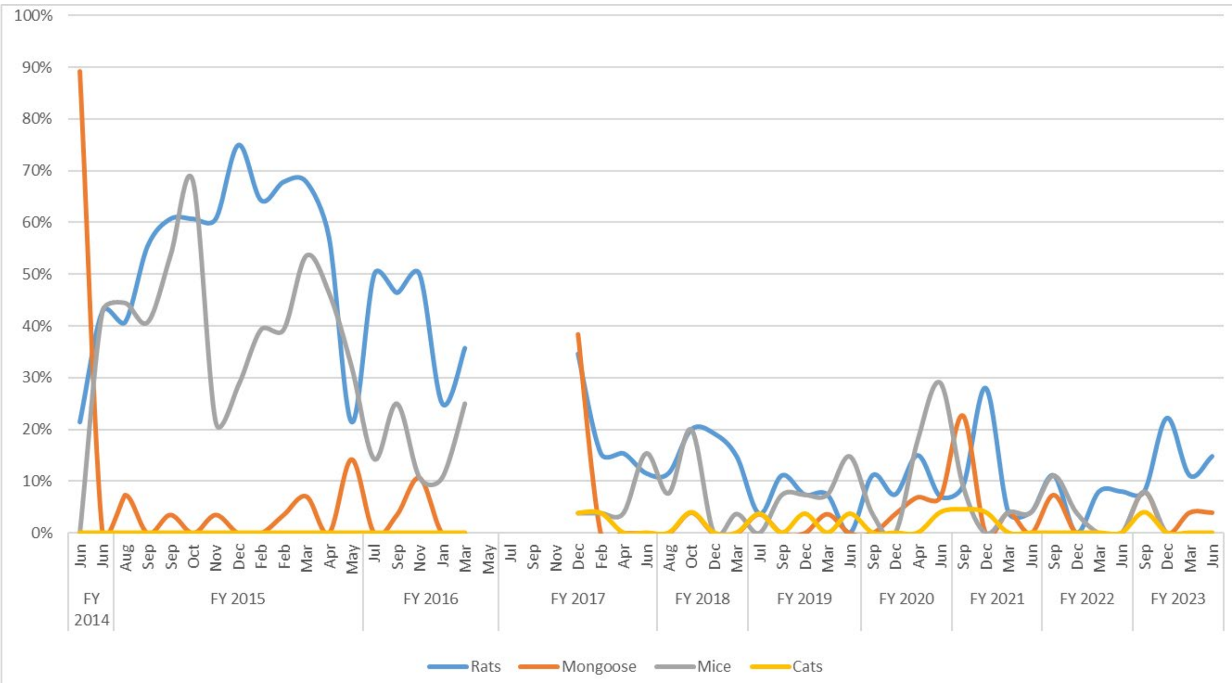


Figure 8. Percent Activity of Tracking Tunnels from FY 2014 to FY 2023

Source: Grey Boar 2023b.

8.1.2.3 Fence Monitoring and Maintenance

Fence inspections were conducted by Grey Boar while checking predator control traps. The fence was visually inspected for any signs of ungulate disturbance, damage, or vandalism. During FY 2023, several sections of fence were repaired. The main causes of fence damage continues to be trespassers and occasionally tree fall.

8.1.2.4 Bat Lanes

Oʻahu Tree Works, LLC finished bat lane construction in December 2017 (FY 2018). During FY 2023, bat lane maintenance occurred on several lanes on November 15 and 16, 2022, and again on January 6, 2023. Figure 9 shows an example of a bat lane following the maintenance visits in FY 2023. In total, there are 16 bat lanes within 10 zones throughout ʻUkoʻa Wetland (Figure 10).

Figure 9. Bat Lane at ʻUkoʻa Wetland

Photo Taken in June 2023.

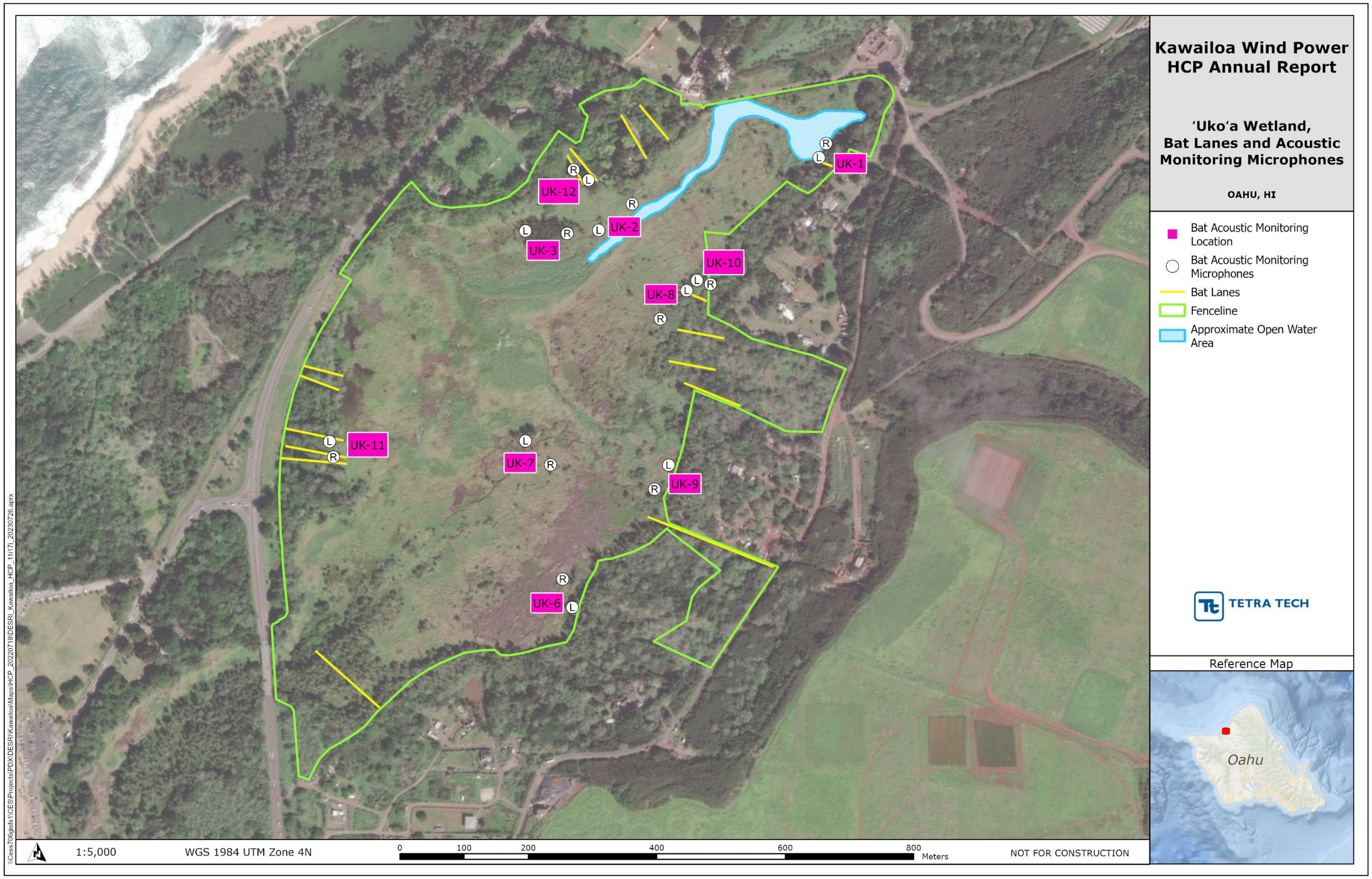


Figure 10. Bat Lanes and Bat Acoustic Detector Microphones at 'Uko'a Wetland

8.1.2.5 Bat Acoustic Surveys at ‘Uko‘a

In June 2017, following the removal of invasive vegetation at the open water areas of ‘Uko‘a Wetland and construction of bat lanes, 10 SM2 acoustic recorders (Wildlife Acoustics, Maynard, MA, USA) were deployed at locations previously monitored between 2012 and 2015 (see Figure 10). The SM2s deployed in June 2017 are similar to those used in previous sampling years to maintain consistency. Each SM2 is equipped with two SMX-U1 ultrasonic microphones (Wildlife Acoustics, Maynard, MA, USA) positioned between 3 and 6.5 meters above ground level.

The proportion of detector-nights containing a single bat pass (any call file containing two or more bat echolocation pulses; Gannon et al. 2003) was used as a measure to quantify bat activity. The sampling period and methods used to analyze bat acoustic data at ‘Uko‘a Wetland are the same as those used for acoustic data at the Project (see Section 8.1.1).

During the 2023 Bat Sampling Period (June 2022 to May 2023), Hawaiian hoary bats were detected on 534 nights out of 2,708 detector-nights sampled (19.7 percent). The annual detection rate in the 2023 Bat Sampling Period was similar to the annual detection rate during the previous sampling year (23.0 percent) (see Table 10).

Table 10. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections at ‘Uko‘a Wetland from April 2012 to May 2023

Bat Sampling Period	Before or After Vegetation Removal	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2012 (April – May 2012)	Before	142	18	0.127
FY 2013 (June 2012 –May 2013)	Before	2,036	191	0.094
FY 2014 (June 2013 – May 2014)	Before	2,694	100	0.037
FY 2015 (June 2014 – May 2015)	Before	2,552	175	0.069
FY 2016 (June – October 2015)	Before	1,211	218	0.180
FY 2018 (June 2017 – May 2018)	After	3,248	444	0.137
FY 2019 (June 2018 – May 2019)	After	3,391	506	0.149
FY 2020 (June 2019 – May 2020)	After	3,339	650	0.195
FY 2021 (June 2020 – May 2021)	After	3,182	613	0.193
FY 2022 (June 2021 – May 2022)	After	2,430	559	0.230
FY 2023 (June 2022 - May 2023)	After	2,708	534	0.197
Notes: 2017 Sampling Period not included due to minimal number of detector-nights compared to other years; no detectors were deployed from November 2015 to May 2017. Beginning FY 2021, the time period for analyzing and reporting bat acoustic data (referred to as the Bat Sampling Period) was changed to June 1 to May 31 rather than the FY (July 1 to June 30) to allow adequate time for data review and analysis. All previous sampling years have been adjusted to reflect this same sampling period.				

Annual detection rates varied across sampling years (Table 10); however, only differences between 2014 and 2020, 2014 and 2021, 2014 and 2022, and 2014 and 2023 were significant (ANOVA: $F_{10,102} = 3.68$, $P < 0.001$; Tukey's HSD: 2014-2020, $P < 0.003$; 2014-2021, $P < 0.015$; 2014-2022, $P < 0.002$, 2014-2023, $P < 0.010$). Across all monitoring years there is a significant increase in the annual detection rates (LM: $R^2 = 17.4$ percent; $F_{1,111} = 23.37$, $P < 0.001$; Figure 11). There are some inconsistencies in sampling periods for some of the monitoring years. Sampling in the 2012 and 2016 Bat Sampling Periods only occurred during the pregnancy and lactation reproductive periods, which have higher rates of detections, and sampling in 2015 did not occur during the months of November and December, which typically have lower rates of detection.

Detection rates in the 2023 Bat Sampling Period increased throughout the lactation reproductive period (mid-June to August) and peaked (0.4) in October of the post-lactation reproductive period (September to mid-December; Figure 12). Following the peak in October, detection rates declined in the month of November and reached the lowest detection rate (0.03) in December at the start of the pre-pregnancy reproductive period (mid-December to March). Detection rates remained low in January and February and began to increase again in March in the pre-pregnancy reproductive period (Figure 12). The detection rate continued to increase throughout the pregnancy reproductive period (April to mid-June) with a second peak (0.29) in May (Figure 12). The temporal patterns in the detection rates for the 2023 Bat Sampling Period are similar to the detection rates observed at 'Uko'a Wetland in previous sampling years (Figure 13).

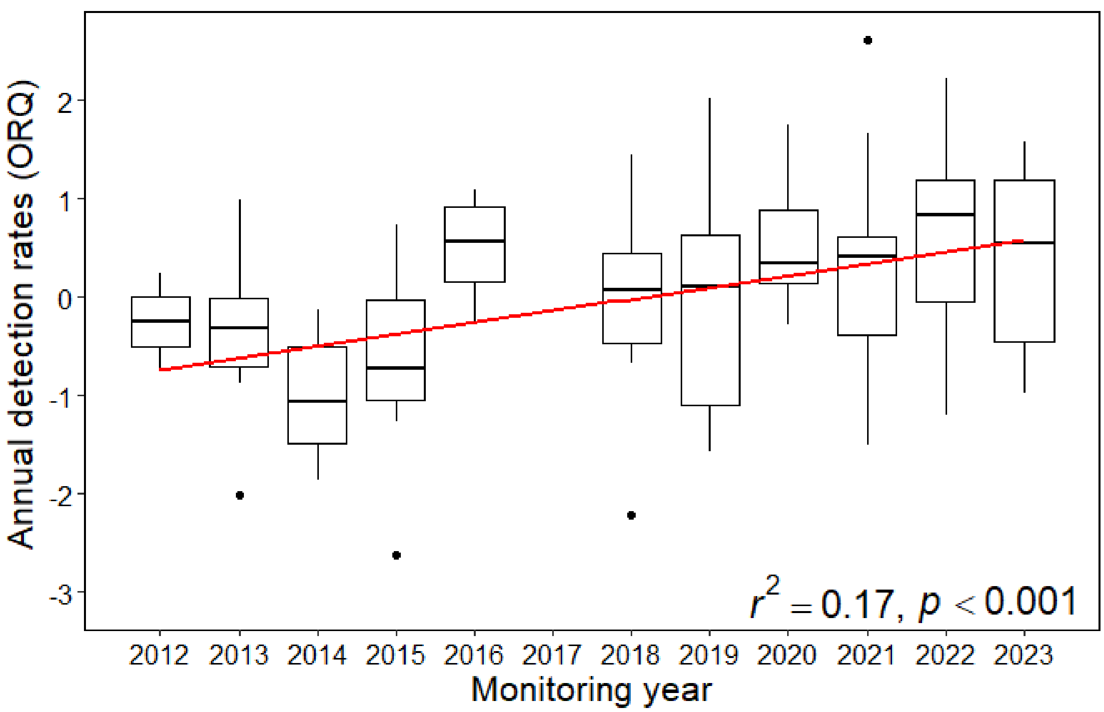


Figure 11. Box-plot Fitted with a Linear Regression Showing the Increasing Trend in the Annual Detection Rates at the Project between 2012 and 2023 Sampling Periods

Note: Annual Detection Rates were Transformed using an Ordered Quantile Normalization Transformation (ORQ).

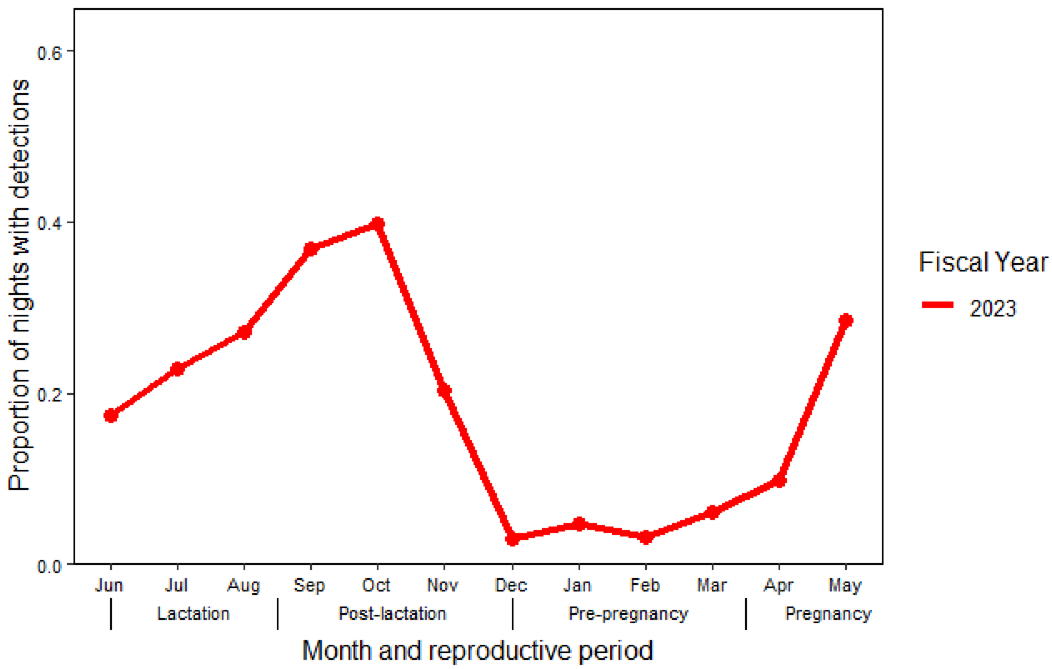


Figure 12. Monthly Bat Detection Rates at ʻUkoʻa Wetland during 2023 Bat Sampling Period with Corresponding Reproductive Periods

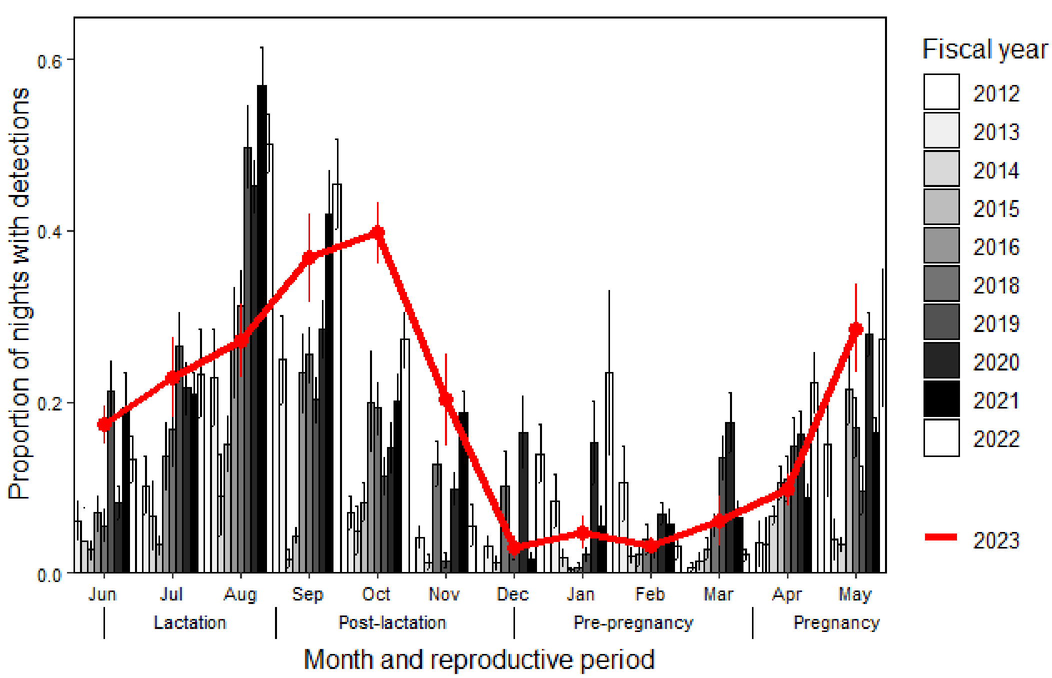


Figure 13. Monthly Bat Detection Rates at ʻUkoʻa Wetland for 2012 to 2023 Bat Sampling Periods with Corresponding Reproductive Periods

Comparison of detection rates for each month before management (2012 to 2016 Sampling Period) and after management (2018 to 2023 Sampling Period) at ’Uko‘a Wetland indicates an increase in the detection rates for several months throughout the year (Figure 14). In addition to observed increases in monthly detection rates, there was also an observed increase in the mean proportion of nights with feeding buzzes recorded at several of the monitoring sites after management was implemented (Figure 15). A feeding buzz is classified as a burst of pulses at a very high rate with less than 11 milliseconds between pulses (Griffin et al. 1960) and is indicative of foraging behaviors. Monitoring sites UK-1, UK-2, UK-6, UK-11, and UK-12 had the greatest observed increase following management activities (Figure 15). The observed increases in the detection rates and feeding buzzes are a positive indication for the effects of management, but may correlate with factors other than the invasive plant species removal or bat lane installation.

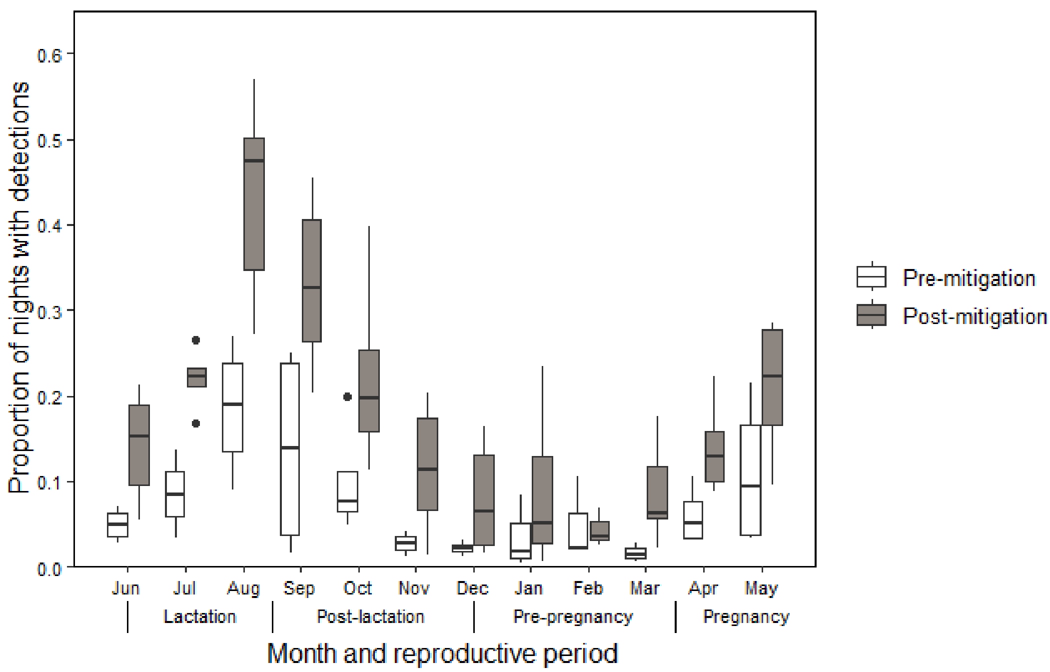


Figure 14. Box-plot Identifying the Median, Lower (Q1) and Upper (Q3) Quartiles, Whiskers (IQR x 1.5), and Outliers for Monthly Bat Detection Rates at ‘Uko‘a Wetland Before (2012 to 2016 Sampling Period) and After (2018 to 2023 Sampling Period) Management

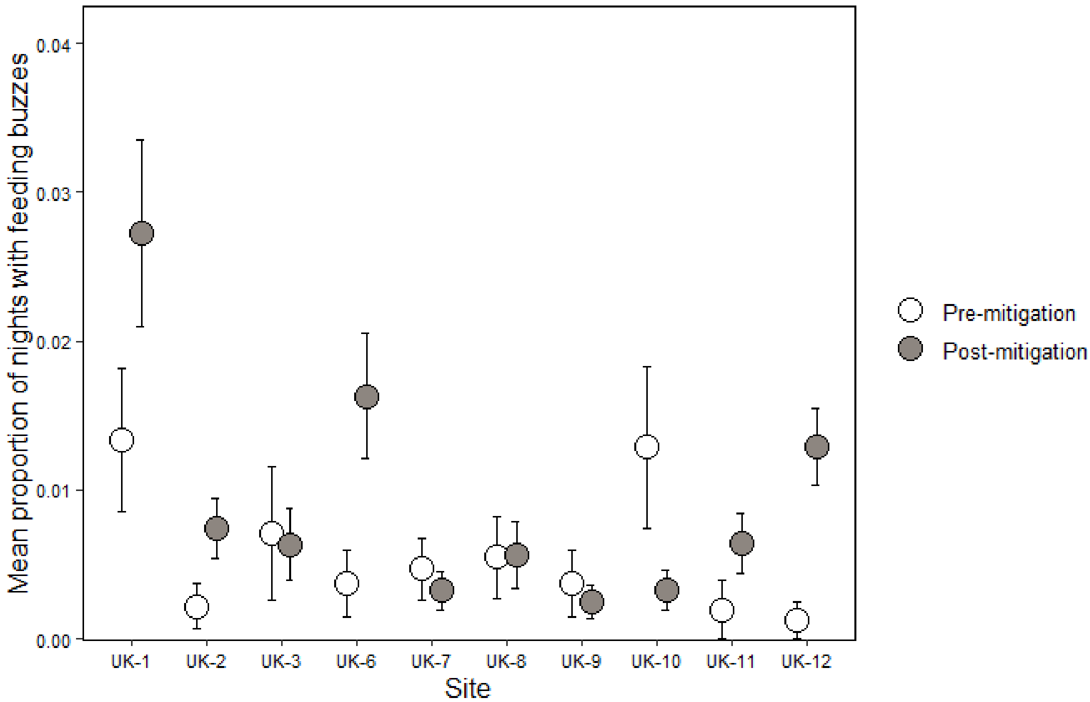


Figure 15. Mean and Standard Error for the Proportion of Feeding Buzzes for each monitoring site at ʻUkoʻa Wetland Before (2012 to 2016 Sampling Period) and After (2018 to 2023 Sampling Period) Management

8.1.2.6 Insect Assessment

In 2014 and 2015, First Wind biologists sampled insects at 10 traps throughout ʻUkoʻa Wetland as part of Tier 1 bat mitigation. Several Endangered Species Recovery Committee (ESRC) members requested Kawailoa Wind conduct a follow-up insect assessment to compare bat prey availability prior to and after management activities at ʻUkoʻa Wetland. DOFAW and USFWS approved Kawailoa Wind's methods for conducting a follow-up insect assessment in April and May 2021, respectively. The purpose of the 2021 insect sampling was to assess the current Hawaiian hoary bat prey availability at ʻUkoʻa Wetland and compare the results to insect sampling conducted in 2014 and 2015. In 2021, prey availability was measured by sampling insects using methods similar to those implemented during the 2014 and 2015 samplings. The results from the insect samplings in 2014, 2015, and 2021 are summarized in Appendix 7. It is important to note that although the management activities conducted at ʻUkoʻa Wetland have the potential to affect changes in insect availability, it is not possible to attribute any observed changes between years to the management activities primarily due to unrelated, naturally occurring interannual variation in insect populations.

8.1.3 Studies (Tier 2/3)

In FY 2017, Kawailoa Wind contracted USGS and Western EcoSystems Technology, Inc. (WEST) to conduct three multi-year studies as Tier 2/3 Hawaiian hoary bat mitigation. These studies were recommended to Kawailoa Wind by USFWS and DOFAW. The total funding for the three projects is over $1.6 million. All three agency-approved research projects are now complete.

One of the USGS research projects (Modeling Foraging Habitat Suitability) was completed in FY 2019 and the research was published in *PLOS ONE* (Gorresen et al. 2018). For USGS' *Hawaiian Hoary Bat Conservation Genetics*, all lab work, data analysis, and funding were completed in FY 2022. Several publications, data releases, and presentations have been made available from this project. The final manuscript for this project (Pinzari et al. 2023) was published in FY 2023.

The final report for WEST's *Oahu Hawaiian Hoary Bat Occupancy and Distribution Study* (Thompson and Starcevich 2022) was submitted to the ESRC in July 2022, and included in the FY 2022 annual report (Tetra Tech 2022). Although Kawailoa Wind paid the remaining funding obligations for this research project in FY 2022, Kawailoa provided an additional $10,000 to WEST in FY 2023 to support continued monitoring of a subset of the deployed detectors during a fifth year. This funding was outside the Tier 2/3 mitigation obligations, which were complete in FY 2022.

8.1.4 Waimea Native Forest (Tier 3)

Funding the above-listed Tier 2/3 studies left an outstanding obligation of $353,702 for Tier 3 bat mitigation. To fulfill the remaining uncommitted funding obligation, Kawailoa Wind provided $353,702 to Trust for Public Land (TPL) in FY 2019 to contribute to the acquisition of the Waimea Native Forest. The acquisition was completed, and ownership of the parcel was transferred to DOFAW in December 2019; therefore, Tier 3 Hawaiian hoary bat mitigation is complete.

8.1.5 Helemano Wilderness Area (Tier 4)

As described in the HCP Amendment (Tetra Tech 2019), Tier 4 Hawaiian hoary bat mitigation included contributing $2,750,000 to TPL toward the purchase and long-term protection of the nearly 2,900-acre Helemano Wilderness Area (HWA). Kawailoa Wind provided these funds to TPL in October 2018, and ownership of the HWA was transferred from TPL to DOFAW in 2018. The area became the Helemano Section of the ʻEwa Forest Reserve in March 2021, and a draft management plan was completed; therefore, Tier 4 Hawaiian hoary bat mitigation is complete. In FY 2023, DOFAW conducted the following: outplanted native species; performed road maintenance and road repair; controlled vegetation along road corridors; fence maintenance; cleared 5 acres and conducted site preparation for an experimental seed orchard; and outplanted 1,200 koa wilt resistant koa (Ryan Peralta/DOFAW, pers. comm, November 2022).

8.1.6 Tier 5 Mitigation

As outlined in the HCP Amendment, Tier 5 bat mitigation will consist of implementation of one or a combination of the following: 1) contributing funding to acquire property that will protect bat roosting and foraging habitat in perpetuity, and/or 2) conduct bat habitat management/restoration to improve bat foraging and/or roosting habitat at the Central Koʻolau area, HWA, Waimea Native Forest, or similar sites (Tetra Tech 2019). In accordance with the mitigation planning requirements under the HCP Amendment, a Site-Specific Mitigation Implementation Plan for Tier 5 mitigation was submitted to USFWS and DOFAW on May 1, 2020. However, Kawailoa Wind has continued planning for Tier 5 mitigation and is conducting site visits and having discussions with landowners for multiple potential mitigation sites. Considering the current rate of take and benefits of deterrents, Tier 5 mitigation may not be needed.

8.2 Waterbirds

As stated above, USFWS and DOFAW provided written confirmation permitting adaptive management for the original waterbird mitigation. Some activities completed for waterbird mitigation at ʻUkoʻa Wetland (e.g., invasive vegetation removal, predator control, fence maintenance) overlap with bat mitigation requirements and are summarized in Section 8.1.2 above.

Tetra Tech conducts waterbird surveys at ʻUkoʻa Wetland as part of the required mitigation. Comprehensive weekly waterbird surveys began at ʻUkoʻa Wetland in January 2017 following invasive vegetation removal in the open water area and have continued annually throughout FY 2023. In FY 2023, waterbird surveys were conducted weekly from July 2022 through August 2022 and then again from December 2022 through June 2023. A total of 39 waterbird surveys were completed in FY 2023. A qualified biologist conducted surveys at nine point-count (PC) stations set up in the vicinity of the open water and in areas with previous waterbird sightings (Figure 16). Independent waterbird observations are also recorded while walking between stations. The detailed protocols for these surveys are provided in the FY 2017 Annual Report (Tetra Tech 2017).

In addition to the weekly surveys, a biologist conducts waterbird surveys prior to any invasive vegetation control (see Section 8.1.2.1). The purpose of these surveys is to identify if listed waterbird nests or chicks are present in the vicinity of the planned work area. If present, control work is modified to avoid and minimize impacts to endangered Hawaiian waterbirds.

Results of the waterbird monitoring are detailed in the sections below. Waterbirds at ʻUkoʻa are not banded; therefore, assessments of changes on an individual basis are not possible. Although successful reproduction of Hawaiian common gallinule has been documented at ʻUkoʻa Wetland, no evidence of Hawaiian stilt/aeʻo (*Himantopus mexicanus knudseni*) or Hawaiian coot/ʻalae keʻokeʻo (*Fulica alai*) breeding has been observed despite years of ongoing management. As a result of minimal observed breeding events at the site (particularly for stilts and coots), Kawailoa Wind is in discussion with USFWS and DOFAW regarding adaptive management of waterbird mitigation.

8.2.1 Hawaiian Common Gallinule

In FY 2023, Hawaiian gallinules (either adults, chicks, or fledglings) were observed on every survey date and were recorded at seven out of the nine PC stations (Figure 16). Average monthly gallinule detections for FY 2023 are summarized in Table 11 and shown in Figure 17 and Figure 18.

Gallinule detections have generally decreased since comprehensive waterbird surveys began in 2017 (Table 11); however, detections began to increase in FY 2022 and FY 2023 compared to the low detections in FY 2020 and FY 2021. The removal of water hyacinth in the open water area has altered habitat available to gallinules at ʻUkoʻa Wetland.

Table 11 also summarizes the number of observed gallinule breeding efforts. Two gallinule breeding events were observed in FY 2023. The breeding event observed in April 2023 resulted in the successful fledging of one gallinule. The second event was observed in late April 2023, so the outcome of this breeding effort has yet to be determined; as of June 30, 2023, one gallinule chick was still present. Both breeding events in FY 2023 were observed in the open water areas around PC 03 and PC 08. All breeding observed during the last 3 years has been along the open water. In total, 14 gallinule fledglings have been recorded since surveys began in FY 2017. Although no waterbird take has been recorded at Kawailoa to date, the Project is required to replace 20 gallinule fledglings.

Figure 16. Waterbird Point Count Station Locations at 'Uko'a Wetland

Table 11. Average Number of Hawaiian Common Gallinule Detected per Survey by Fiscal Year

Sampling Period	No. of Waterbird Surveys	Average No. of Adults Detected per Survey	Average No. of Chicks Detected per Survey	Average No. of Fledglings Detected per Survey	Total No. of Breeding Efforts Observed	No. of Failed Breeding Efforts Observed	Total No. Fledged
FY 2017 (Aug 2016-Dec 2016)[1]	N/A	N/A	N/A	N/A	3	0	5
FY 2017 (Jan 2017–June 2017)	25	5.7	0.8	1.0	4	2	3
FY 2018 (July 2017–June 2018)	38	4.1	0.4	0.0	6	6	0
FY 2019 (July 2018–June 2019)	41	3.0	0.4	0.0	4	4	0
FY 2020 (July 2019–June 2020)	40	1.9	0.1	0.0	3	3	0
FY 2021 (July 2020–June 2021)	40	1.9	0.4	0.1	1	0	1
FY 2022 (July 2021–June 2022)	38	3.0	0.4	0.3	2	0	4
FY 2023 (July 2022-June 2023)	39	5.3	0.5	0.3	2	0	1
Total No. Hawaiian Common Gallinule Fledglings							**14**

1. FY 2017 is divided into 2 parts because comprehensive waterbird surveys at PC stations began in January 2017 and detections in late 2016 were incidental to other monitoring that occurred during vegetation removal in the open water areas.

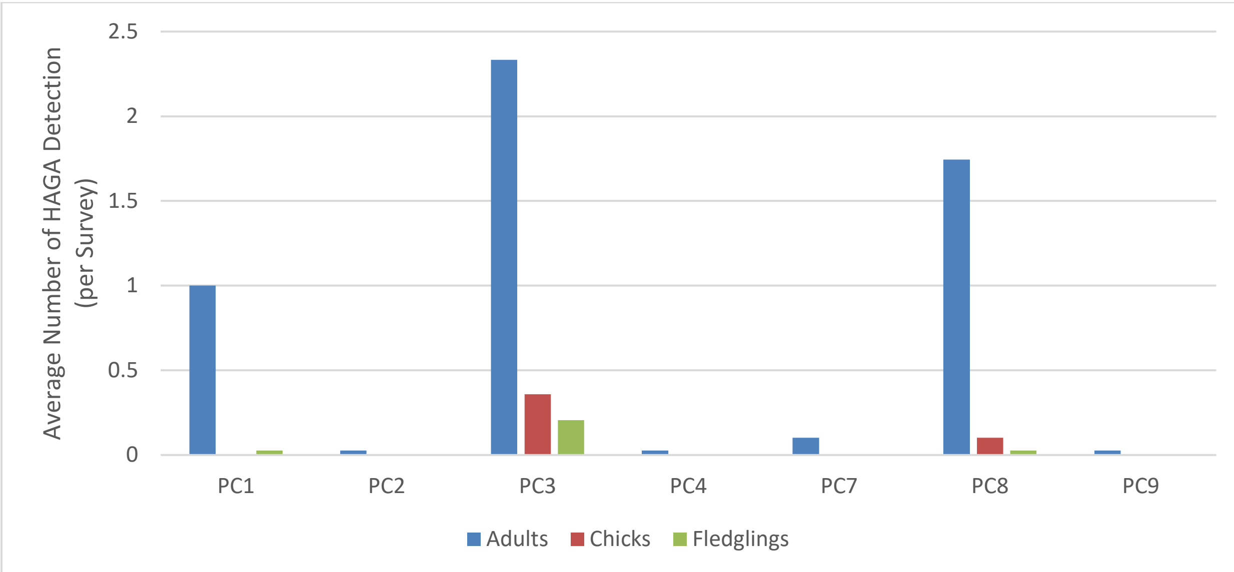


Figure 17. Average Number of Hawaiian Common Gallinule (HAGA) Detections per Survey at Point Count Stations in FY 2023

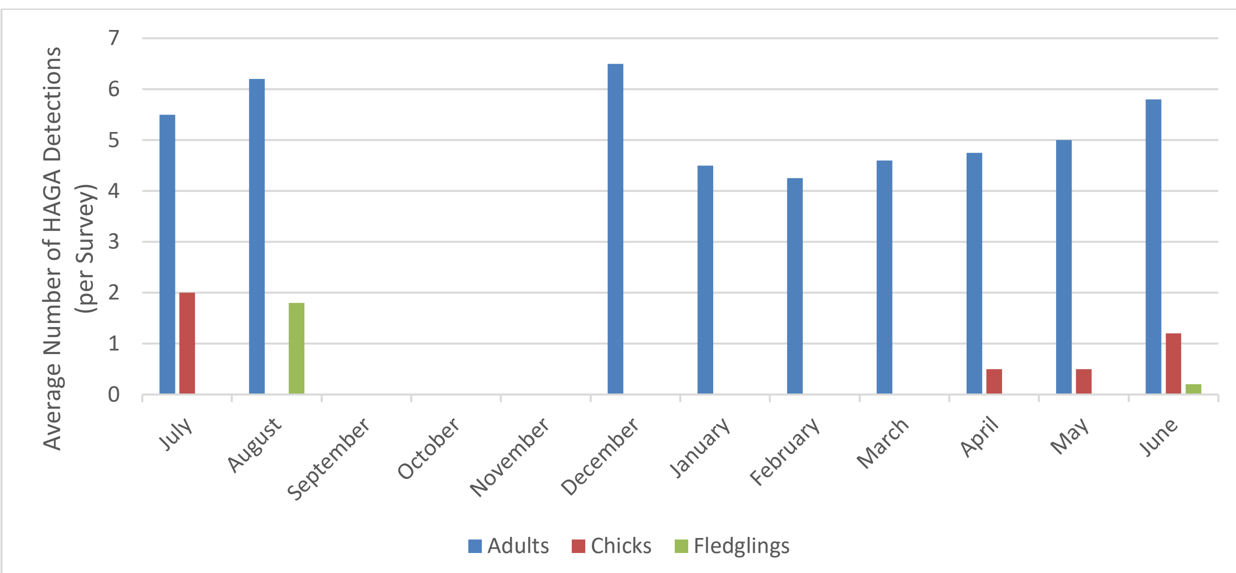


Figure 18. Average Number of Hawaiian Common Gallinule (HAGA) Detections by Month (per Survey) at Point Count Stations in FY 2023

8.2.2 Hawaiian Stilt

In FY 2023, Hawaiian stilts were observed on 13 of the 39 survey dates. As shown in Table 12, Hawaiian stilt detections have increased in comparison to previous fiscal years, but individual Hawaiian stilt numbers continue to be low. Due to the recent increase in stilt detections, the Project removed invasive pluchea (mostly *Pluchea indica*) within an approximately 1-acre area near PC 4 in FY 2023 to improve stilt nesting habitat.

No Hawaiian stilt nests, chicks, or evidence of reproductive activity have been observed at ʻUkoʻa Wetland since comprehensive surveys began. Although no take of Hawaiian stilts has been recorded at Kawailoa to date, the Project is required to replace 24 stilt fledglings.

Table 12. Average Number of Hawaiian Stilts Detected per Survey and Proportion of Surveys with at Least One Detection by Fiscal Year

Sampling Period	No. of Surveys	Average No. of Adults Detected per Survey	Proportion of Surveys with at Least One Detection
FY 2017 (January 2017–June 2017)	25	0.68	0.24
FY 2018 (July 2017–June 2018)	38	0.71	0.29
FY 2019 (July 2018–June 2019)	41	0.15	0.05
FY 2020 (July 2019–June 2020)	40	0.13	0.07
FY 2021 (July 2020–June 2021)	40	0.00	0.00
FY 2022 (July 2021–June 2022)	38	0.05	0.03
FY 2023 (July 2022–June 2023)	39	0.85	0.33

8.2.3 Hawaiian Coot

Since comprehensive waterbird surveys begin in January 2017, only one Hawaiian coot has been detected during the surveys; a single adult Hawaiian coot was recorded in March 2017. Although no waterbird take has been recorded at Kawailoa to date, the Project is required to replace 20 coot fledglings.

8.3 Seabirds

8.3.1 Newell's Shearwater

Tier 1 mitigation for Newell's shearwater was completed in FY 2015.

8.3.2 Hawaiian Petrel

As stated in Section 1.0, the Hawaiian petrel was added as a Covered Species in the HCP Amendment (Tetra Tech 2019). To mitigate for impacts to this species, Kawailoa Wind funded 1 year of monitoring and predator control at the Hanakāpīʻai and Hanakoa seabird colonies within the Hono O Nā Pali Natural Area Reserve on Kauaʻi in 2020. Final reports from Kauaʻi Endangered Seabird Recovery Project (Raine et al. 2020) and Hallux Ecosystem Restoration LLC (Dutcher and Pias 2021) for this mitigation project were included in the FY 2021 Annual Report. The reports confirmed Kawailoa Wind's mitigation obligations for the Hawaiian petrel are complete.

8.4 Hawaiian Short-eared Owls or Pueo

Mitigation for the Hawaiian short-eared owl (or pueo) was completed in FY 2017.

9.0 Other Compliance Items

In response to a contested case settlement, Kawailoa Wind provided $250,000 to Pacific Rim Conservation in FY 2022 to carry out research related to Hawaiian petrels on Oʻahu. The goal of this research project is to determine whether Hawaiian petrels detected in previous surveys are prospecting or breeding on Oʻahu. Pacific Rim Conservation is conducting ground searches and auditory surveys, as well as deploying automated acoustic recording units to accomplish this goal. The funds from Kawailoa Wind were used during the 2022 and 2023 breeding seasons and will also be used for the 2024 to 2026 breedings seasons. Pacific Rim Conservation confirmed that no Hawaiian petrel nests were found during the 2023 breeding season (L. Young/Pacific Rim, per. comm., November2023).

10.0 Adaptive Management

Kawailoa Wind is committed to the ongoing implementation of operational avoidance and minimization measures described in the HCP and HCP Amendment. Kawailoa Wind has been evaluating options to reduce the risk to bats since Project operations began in 2012. Kawailoa Wind implemented multiple adaptive management actions to understand and reduce the risk to the Hawaiian hoary bat in previous fiscal years including modifying the low wind speed curtailment (LWSC) regime, implementing innovative approaches to post-construction mortality monitoring, and supporting development of the latest technologies that could reduce WTG collision risk to bats. Details on the Project's adaptive management actions are provided in previous annual reports (Tetra Tech 2018, Tetra Tech 2019, Tetra Tech 2020, Tetra Tech 2021, Tetra Tech 2022) and the HCP Amendment (Tetra Tech 2019).

As outlined in the FY 2021 Kawailoa Annual Report (Tetra Tech 2021), Kawailoa Wind returned to a 10-minute rolling average on April 3, 2021. The Project continued to operate under the 10-minute rolling average LWSC regime for all of FY 2023.

Kawailoa Wind installed acoustic deterrents at all 30 Project WTGs in May and June 2019. Deterrent functionality is monitored remotely to ensure the systems are functioning properly. Deterrent units (DU) and deterrent unit controllers (DUC) that are identified as underperforming are replaced as soon as possible based on manufacturer recommendations. Each WTG is installed with five DUs, each having overlap in coverage in the deterred airspace. The result of a single DU failure is less than one-fifth of the rotor swept area. If one DU is deficient, a WTG has adequate coverage across the rotor swept area due to redundancy provided by the other four DUs. Kawailoa Wind and NRG work together to install replacements as quickly as feasible. Based on data provided by NRG, the total sitewide deterrent availability for the Project was 98.2 percent in FY 2023.

11.0 Collection Permits

Annual reports for the Project's federal and state collection permits were submitted in Q2 of FY 2023. The USFWS special purpose utility permit (MB22099C) expires March 31, 2025. The State's Protected Wildlife Permit (Permit No. WL21-05) expired on February 10, 2023. A renewal application was submitted, and a new Protected Wildlife Permit (Permit No. WL23-15) was issued for review on May 3, 2023. As of June 30, 2023, DOFAW was still processing the fully executed Protected Wildlife Permit.

12.0 Agency Meetings, Consultations, and Visits

Kawailoa Wind and Tetra Tech participated in both virtual and in-person meetings with USFWS and DOFAW staff in FY 2023, as well as one ESRC meeting. This included the following:

- August 29, 2022 – Consulted with DOFAW on alternative waterbird mitigation options
- October 28, 2022 – USFWS and DOFAW semi-annual meeting
- November 10, 2022 – Visited alternative waterbird mitigation site (Kawainui Marsh) with DOFAW staff
- November 14, 2022 – Meeting with USFWS and DOFAW on current status of ʻUkoʻa Wetland waterbird mitigation.
- December 22, 2022 – Consulted with DOFAW on waterbird adaptive management
- December 29, 2022 – Consulted with USFWS on waterbird adaptive management
- January 11, 2023 – ESRC FY 2022 annual report review
- June 13, 2023 – USFWS and DOFAW semi-annual meeting

13.0 Expenditures

Total HCP-related expenditures for the Project in FY 2023 were approximately $539,340 (Table 13).

Table 13. Estimated HCP-Related Expenditures at the Project in FY 2023.

Category	Amount
Permit Compliance	$107,620
Facility Vegetation Management	$159,000
Fatality Monitoring	$118,200
‘Uko‘a Wetland Mitigation Compliance	$137,295
Pacific Rim Seabird Research Coordination	$570
WEST Occupancy and Distriction Research (Yr 5)	$10,000
Tier 5 Bat Mitigation Preparation	$6,655
Total Cost for FY 2023	**$539,340**

14.0 Literature Cited

Dalthorp, D., M. Huso, and D. Dail. 2017. Evidence of absence (v2.0) software user guide: U.S. Geological Survey Data Series 1055, 109 p., https://doi.org/10.3133/ds1055.

DAPPER Stats. 2023. Analysis of Impact of Deterrents at the Kawailoa Wind Project. Prepared for Tetra Tech and Kawailoa Wind LLC.

Dutcher, A. and K. Pias. 2021. Hanakāpīʻai – Hanakoa 2020 Final Report. Hallux Ecosystem Restoration LLC. Prepared for Kawailoa Wind, LLC.

Gannon, W. L., R. E. Sherwin, S. Haymond. 2003. On the importance of articulating assumptions when conducting acoustic studies of habitat use by bats. Wildlife Society Bulletin 31:45-61.

Gorresen, P.M., Bonaccorso, F., Pinzari, C., Todd, C., Montoya-Aiona, K. and Brinck, K. 2013. A Five Year Study of Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) Occupancy on the Island of Hawaii. Hawai'i Cooperative Studies Unit. Technical Report HCSU-041.

Gorresen, P.M., K.W. Brinck, M.A. DeLisle, K. Montoya-Aiona, C.A. Pinzari, F.J. Bonaccorso. 2018. Multi-state occupancy models of foraging habitat use by the Hawaiian hoary bat (*Lasiurus cinereus semotus*). PLoS ONE 13(10): e0205150. Available at: https://doi.org/10.1371/journal.pone.0205150.

Grey Boar (Grey Boar Wildlife Services LLC). 2022a. Ukoa Predator Control Program. 3rd Quarter Report 2022. Prepared for Kawailoa Wind LLC.

Grey Boar. 2022b. Ukoa Predator Control Program. 4th Quarter Report 2022. Prepared for Kawailoa Wind LLC.

Grey Boar. 2023a. Ukoa Predator Control Program. 1st Quarter Report 2023. Prepared for Kawailoa Wind LLC.

Grey Boar. 2023b. Ukoa Predator Control Program. 2nd Quarter Report 2023. Prepared for Kawailoa Wind LLC.

Griffin, D.R., F.A. Webster, and C.R. Michael. 1960. The echolocation of flying insects by bats. Animal Behavior 8:141-154.

H. T. Harvey and SWCA (H. T. Harvey and Associates and SWCA Environmental Consultants). 2014. ʻUkoʻa Wetland Hawaiian Hoary Bat Mitigation Management Plan. Prepared for First Wind. Approved by USFWS and DOFAW 2014.

Peterson, R. A. 2021. "Finding Optimal Normalizing Transformations via best Normalize." R Journal 13(1).

Pinzari, C.A. and Bonaccorso, F.J., 2018, Hawaiian Islands Hawaiian Hoary Bat Genetic Sexing 2009-2020 (ver. 7.0, June 2022): U.S. Geological Survey data release, https://doi.org/10.5066/P9R7L1NS.

R Core Team. 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.R-project.org/

Raine, A.F. J. Rothe, S. Driskill, and S. Rossiter. 2020. Monitoring of Endangered Seabirds at Hanakāpīʻai and Hanakoa, Annual Report 2020. Kauaʻi Endangered Seabird Recovery Project (KESRP), Pacific Cooperative Studies Unit (PCSU), University of Hawaiʻi and Division of Forestry and Wildlife (DOFAW).

SWCA (SWCA Environmental Consultants). 2011. Kawailoa Wind Power Habitat Conservation Plan. Prepared for Kawailoa Wind Power. Dated October 2011.

Tetra Tech (Tetra Tech, Inc.). 2017. Kawailoa Wind Power Habitat Conservation Plan, FY 2017 Annual Report.

Tetra Tech. 2018. Kawailoa Wind Power Habitat Conservation Plan, FY 2018 Annual Report.

Tetra Tech. 2019. Kawailoa Wind Power Habitat Conservation Plan Amendment.

Tetra Tech. 2020. Kawailoa Wind Project Habitat Conservation Plan, FY 2020 Annual Report.

Tetra Tech. 2021. Kawailoa Wind Project Habitat Conservation Plan, FY 2021 Annual Report.

Tetra Tech. 2022. Kawailoa Wind Project Habitat Conservation Plan, FY 2022 Annual Report.

Thompson, J. and L.A. Starcevich. 2021. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study. Project Update and Third Year Analysis. Dated May 2021. Prepared for: Hawaii Endangered Species Research Committee.

Thompson, J. and L.A. Starcevich. 2022. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study, Final Report. Dated July 2022. Prepared for: Hawaii Endangered Species Research Committee.

Todd, C.M. 2012. Effects of Prey Abundance on Seasonal Movements of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*). ProQuest. Presented to the faculty of the Tropical Conservation Biology and Environmental Science Graduate Program University of Hawaiʻi at Hilo.

USFWS (U.S. Fish and Wildlife Service). 2016. Wildlife agency guidance for calculation of Hawaiian hoary bat indirect take. USFWS Pacific Islands Field Office. Honolulu, HI. October 2016.

Appendix 1. Documented Fatalities at the Project during FY 2023

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Species[1]	Date Documented	WTG	Distance to WTG (meters)	Bearing from WTG (degrees)
Spilopelia chinensis (Spotted Dove)	7/12/2022	14	1	30
Phaethon lepturus (White-tailed Tropicbird)	8/8/2022	01	21	275
Francolinus francolinus (Black Francolin)	8/11/2022	17	1	73
Estrilda astrild (Common Waxbill)	9/22/2022	09	2	344
Pluvialis fulva (Pacific Golden-Plover)	9/22/2022	09	1	134
Haemorhous mexicanus (House Finch)	11/10/2022	22	19	140
Haemorhous mexicanus (House Finch)	11/17/2022	29	33	114
Francolinus francolinus (Black Francolin)	11/24/2022	03	1	38
Zosterops japonicus (Warbling White-eye)	12/2/2022	16	23	260
Estrilda astrild (Common Waxbill)	12/22/2022	19	1	220
Geopelia striata (Zebra Dove)	12/29/2022	06	1	234
Geopelia striata (Zebra Dove)	1/19/2023	29	2	20
Spilopelia chinensis (Spotted Dove)	2/2/2023	28	2	240
Francolinus francolinus (Black Francolin)	3/6/2023	28	1	130
Acridotheres tristis (Common Myna)	3/21/2023	24	12	340
Estrilda astrild (Common Waxbill)	3/28/2023	23	1	314
Spilopelia chinensis (Spotted Dove)	3/28/2023	16	1	322
Spilopelia chinensis (Spotted Dove)	4/11/2023	27	2	20
Francolinus pondicerianus (Gray Francolin)	5/4/2023	22	10	11
Phaethon lepturus (White-tailed Tropicbird)	6/2/2023	18	11	270
Acridotheres tristis (Common Myna)	6/22/2023	17	1	60
Phaethon lepturus (White-tailed Tropicbird)	6/28/2023	19	60	310
1. Species protected by the Migratory Bird Treaty Act are highlighted in gray.				

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Appendix 2.
Dalthorp et al. (2017) Fatality Estimation for Hawaiian hoary bats at Project through FY 2023

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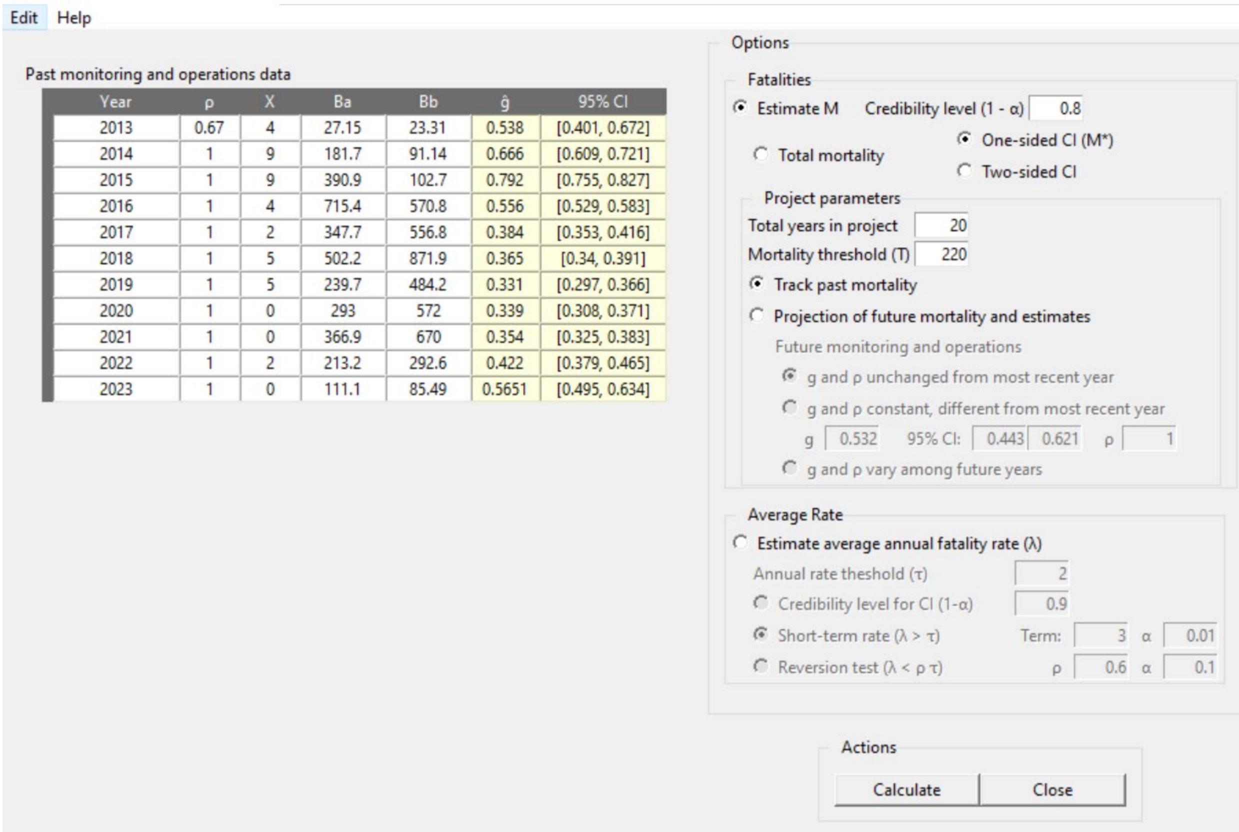
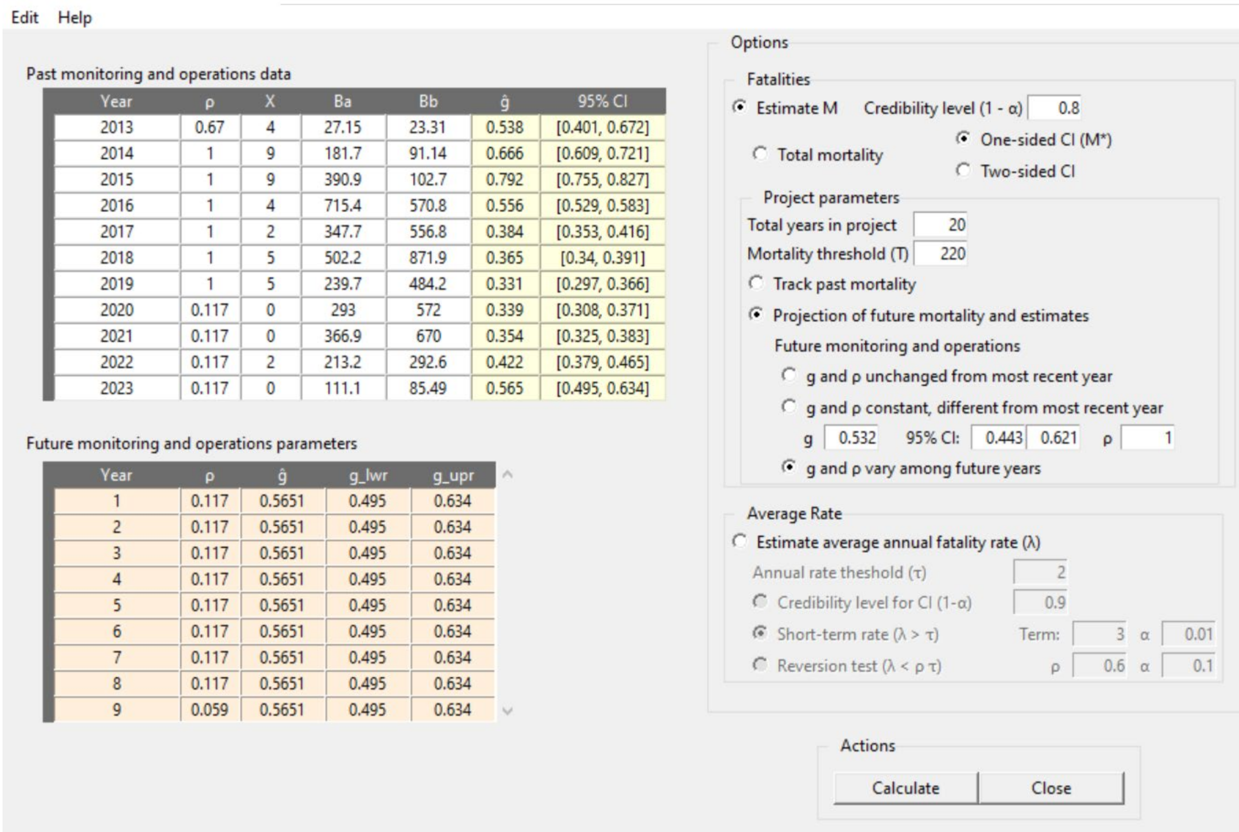
Figure 1. Dalthorp et al. (2017) Fatality Estimation for Hawaiian Hoary Bats at Project through FY 2023 with No Rho Adjustment.[4]



Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	0.67	4	27.15	23.31	0.538	[0.401, 0.672]
2014	1	9	181.7	91.14	0.666	[0.609, 0.721]
2015	1	9	390.9	102.7	0.792	[0.755, 0.827]
2016	1	4	715.4	570.8	0.556	[0.529, 0.583]
2017	1	2	347.7	556.8	0.384	[0.353, 0.416]
2018	1	5	502.2	871.9	0.365	[0.34, 0.391]
2019	1	5	239.7	484.2	0.331	[0.297, 0.366]
2020	1	0	293	572	0.339	[0.308, 0.371]
2021	1	0	366.9	670	0.354	[0.325, 0.383]
2022	1	2	213.2	292.6	0.422	[0.379, 0.465]
2023	1	0	111.1	85.49	0.5651	[0.495, 0.634]

[4] Rho represents the portion of a year represented for each line of data. Year 2013 represents a partial year (November 2012 to June 2013) because the Project began operations in November; all remaining years represent a full fiscal year.

Figure 2. Dalthorp et al. (2017) Fatality Estimation for Hawaiian Hoary Bats at Project through FY 2023 with Rho Adjustment.[5, 5]



Year	ρ	X	Ba	Bb	ĝ	95% CI
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2014	1	9	181.7	91.14	0.666	[0.609, 0.721]
2015	1	9	390.9	102.7	0.792	[0.755, 0.827]
2016	1	4	715.4	570.8	0.556	[0.529, 0.583]
2017	1	2	347.7	556.8	0.384	[0.353, 0.416]
2018	1	5	502.2	871.9	0.365	[0.34, 0.391]
2019	1	5	239.7	484.2	0.331	[0.297, 0.366]
2020	0.117	0	293	572	0.339	[0.308, 0.371]
2021	0.117	0	366.9	670	0.354	[0.325, 0.383]
2022	0.117	2	213.2	292.6	0.422	[0.379, 0.465]
2023	0.117	0	111.1	85.49	0.565	[0.495, 0.634]

Year	ρ	ĝ	g_lwr	g_upr
1	0.117	0.5651	0.495	0.634
2	0.117	0.5651	0.495	0.634
3	0.117	0.5651	0.495	0.634
4	0.117	0.5651	0.495	0.634
5	0.117	0.5651	0.495	0.634
6	0.117	0.5651	0.495	0.634
7	0.117	0.5651	0.495	0.634
8	0.117	0.5651	0.495	0.634
9	0.059	0.5651	0.495	0.634

[5] The methodology and calculation of the adjusted rho value is provided in Appendices 4 and 5.

Figure 3. Posterior Distribution: Dalthorp et al. (2017) Fatality Estimation for Hawaiian Hoary Bats at Project for FY 2023 with No Rho Adjustment

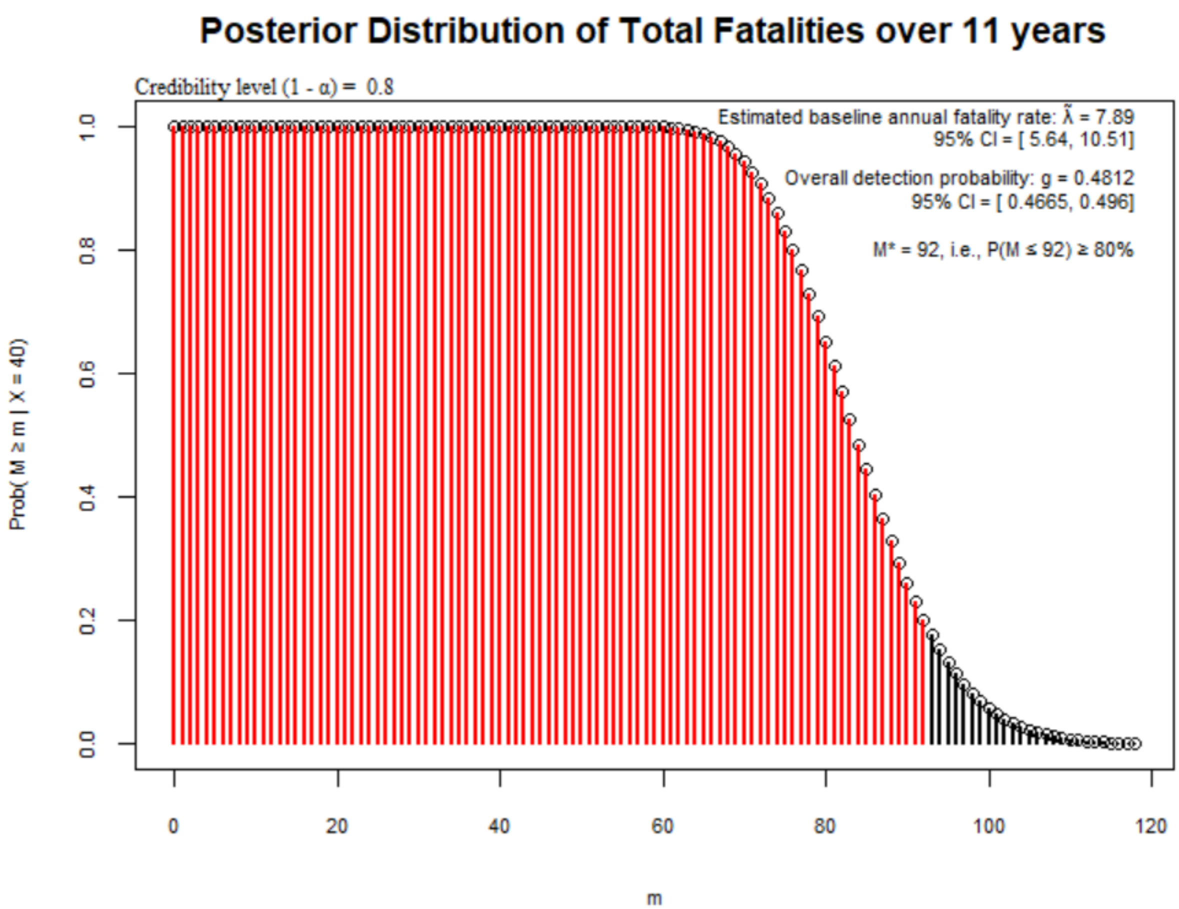
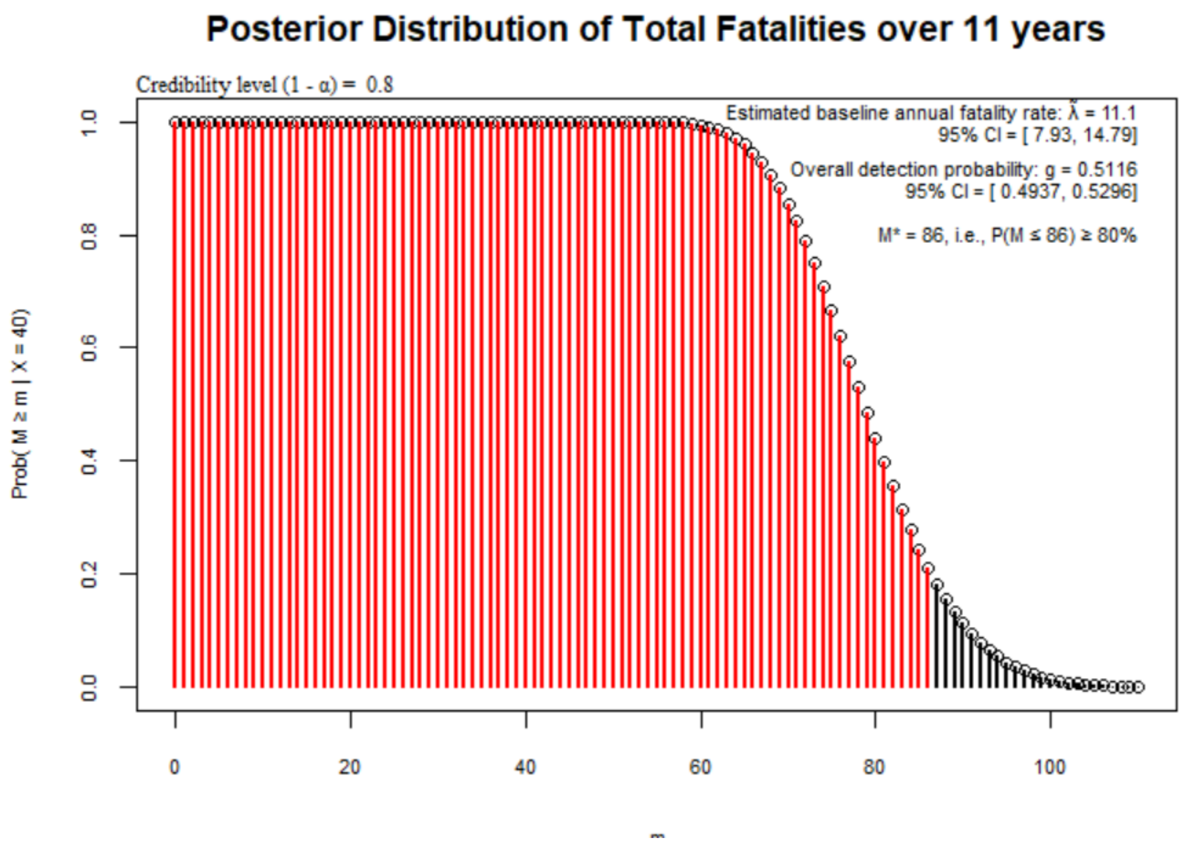


Figure 4. Posterior Distribution: Dalthorp et al. (2017) Fatality Estimation for Hawaiian Hoary Bats at Project for FY 2023 with Rho Adjustment[6]



[6] The methodology and calculation of the adjusted rho value is provided in Appendices 4 and 5.

Appendix 3.
Methodology for Demonstrating Bat Deterrent Effectiveness

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In May and June 2019, Kawailoa Wind, LLC (Kawailoa Wind) installed ultrasonic acoustic deterrents (UAD) at all 30 wind turbine generators (WTG) at the Kawailoa Wind Project (Project). The installation of UADs is correlated with a reduction in fatality rates for mainland hoary bats (Weaver et al. 2020) and is a minimization measure encouraged by USFWS and DOFAW to reduce the risk to Hawaiian hoary bats at the Project.

The effectiveness of UADs on the Hawaiian hoary bat is not known, but evidence from monitoring at the Project confirms the Hawaiian hoary bat fatality rate is reduced at the Project after installation of UADs. The effectiveness of UADs for mainland hoary bats at Los Vientos Wind Farm in Texas was found to be 78.4 percent (95 percent confidence interval [CI]: 61.5 to 95.1 percent) reduced relative to WTGs without UADs active (Weaver et al. 2020). Differences in site conditions and the species-specific responses led to uncertainty if this reduction will be replicated at the Project. Additionally, the Project has implemented low wind speed curtailment at 5 meters per second (m/s) with a 0.2 m/s hysteresis, further reducing the risk to bats relative to the study at Los Vientos.

The Evidence of Absence (EoA) software program incorporates a parameter called rho (ρ), which adjusts the expected fatality rate. A rho value of 1 is typically used when assessing compliance with authorized take limits. The use of a rho value of 1 assumes the risk is the same from year to year. Rho has also been used to account for the proportion of the year covered by search parameters, such as the partial year of fatality monitoring at the Project's start in fiscal year (FY) 2013 and the change in search areas that occurred in FY 2016. The EoA user's manual (Dalthorp et al. 2017) describes rho as follows:

> The assumed relative mortality rate is ρ. If there are no changes in operations and no reason to suspect mortality rates varied systematically from year to year, then ρ=1 each year. However, if operations or ecological conditions change, the ρ parameter should be adjusted to reflect changes. For example, if a site is expanded by 20% in year 3, then ρ=1 for years 1 and 2 as a baseline and ρ=1.2 in year 3 would be appropriate. Or if minimization measures that are expected to reduce fatalities by 30% are implemented in year 3, then ρ=1 for years 1 and 2, and ρ=0.7 for year 3.

To test if the fatality rate is reduced, Tetra Tech used EoA to compare fatality rates and check for misspecification in rho. In other words, "Does the fatality monitoring data provide evidence that minimization measures have reduced the risk to bats?" To compare the fatality rate in each year, Tetra Tech used the multi-year module of EoA to compare the fatality rates. The fatality rates (lambda[λ]) for each year are shown in Table 1 and Figure 1. These illustrate that the interquartile ranges are non-overlapping, although the 95 percent confidence intervals overlap.

To test if the rho value is appropriately specified before and after installation of UADs, each period was grouped as a single period in the multi-year module of EoA and tested for misspecification of rho using the multi-year module of EoA. For the pre-UAD period, rho = 1 for each full year; the rho for a partial year is calculated as the proportion of the year involved. The rho for the post-UAD period will begin with rho=1 for all years (i.e., after 4 years, rho=4). For multiple years, the rho value for the post-UAD period is represented by the equation: rho * years of monitoring. In practice this would be assumed to be the same for all years. For example, if after year four, the cumulative rho value of 0.5 for the post-UAD period (2020 to 2023) is indicated by the EoA test for misspecification of rho, the annual rho value would be 0.5/4 years, or 0.125. Similarly, if a rho value of 4 is indicted by the EoA test for misspecification of rho for the same period (2020 to 2023), the rho value would be 1 for all years (4 rho/4 years = 1 rho/year).

November 2012 to June 2019, which correlates with FY 2013 to 2019, represents the pre-UAD period, and July 2019 to June 2022, which correlates with FY 2020 to 2023, represents the post-UAD installation period. The cumulative detection probability for each period was calculated using EoA to group the years (FY 2013 to 2019, and FY 2020 to 2023) and provide a cumulative detection probability. For each period, the observed fatalities were summed to calculate the total observed fatalities for the period. The pre-deterrent period therefore represents the pooled data from FY 2013 to FY 2019 including: rho which represents the years of monitoring from November 2012 to June 2019 or 6.67 years, the sum of observed bat fatalities (38 bats), and the cumulative detection probability from November 2012 to June 2019 (0.518). The post-deterrent period represents the pooled data from FY 2020 to FY 2023 including: rho which represents the years of monitoring from July 2019 to June 2023 or 4 years, the sum of observed bat fatalities (two bats), and the cumulative detection probability from July 2019 to June 2023 (0.420). The inputs are provided in Table 2.

Comparing the fatality monitoring data before and after UADs demonstrates that fatality rates are overestimated after installation of UADs if the same rho is used for both periods. At a rho value of 4 (annual rho of 1), the test for misspecification returns a significant result when testing for a p value less than 0.05 (p value = 0.00002); the EoA outputs for this trial are shown in Figure 2. The rho value was decreased incrementally by 0.05 until the p value for the test of misspecification of rho exceeded a p value of 0.05. The first rho value with a test of misspecification p value greater than 0.05 (p value= 0.05258) was found when the combined rho FY 2020 to FY 2023 = 1.4 (a 0.35 annual rho) or a 65.0 percent reduction in the annual fatality rate after installation of UADs; the EoA outputs for this trial are shown in Figure 3. Therefore, Project data suggest with 95 percent confidence that Hawaiian hoary bat risk at the Project is reduced by at least 65.0 percent through the use of UADs.

As shown in Figure 1, fatality rates can vary significantly from year to year. Kawailoa Wind, USFWS, and DOFAW will need to continue to evaluate the results of fatality monitoring to ensure the rho value is appropriately specified. The methods outlined here represent the means by which the efficacy of the minimization measure can be confirmed, and which are consistent with the recommended methodology outlined in the USFWS Programmatic Environmental Impact Statement (USFWS 2019), which states:

> All projects start off with using $\rho = 1$. If an additional minimization such as raising the cut in speed (see Appendix D) or deterrents are implemented, the rho-value is still kept at 1 until tests on assumed weights indicate that there may be a difference in fatality rates. This may require several years of deploying the minimization action before any difference can be supported by the test on the rho-value. If the tests do confirm a change in the fatality rates between periods beyond a reasonable doubt, a rho-value can be put in place, retroactively, for the periods in which the minimization action was deployed, if approved by the Service.

> The tests can be rerun to determine if the rho value continues to be reasonable. Note, however, that the actual rho-value is not calculated by the model and may never be known. The best that can be done is to maintain testing of the rho value being used to see if it is reasonable.

Following the determination that the minimization measure has been effective, an appropriate rho value needs to be incorporated in the Project EoA assessment to account for the reduced risk to bats from the installation of UADs at the Project. An appropriate rho value will have sufficient years of supporting data for both pre- and post-minimization effectiveness to statistically account for inter-annual variability in the observed take rate, represent an unbiased estimate, and be updated annually to ensure new data are incorporated. A final rho may be determined once annual updates indicate the estimate of rho is stable.

Table 1. Fatality Rates for Each Year of Project Operation

Year	Observed Fatalities	Detection Probability	Fatality Estimate at the 80% Credible Level	Median Fatality Estimate	Fatality Estimate 95% CI	Lambda	Lambda 95% CI
2013	4	0.538	10	7	[4,14]	8.588	[2.486, 18.83]
2014	9	0.666	16	13	[10,20]	14.30	[6.669, 24.87]
2015	9	0.792	13	11	[9,15]	12.01	[5.619, 20.79]
2016	4	0.556	10	7	[4,12]	8.097	[2.427, 17.14]
2017	2	0.384	8	5	[2,12]	6.520	[1.081, 16.78]
2018	5	0.365	19	14	[7,26]	15.08	[5.215, 30.13]
2019	5	0.331	21	15	[7,28]	16.68	[5.749, 33.44]
2020	0	0.339	2	0	[0,4]	1.481	[0.001433, 7.448]
2021	0	0.354	1	0	[0,4]	1.416	[0.001433, 7.123]
2022	2	0.421	8	5	[2,11]	5.9550	[0.9859, 15.34]
2023	0	0.565	1	0	[0,2]	0.8898	[0.0009, 4.48]

Table 2. Inputs for the Test of Misspecification of Rho

Year	P (rho)	X (Observed Fatalities)	Ba (Shape)	Bb (Scale)	$\hat{g}$ (Detection Probability)	95% CI
2013 – 2019	6.67	38	1356	1262	0.518	[0.499, 0.537]
2020 – 2023	4 or 1.4	2	741.9	1025	0.420	[0.397, 0.443]

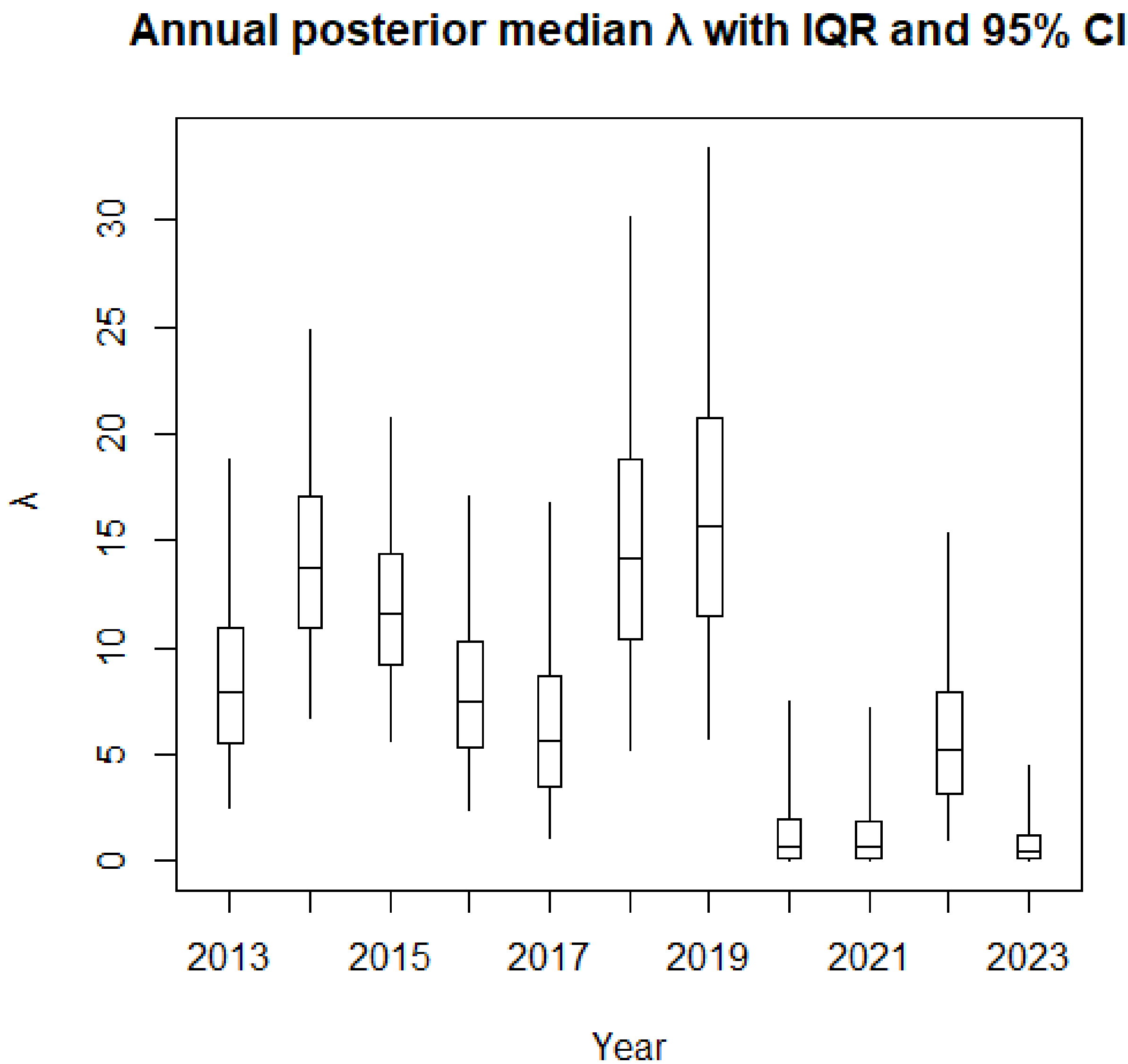

Figure 1. Annual Hawaiian Hoary Bat Fatality Rates Estimated by EoA for the Project

```
Summary statistics for mortality estimates through 2 years
------------------------------------
Results

M* = 92 for 1 - α = 0.8, i.e., P(M <= 92) >= 80%
Estimated overall detection probability: g = 0.481, 95% CI = [0.466, 0.496]
   Ba = 2062.2, Bb = 2225.2
Estimated baseline fatality rate (for rho = 1): lambda = 7.894, 95% CI = [5.64, 10.5]

Cumulative Mortality Estimates
                                              mean
Year           X    g      M*  median  95% CI  lambda       95% CI
FY2013-2019  38 0.518   81    73     [59, 91]  74.37   [52.64, 99.84]
FY2020-2023  40 0.481   92    83     [66, 103]  84.23   [60.22, 112.2]


Annual Mortality Estimates
                                              mean
Year           X    g      M*  median  95% CI  lambda       95% CI
FY2013-2019  38 0.518   81    73     [59, 91] 74.3700   [52.6400, 99.8400]
FY2020-2023   2 0.419    8     5     [2, 11] 5.9680   [0.9910, 15.3400]


Test of assumed relative weights (rho) and potential bias
              Fitted rho
Assumed rho     95% CI
   6.67     [8.827, 10.549]
      4     [0.120, 1.832]

p = 2e-05 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.057

================================================================================
Input
Year (or period)  rho    X    Ba     Bb   ghat    95% CI
FY2013-2019      6.670  38   1356   1262 0.518 [0.499, 0.537]
FY2020-2023      4.000   2  684.3  947.5 0.419 [0.396, 0.443]
```

Figure 2. Testing for Misspecification of Rho with a Rho Value of 4

```
Summary statistics for mortality estimates through 2 years
------------------------------------
Results

M* = 88 for 1 - α = 0.8, i.e., P(M <= 88) >= 80%
Estimated overall detection probability: g = 0.501, 95% CI = [0.485, 0.517]
   Ba = 1807.4, Bb = 1800.6
Estimated baseline fatality rate (for rho = 1): lambda = 10.02, 95% CI = [7.16, 13.4]

Cumulative Mortality Estimates
                                              mean
Year           X    g     M*  median  95% CI  lambda       95% CI
FY2013-2019  38 0.518    81     73    [59, 91]  74.37    [52.64, 99.84]
FY2020-2023  40 0.501    88     80    [64, 99]  80.88    [57.81, 107.8]


Annual Mortality Estimates
                                              mean
Year           X    g     M*  median  95% CI  lambda       95% CI
FY2013-2019  38 0.518    81     73    [59, 91] 74.3700    [52.6400, 99.8400]
FY2020-2023   2 0.420     8      5    [2, 11] 5.9600   [0.9898, 15.3100]


Test of assumed relative weights (rho) and potential bias
              Fitted rho
Assumed rho     95% CI
   6.67     [6.627, 7.960]
    1.4     [0.108, 1.421]

p = 0.05258 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.016

================================================================================
Input
Year (or period)  rho    X    Ba     Bb   ghat    95% CI
FY2013-2019      6.670  38   1356   1262 0.518 [0.499, 0.537]
FY2020-2023      1.400   2  741.9   1025 0.420 [0.397, 0.443]
```

Figure 3. Testing for Misspecification of Rho with a Rho Value of 1.4 (Annual Rho of 0.350)

Literature Cited:

Dalthorp, D., M. Huso, and D. Dail. 2017. Evidence of absence (v2.0) software user guide: U.S. Geological Survey Data Series 1055. 109 p. https://doi.org/10.3133/ds1055.

USFWS (U.S. Fish and Wildlife Service). 2019. Final Programmatic Environmental Impact Statement Addressing the Issuance of Incidental Take Permits for Four Wind Energy Projects in Hawaiʻi. U.S. Department of the Interior, Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office. July.

Weaver, S.P., C.D. Hein, T.R. Simpson, J.W. Evans, and I. Castro-Arellano and I. Castro-Arellano. 2019. Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines. Global Ecology and Conservation 23 e01099. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Weaver-et-al-2020.pdf.

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Appendix 4.
Methodology for Estimating Bat Deterrent Effectiveness (DAPPER Stats 2023)

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Analysis of Impact of Deterrents at the Kawailoa Wind Project
Prepared by Juniper L. Simonis, DAPPER Stats for Tetra Tech and Kawailoa Wind LLC.
2023-01-23

OVERVIEW

This report describes evaluation of posterior distributions of annual fatality rates (λ) and the relative impact of deterrents on fatality rates (δ) generated by analysis using the Evidence of Absence (EoA; Dalthorp et al. 2017) methodology at the Kawailoa Wind Project. Note that the term for a component year's weight within a multi-year estimate of λ (i.e., ρ) is the same as that which was proposed for use as the relative impact of deterrence, and so we have introduced δ to avoid confusion.

BACKGROUND

The methods used to fit the EoA model framework are Bayesian in flavor and leverage Gibbs Sampling via JAGS (Just Another Gibbs Sampler; Plummer 2015) to estimate the posterior distribution of λ, given the observed carcasses (X) and fitted detection parameters ($\hat{g}$ or Ba, Bb) for each year (Dalthorp et al. 2017). Posteriors from different years are fitted to different data (each year's observations) in each model and so may not necessarily meet requirements for frequentist methods.

As we are working with Bayesian posteriors, we should avoid thinking of how to process them under frequentist frameworks that, for example, seek to ask if distributions are "statistically significantly different" from each other at confidence level α. Rather, consistent with the Bayesian approach, we can ask "how much do these λ distributions overlap?" and directly answer with a specific value, called the Overlap Coefficient (o) (Weitzman 1970, Jose et al. 2019, Simonis 2021). Furthermore, we can quantify the relation of post-deterrence to pre-deterrence λ values using a ratio distribution for δ and ask "how much of that distribution lies at or above a value of 1.0? (equivalent pre- and post-deterrence λ distributions)". This approach gives us distributions for the focal quantities of interest (o, δ) and allows each reader to interpret them with their own degree of certainty. As a benefit this means the analysis is not locked into a particular confidence level.

METHODS

Mathematics

The output from EoA models with regards to λ for a given time period (individual "years" or "pre-deterrence"/ "post-deterrence" groups of years) is a set of distribution functions: the cumulative distribution function (CDF, F) and probability distribution function (PDF, f). PDFs are produced for individual year models only, whereas CDFs are produced for individual year models and also from weighted composites via the Multi Year Module (Dalthorp et al. 2017). This provides a very useful means for generating weighted composites across years, but vitally it *does not fit a model to data*, but rather combines the existing models based on weights (ρ).

For both single and multi-year outputs, EoA generates functions (in the sense of code) that correspond directly to the functions (in the sense of distributions, i.e., CDFs), which take a single dimension of potential loss values to evaluate (l) and return the probability that λ is below each value of l. We can use these CDF functions for a pair of two distributions (one for each of two years or for pre-/post-) to calculate their overlap (Weitzman 1970, Jose et al. 2019, Simonis 2021). Note, however, that overlap values are not independent of each other, due to the repeated use of each single distribution across the others.

A ratio distribution is created by taking the quotient of two distributions (Springer 1979), and we leverage this approach to evaluate the impact of deterrence on fatality rates. For example, the distribution for the fatality rate for "year" (really, time window) i (λ_i) divided by the distribution for the fatality rate for year j (λ_j) is the ratio distribution δ_{ij}:

$$\delta_{ij} = \frac{\lambda_i}{\lambda_j}$$

In the situation where the two yearly distributions are equivalent ($\lambda_i \equiv \lambda_j$), the ratio distribution then has an expected value of 1.0 (Conner et al. 2016). In computing the ratio distribution, we take a Monte Carlo approach, repeatedly drawing from the posterior distributions for the respective λ's to create a sample draw of δ values from the distribution (Conner et al. 2016).

Our particular δ of interest is that between post- and pre-deterrence. Given the study design (only implementation sites, relatively few years of data post implementation), we take a more descriptive approach to δ at this time (Christie et al. 2019). We use two methods to estimating this distribution. First, we create a composite of all (seven) pre-deterrence years (λ_{pre}) and a composite of all (three) post-deterrence years (λ_{post}) and then compute $\delta_{pre-post}$ using those two composites:

$$\lambda_{pre} = \frac{\sum_{i=1}^{7} \lambda_i}{7}$$
$$\lambda_{post} = \frac{\sum_{i=1}^{3} \lambda_i}{3}$$

$$\delta_{pre-post} = \frac{\lambda_{pre}}{\lambda_{post}}$$

In this calculation, all of the among-year within-treatment variance is lost, effectively calculating the quotient of the average years. Alternatively, we take a year-level approach and extend the Monte Carlo to the selection of years to incorporate among-year variance. We repeatedly randomly draw pairs of years for pre- (one year i from 1 to 7) and post-deterrence (one year j from 8 to 10) and calculate their δ_{ij}, which we composite across the random draws to build the distribution of $\delta_{pre-post}$ accounting for the year-to-year variation.

Code

We execute this set of calculations using code in R v4.0.5 (R Core Team 2021) from the eoa v2.0.7 (Dalthorp et al. 2017) and bbplot v0.0.1 (Simonis 2020) packages using existing methods (Simonis 2021) and additional custom-written scripts (Appendix A). We replicated the previous analyses of single-year and multi-year overlaps (based on pre- and post-deterrent installation) with the addition of the 2022 data (Simonis 2021) and extend the code to incorporate the new estimation of δ.

RESULTS

The matrix returned by the overlap function (Table 1) is a symmetric matrix with values of 1 on the diagonal as all distributions overlap fully with themselves. The resulting overlap coefficients between different years range between functionally 0 (any year and 2020 or 2021) and 1 (2020 and 2021) (Table 1). The overlap coefficient between the pre- and post-deterrence fatality estimates is very low (0.02406), which indicates there is very little similarity between the pre- (mean: 11.14, median: 11.04, sd: 1.81, 95% CI: [7.89, 14.95]) and post-deterrence (mean: 2.25, median: 1.96, sd: 1.42, 95% CI: [0.37, 5.75]) λ's (Fig. 1).

To be expected, given the difference in the multi-year estimates for post- and pre-deterrence λ, the ratio of the two (an estimate of δ) was much smaller than 1 (Fig. 2). This was true whether we used the composite λ's to estimate δ (mean: 0.206, median: 0.176, 95% CI: [0.033, 0.549]) or the single-year version (mean: 0.321, median: 0.117, 95% CI: [0.000, 1.770]), both of which indicated an ~85% reduction in median fatality with use of the deterrents. However, the variance and skewness were (as expected) much higher for the single-year λ approach (var: 0.467, skew: 13.73) compared to the composite λ method (var: 0.019, skew: 1.45). As a result, a larger proportion of the distribution (0.071 vs. 0.001) was at or above 1.0, indicating no change or an increase in λ with deterrence (Fig. 2). These proportions can be considered Bayesian p-values, in which sense the former is "non-significant", while the latter is "significant".

The introduction of deterrents has decreased the 0.8 quantile for λ from 12.63 to 3.27 fatalities per year using the multi-year estimates (Fig. 1). This translated to a 74% reduction, a bit less than the 82% reduction in the medians of the distributions. Single-year values for the 0.80 λ quantile of the pre-deterrence period were 17.8, 18.1, 15.1, 11.1, 9.6, 19.9, and 22.3 compared to 2.5, 2.3, and 8.7 for the post-deterrence period years.

DISCUSSION

At this time, we have a limited set of model tools to compare the pre- and post-deterrence fatality estimates, based on the study design (implementation across all turbines), current duration of observations, and aggregation of the available data. Given these restrictions, we focused on simple, descriptive comparisons between pre- and post-deterrent λ's using two approaches Although both the composite and single-year λ methods gave roughly similar estimates of average impact, the single-year method, which was more inclusive of variance, indicated that the decrease in λ, while strong, was not able to outweigh the year-to-year variance in λ, especially considering the small sample size. Undoubtedly, additional years of post-deterrence data will aid in the estimation of effects by improving precision.

An increase in sample size with time will also facilitate the use of more advanced statistical methods. The ideal approach for causally linking changes in fatality to management practices such as implementing deterrence is to include a control group – here being turbines where deterrents were not installed – akin to what is known as a BACI (Before-After Control-Impact) study (Smokorowski and Randall 2017). In the short-term, the lack of a control group prevents us from definitively attributing the changes in fatality rates to the implementation of deterrence (Christie et al. 2019). This shortcoming can be assuaged, however, as the data set is growing every year and will eventually reach a size where methods that leverage temporal replication such as Interrupted Time Series models (McDowell et al. 2019) could be leveraged.

Additional information can be extracted from the existing data, as well, if the fatality observations are disaggregated to the turbine level. Presently, the fatality count is presented for all turbines across all searches. If, instead, observations were provided turbine-by-turbine and search-by-search, the within-year-among-turbine variation could be accounted for and increase the precision of the estimate of the impact (Christie et al. 2019). Including turbine- and search-level data will necessarily increase model complexity and require further extension of the existing EoA model or a shift to other tools.

LITERATURE CITED

Christie, A. P., T. Amano, P. A. Martin, G. E. Shackelford, B. I. Simmons, and W. J. Sutherland. 2019. Simple study designs in ecology produce inaccurate estimates of biodiversity responses. *Journal of Applied Ecology* **56**: 2742– 2754. https://doi.org/10.1111/1365-2664.13499.

Conner, M., W. Saunders, N. Bouwes, and C. Jordan. 2016. Evaluating impacts using a BACI design, ratios, and a Bayesian approach with a focus on restoration. *Environmental Monitoring and Assessment* **188**: 555. https://doi.org/10.1139/facets-2016-0058.

Dalthorp, D., M. Huso, and D. Dail. 2017. Evidence of absence (v2.0) software user guide. *U.S. Geological Survey Data Series* 1055. 109 pp. https://doi.org/10.3133/ds1055.

Dietze, M. 2017. Ecological Forecasting. Princeton University Press, Princeton, N. J., USA.

Dietze, M. C., A. Fox, L. M. Beck-Johnson, J. L. Betancourt, M B. Hooten, et al. 2018. Iterative near-term ecological forecasting: needs, opportunities, and challenges. *Proceedings of the Natural Academy of Sciences* **115**:1424-1432.

Hooten, M. B. and N. T. Hobbs. 2015. Bayesian Models: A Statistical Primer for Ecologists. Princeton University Press, Princeton, NJ, USA.

Jose, S., S. Thomas, and T. Mathew. 2019. Interval estimation of the Overlapping Coefficient of two exponential distributions. *Journal of Statistical Theory and Applications* **18**:26-32. https://doi.org/10.2991/jsta.d.190306.004

Kruschke, J. K. 2015. Doing Bayesian Data Analysis: A Tutorial with R, JAGS, and Stan. Academic Press, San Diego, CA.

McDowall, D., R. McCleary, and B. J. Bartos. 2019. *Interrupted Time Series Analysis*. Oxford University Press.

Plummer, M. 2015. JAGS version 4.0.0 user manual. 43 pp.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Simonis J. L. 2020. bbplot. R software package v.0.0.1. https://github.com/dapperstats/bbplot

Simonis, J. L. 2021. Analysis of Interannual Variation in Lambda. Prepared for Tetra Tech. DAPPER Stats, Portland, OR. 7 pp.

Smokorowski, K. E. and R. G. Randall. 2016. Cautions on using the Before-After-Control-Impact design in environmental effects monitoring programs. *FACETS* **2**: 212-232. https://doi.org/10.1139/facets-2016-0058.

Springer, M. D. 1979. *The Algebra of Random Variables*. Wiley, New York.

Weitzman, M. A. 1970. *Department of Commerce, Bureau of Census* Technical paper No. 22. Washington, U.S.A, 1970.

Table 1. Overlap coefficients between pairs of λ distributions from different years.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2013	1.00000	0.77602	0.79597	0.64581	0.52813	0.83871	0.75948	0.00015	0.00008	0.47770
2014	0.77602	1.00000	0.79090	0.44645	0.34248	0.85988	0.80773	0.00006	0.00003	0.29680
2015	0.79597	0.79090	1.00000	0.58115	0.43786	0.75036	0.66538	0.00007	0.00004	0.38635
2016	0.64581	0.44645	0.58115	1.00000	0.78781	0.49011	0.42478	0.00019	0.00010	0.73494
2017	0.52813	0.34248	0.43786	0.78781	1.00000	0.39568	0.34657	0.00022	0.00011	0.94454
2018	0.83871	0.85988	0.75036	0.49011	0.39568	1.00000	0.90835	0.00011	0.00006	0.35036
2019	0.75948	0.80773	0.66538	0.42478	0.34657	0.90835	1.00000	0.00010	0.00005	0.30476
2020	0.00015	0.00006	0.00007	0.00019	0.00022	0.00011	0.00010	1.00000	0.99989	0.00022
2021	0.00008	0.00003	0.00004	0.00010	0.00011	0.00006	0.00005	0.99989	1.00000	0.00011
2022	0.47770	0.29680	0.38635	0.73494	0.94454	0.35036	0.30476	0.00022	0.00011	1.00000

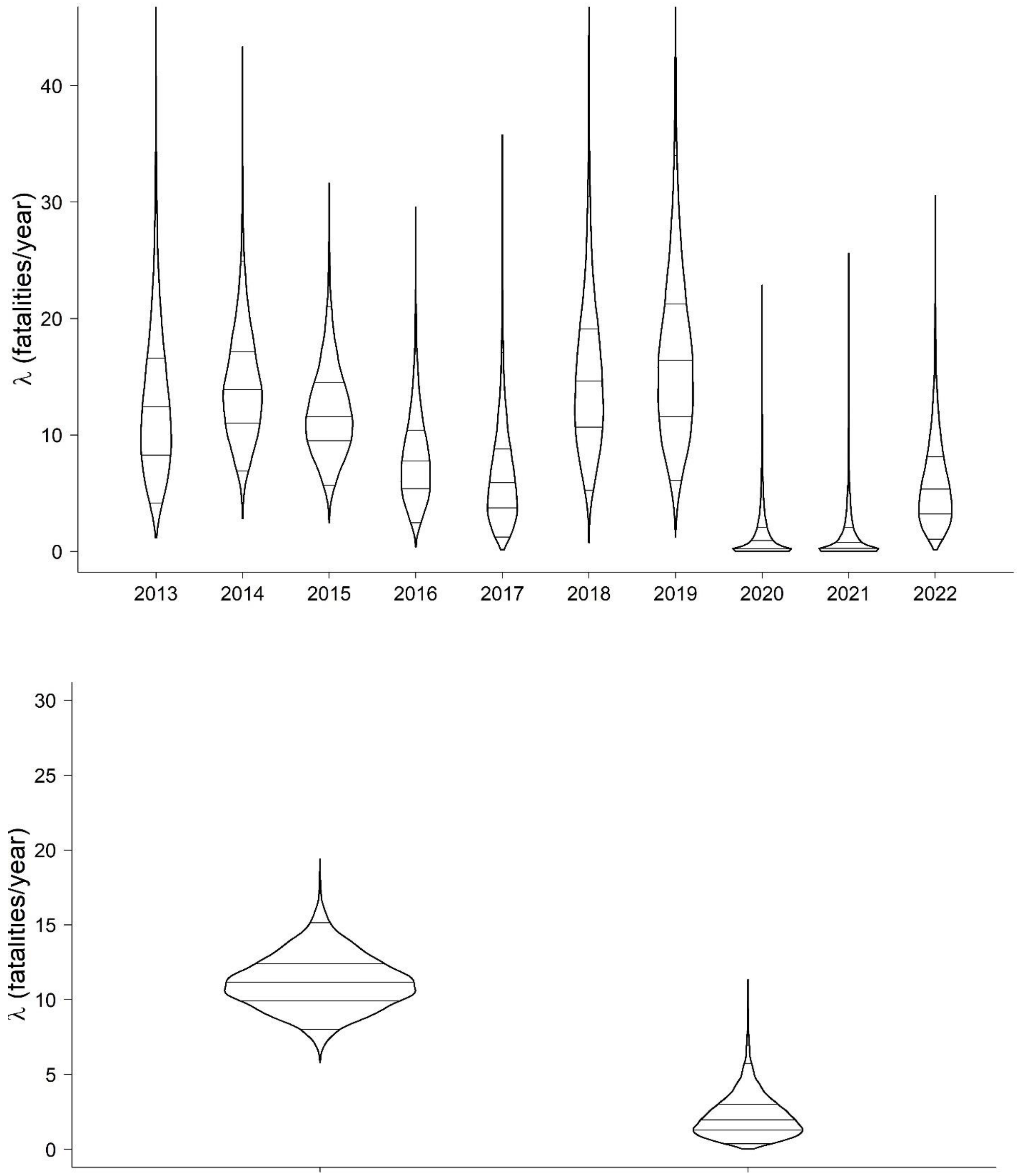

Figure 1. Top: Year-based distributions of annual λ rates. Bottom: Deterrence period based distributions of λ. Horizontal lines across violins represent the 2.5%, 25%, 50%, 75%, and 97.5% values.

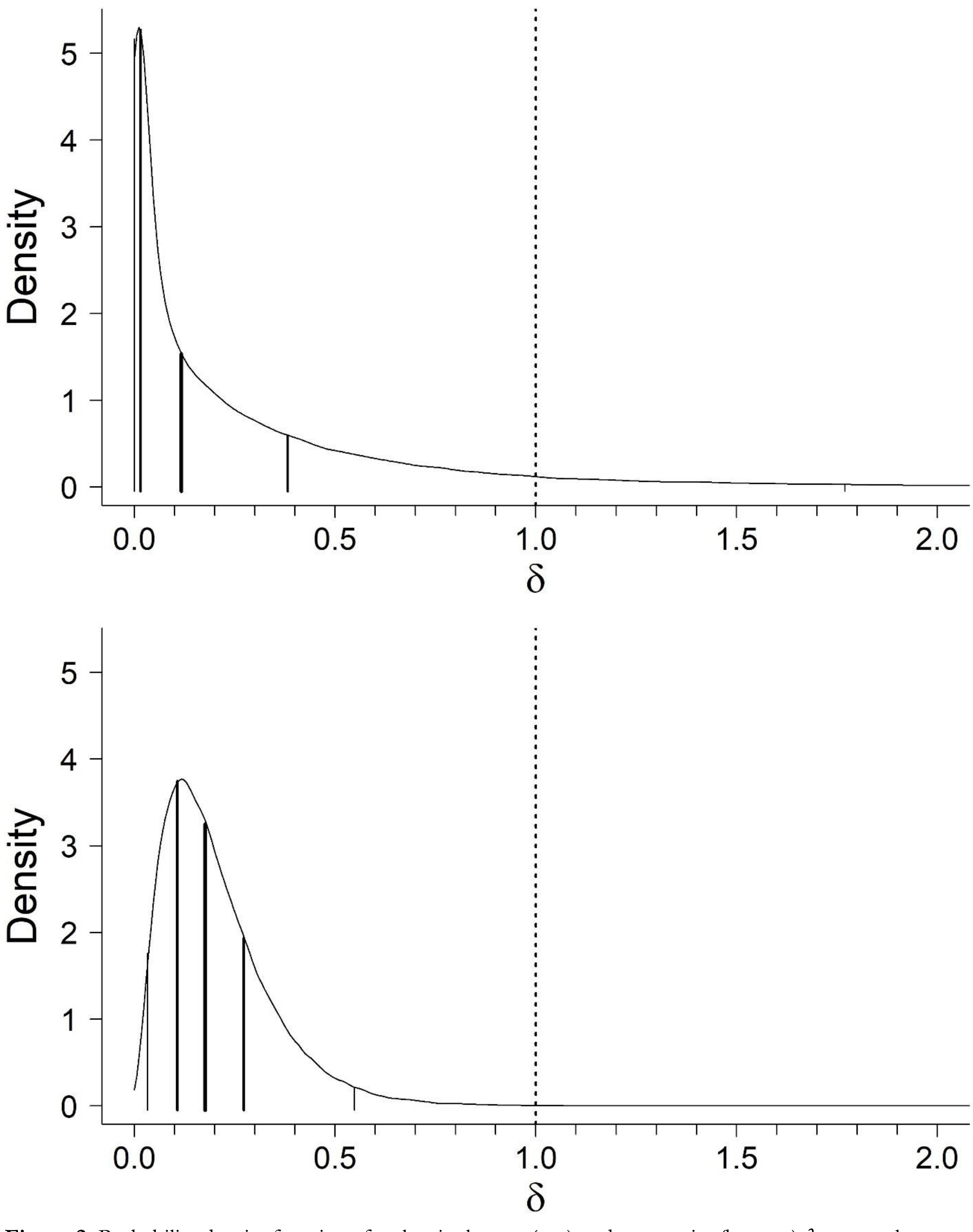

Figure 2. Probability density functions for the single-year (top) and composite (bottom) λ approaches to calculating δ. Vertical lines within the distributions show the 2.5%, 25%, 50%, 75%, and 97.5% values. The vertical dashed line at 1.0 indicates the point of equivalence between λ values.

APPENDIX A

Additional Code Details

This appendix includes additional code for the implementation of the current analyses. The following session information details the R setup used:

```
R version 4.0.5 (2021-03-31)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows 10 x64 (build 19043)

Matrix products: default

locale:
[1] LC_COLLATE=English_United States.1252
[2] LC_CTYPE=English_United States.1252
[3] LC_MONETARY=English_United States.1252
[4] LC_NUMERIC=C
[5] LC_TIME=English_United States.1252

attached base packages:
[1] tcltk     stats     graphics  grDevices utils     datasets  methods
[8] base

other attached packages:
[1] pracma_2.3.3   moments_0.14.1 eoa_2.0.7      tcltk2_1.2-11  R6_2.5.1
[6] bbplot_0.0.1

loaded via a namespace (and not attached):
[1] compiler_4.0.5 tools_4.0.5
```

All custom scripts are included here as a main script .R file and a set of R scripts within a code folder, zipped together into a single file.

Appendix 5.
FY 2023 Estimate of Bat Deterrent Effectiveness

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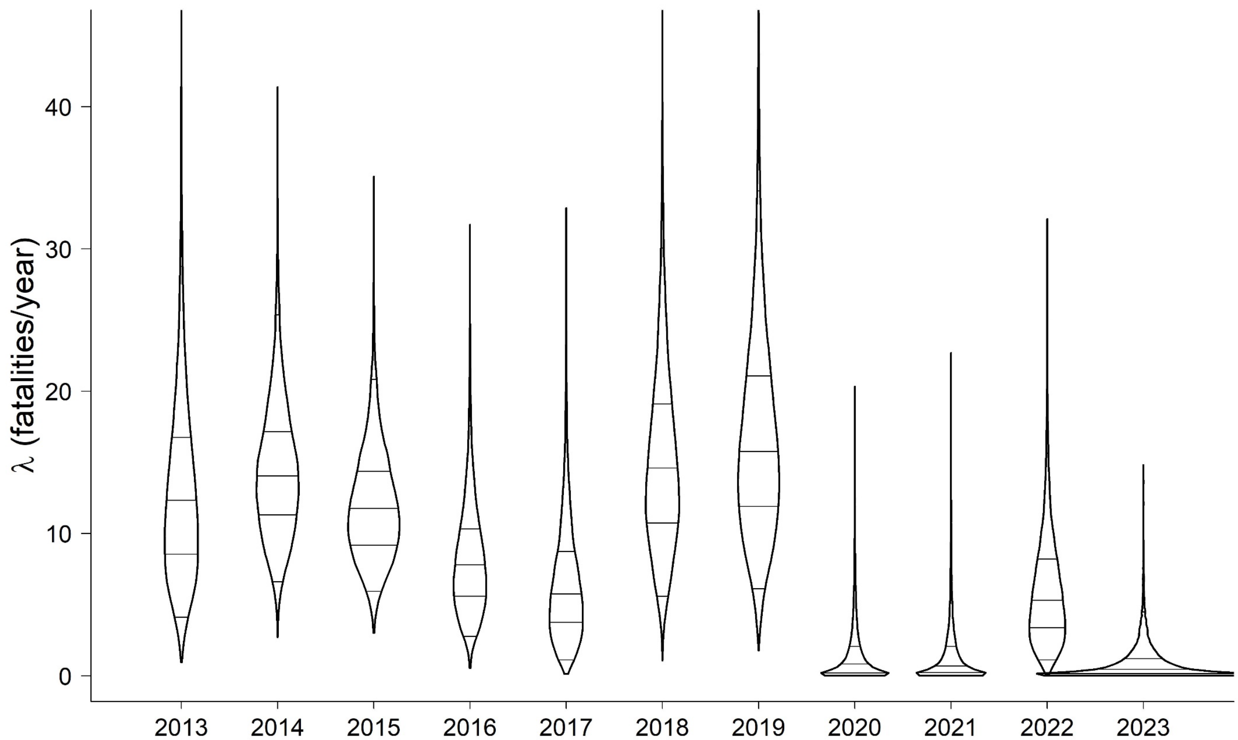
Four years of post-construction mortality monitoring data confirm the Hawaiian hoary bat fatality rate is reduced at the Kawailoa Wind Project (Project) after installation of ultrasonic acoustic deterrents (UADs) (Appendix 3). In FY 2023, Kawailoa Wind hired DAPPER Stats to develop a statistical method to estimate the effectiveness of the deterrents (DAPPER Stats 2023; Appendix 4). Appendix 4 presents results of the analysis through FY 2022. Here we duplicate the analysis and present results through FY 2023. Note that the approach used in the DAPPER Stats approach uses the term delta (δ) to replace rho (ρ) in the context of this analysis with the following explanation:

> *This report describes evaluation of posterior distributions of annual fatality rates (λ) and the relative impact of deterrents on fatality rates (δ) generated by analysis using the Evidence of Absence (EoA; Dalthorp et al. 2017) methodology at the Kawailoa Wind Project. Note that the term for a component year's weight within a multi-year estimate of λ (i.e., ρ) is the same as that which was proposed for use as the relative impact of deterrence, and so we have introduced δ to avoid confusion.*

As a result, information in this appendix uses the term δ as the measure of the benefit of deterrence at the Project.

In March 2023, Kawailoa Wind provided the DAPPER Stats memo (Appendix 4) and associated code in R v4.0.5 (R Core Team 2021) to the U.S. Fish and Wildlife Service (USFWS) and Department of Land and Natural Resources—Division of Forestry and Wildlife (DOFAW) for review and recommended the incorporation of use of the greater of two potential median δ values generated by the code. A larger δ value is conservative in that it estimates the deterrent benefit to be less. The two estimates represent two distinct methodologies. The first approach is the composite approach in which all data for years of operations with UADs are combined and compared to the combined data for years of operations without UADs. The second approach (single year approach) compares individual years, thus accounting for among-year variance.

The composite approach yields a median estimate of δ and its 95 percent confidence interval (CI) at 0.117 (0.022 – 0.364). The single year approach yields an estimate 0.101 (0.001 – 1.640). Comparative distributions of λ and probability density distributions of δ for the two approaches are provided below. The strongly skewed probability density functions indicate the median estimate is the appropriate estimate. As proposed to USFWS and DOFAW in our March 2023 transmittal of the DAPPER Stats memo, we have added context to the annual report by supplementing analyses using no modification to rho with analyses using a modified rho (δ in this appendix) of 0.117.



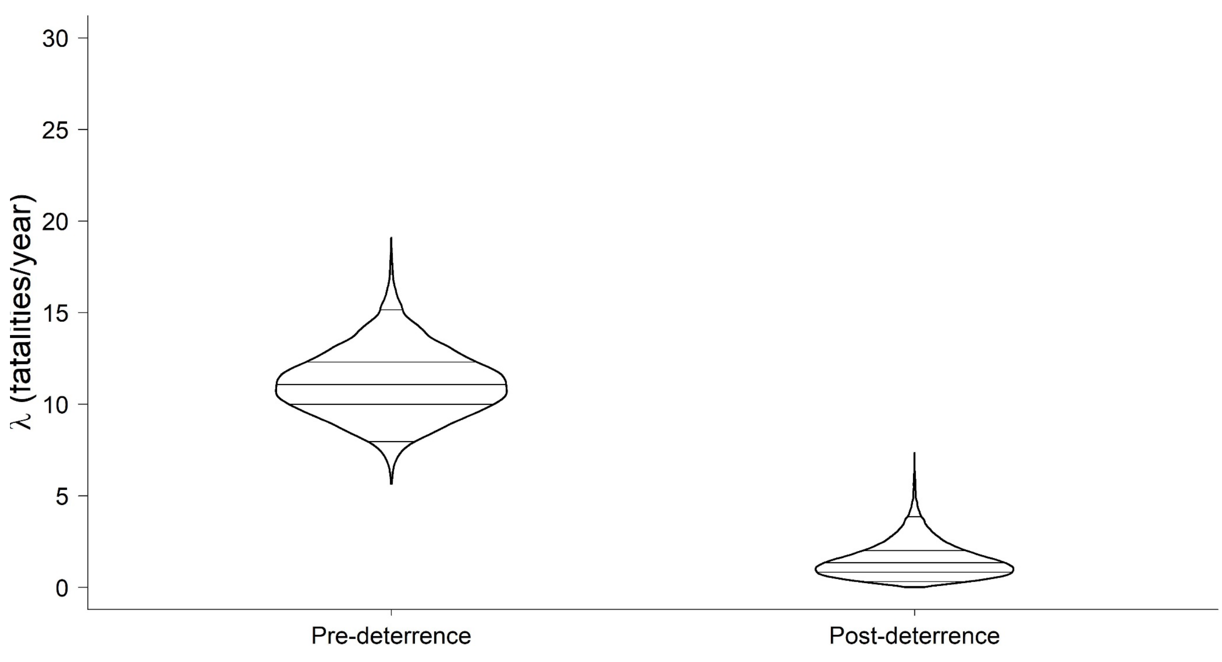
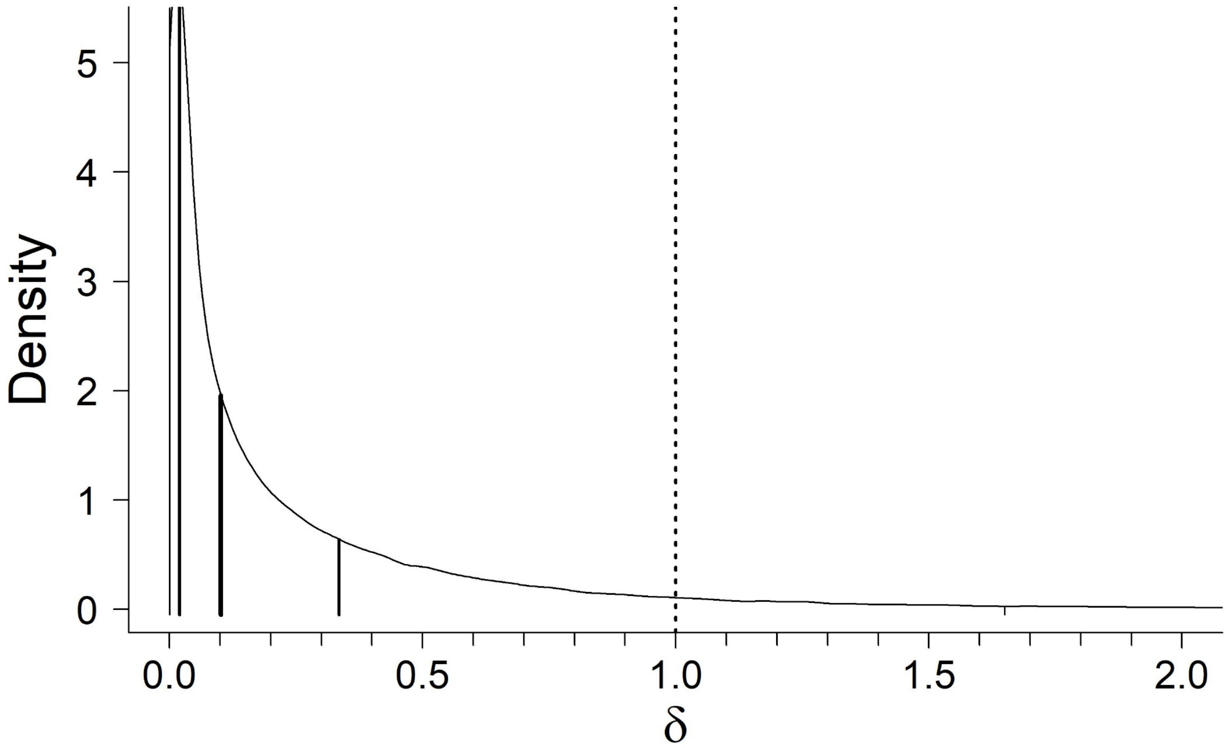


Figure 1. Top: Year-based distributions of annual λ rates. Bottom: Deterrence period-based distributions of λ. Horizontal lines across violins represent the 2.5%, 25%, 50%, 75%, and 97.5% values.



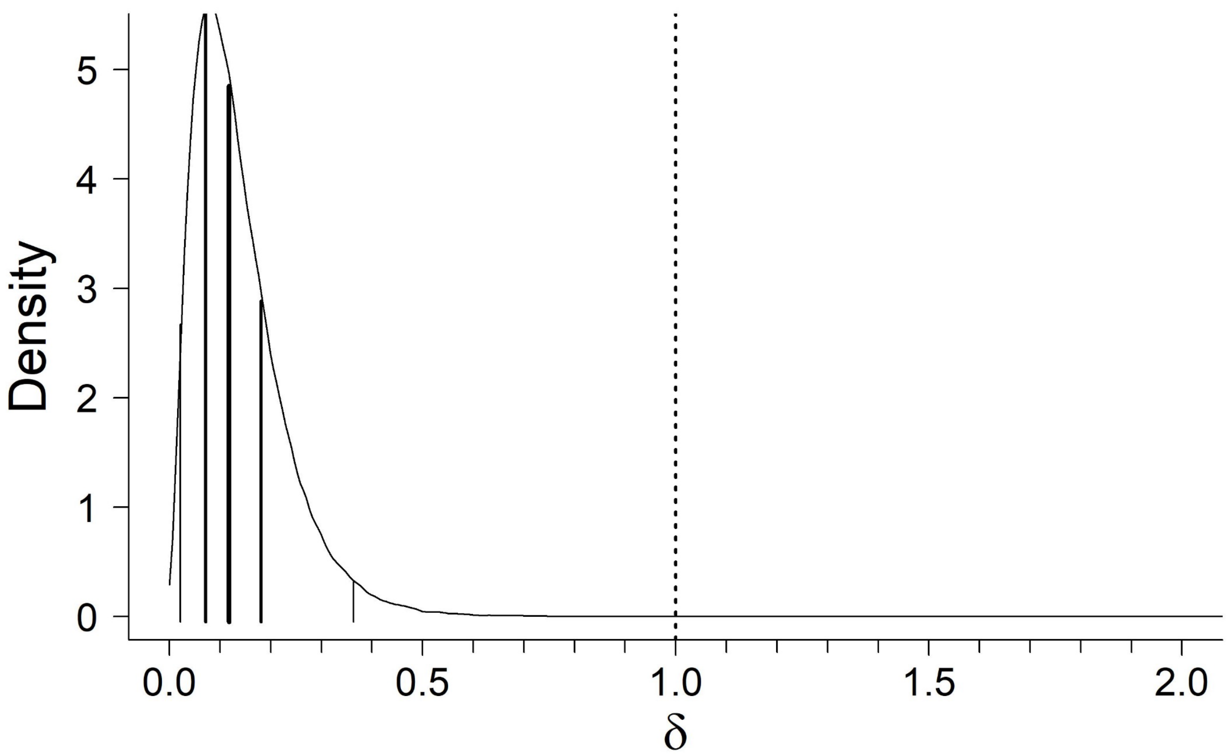


Figure 2. Probability density functions for the single-year (top) and composite (bottom) λ approaches to calculating δ. Vertical lines within the distributions show the 2.5%, 25%, 50%, 75%, and 97.5% values. The vertical dashed line at 1.0 indicates the point of equivalence between λ values.

Literature Cited:

Dalthorp, D., M. Huso, and D. Dail. 2017. Evidence of absence (v2.0) software user guide. U.S. Geological Survey Data Series 1055. 109 pp. https://doi.org/10.3133/ds1055.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

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Appendix 6.
Dalthorp et al. (2017) Fatality Estimation for Hawaiian Petrels at Project through FY 2023

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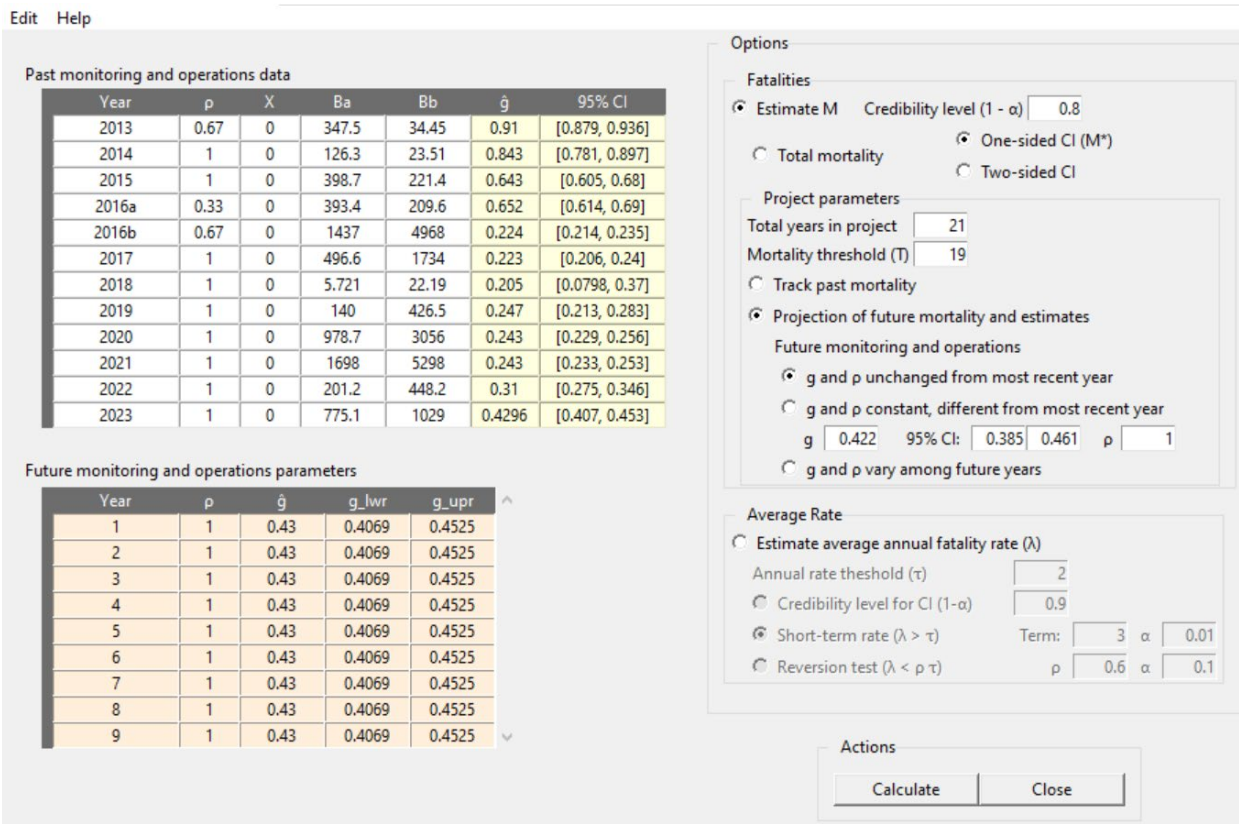
Figure 1. Dalthorp et al. (2017) Fatality Estimation for Hawaiian Petrels at Project through FY 2023.[7]

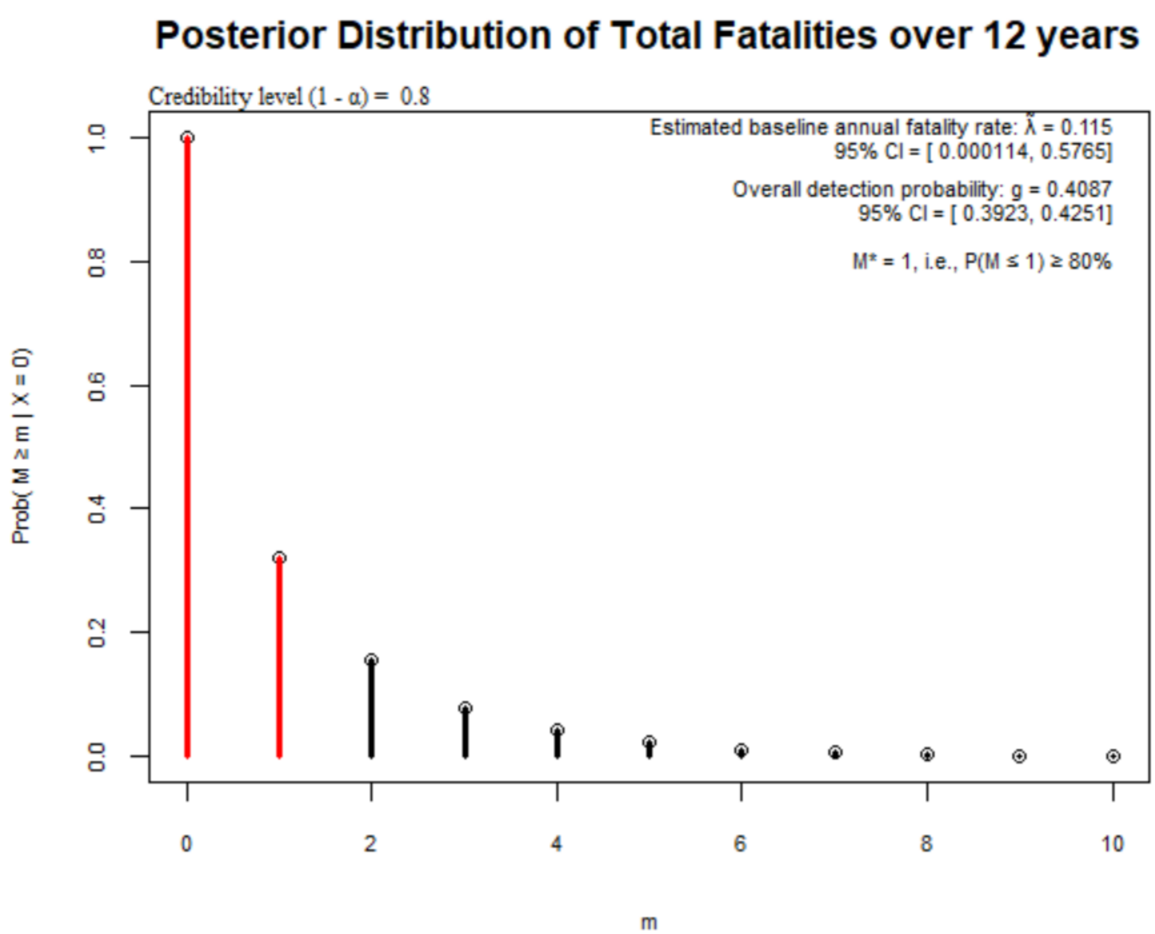


Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	0.67	0	347.5	34.45	0.91	[0.879, 0.936]
2014	1	0	126.3	23.51	0.843	[0.781, 0.897]
2015	1	0	398.7	221.4	0.643	[0.605, 0.68]
2016a	0.33	0	393.4	209.6	0.652	[0.614, 0.69]
2016b	0.67	0	1437	4968	0.224	[0.214, 0.235]
2017	1	0	496.6	1734	0.223	[0.206, 0.24]
2018	1	0	5.721	22.19	0.205	[0.0798, 0.37]
2019	1	0	140	426.5	0.247	[0.213, 0.283]
2020	1	0	978.7	3056	0.243	[0.229, 0.256]
2021	1	0	1698	5298	0.243	[0.233, 0.253]
2022	1	0	201.2	448.2	0.31	[0.275, 0.346]
2023	1	0	775.1	1029	0.4296	[0.407, 0.453]

Year	ρ	ĝ	g_lwr	g_upr
1	1	0.43	0.4069	0.4525
2	1	0.43	0.4069	0.4525
3	1	0.43	0.4069	0.4525
4	1	0.43	0.4069	0.4525
5	1	0.43	0.4069	0.4525
6	1	0.43	0.4069	0.4525
7	1	0.43	0.4069	0.4525
8	1	0.43	0.4069	0.4525
9	1	0.43	0.4069	0.4525

[7] Rho represents the portion of a year represented for each line of data. FY 2013 represents a partial year (November 2012 to June 2013) because the Project began operations in November. In FY 2016 the search strategy was changed, so the analysis period is broken into two components. All remaining years represent a full fiscal year.

Figure 2. Posterior Distribution: Dalthorp et al. (2017) Fatality Estimation for Hawaiian Petrels at Project for FY 2023.



Appendix 7.
‘Uko‘a Wetland Insect Assessment Report

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Kawailoa Wind Project

DRAFT ‘Uko‘a Wetland Insect Assessment Report

Prepared for:

Kawailoa Wind, LLC

June 1, 2023

TETRA TECH

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1.0 Introduction

The Kawailoa Wind Project (Project) is conducting Tier 1 mitigation for the Hawaiian hoary bat/ ʻōpeʻapeʻa (*Lasiurus semotus*) at ʻUkoʻa Wetland based on the requirements in the Habitat Conservation Plan (HCP; SWCA 2011) and on-going coordination with the U.S. Fish and Wildlife Service (USFWS) and the Hawaiʻi Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW). Tier 1 bat mitigation at ʻUkoʻa Wetland has been adaptively managed in coordination with USFWS and DLNR and includes:

- Acoustic monitoring for bats;
- Removal of invasive vegetation in open water areas to promote improved foraging areas;
- The creation and maintenance of bat lanes in adjacent forest areas to improve foraging and movement corridors;
- Insect sampling;
- Construction and maintenance of an ungulate fence; and
- Predator control within the fenced area.

The ʻUkoʻa Wetland Hawaiian Hoary Bat Mitigation Management Plan (H.T. Harvey and SWCA 2014) states that the purpose of the Project's insect assessment is to measure changes in availability of bat prey at ʻUkoʻa Wetland through insect sampling. It lists "relative increases in numbers of available insect prey" as a measure of success for mitigation activities. However, in March 2016, USFWS and DOFAW provided written confirmation permitting adaptive management of the Tier 1 bat mitigation and confirmed that the bat success criteria are based on the completion of all other management and monitoring components, instead of increased bat activity.

Insect sampling was conducted in 2014 and 2015 by First Wind biologists using 10 insect traps throughout ʻUkoʻa Wetland**.** During several subsequent Endangered Species Recovery Committee (ESRC) meetings, committee members requested Kawailoa Wind conduct a follow-up insect assessment to compare bat prey availability before and after management activities at ʻUkoʻa Wetland. However, it is important to note that although the management activities conducted at ʻUkoʻa Wetland (e.g., clearing vegetation over open water, creating bat foraging lanes through forested areas) have the potential to affect changes in insect prey availability, it is not possible to attribute any observed changes in insect prey availability between years to the management activities specifically, due to unrelated, naturally occurring interannual variation in insect populations (K. Magnacca, pers. comm., 2018). Furthermore, due to the initial study design, changes in management activities, and challenges with trap functionality, the study cannot adequately test whether management activities resulted in changes in insect prey.

The purpose of the 2021 insect sampling was to assess the current Hawaiian hoary bat prey availability at ʻUkoʻa Wetland and compare the results to those from insect sampling conducted in 2014 and 2015. In 2021, prey availability was measured by sampling insects using methods similar to those used in the assessments conducted by First Wind biologists in 2014 and 2015. However, minor modifications to the methodology (see Section 3.0) were applied because of 1) agency-approved alterations in wetland management activities that were conducted and 2) input from entomologists and Hawaiian hoary bat experts. The 2021 sampling represents the final insect sampling Kawailoa Wind will conduct at ‘Uko‘a Wetland, and fulfills the follow-up monitoring requirement identified in the HCP. This report summarizes insect sampling results from the 2014 and 2015 surveys conducted by First Wind and the 2021 sampling conducted by Tetra Tech.

2.0 Description of Study Area

‘Uko‘a Wetland is located on the north shore of O‘ahu in the ahupua‘a of Kawailoa. It is roughly 0.72 kilometers northeast of Hale‘iwa Boat Harbor, and 3.2 kilometers southwest of the Project. ‘Uko‘a Wetland is bordered by Kamehameha Highway to the northwest, Joseph Leong Highway to the southwest, Kawailoa Drive to the north, and Cane Haul Road to the east (Figure 1). Approximately 55 hectares (135 acres) of ‘Uko‘a Wetland are fenced. The fence was completed in July 2013, and fence monitoring and maintenance is conducted monthly. The fenced portions of ‘Uko‘a Wetland consists of degraded upland and wetland areas dominated by non-native plant and wildlife species. Portions of the fenced area are managed for the Hawaiian hoary bat, as well as three state and federally-listed waterbirds, as part of the Project’s required mitigation.

2.1 Climate

The local climate at ‘Uko‘a Wetland is characterized as very dry (Price et al. 2012). According to the Online Rainfall Atlas of Hawai‘i (Giambelluca et al. 2013), the area receives approximately 859 millimeters per year. Rainfall is typically highest in January and lowest in June (Giambelluca et al. 2013). Monthly precipitation totals recorded at the closest active rain gauge (Waimea Valley 892.2, located roughly 4.8 kilometers north of ‘Uko‘a Wetland) prior to and during the insect sampling periods (June to October) are provided in Table 1. The total rainfall amounts during the sampling periods were highest in 2014 and lowest in 2021 (NRCS 2022), suggesting conditions may have varied across sampling years.

Table 1. Monthly Total Precipitation at the Waimea Valley Rain Gage Prior to and During the Sampling

Month	Rainfall (millimeters)		
	2014	2015	2021
May	90.4	81.5	68.1
June	80.3	71.4	65.8
July	158.0	110.2	88.4
August	127.0	86.4	79.3
September	77.5	183.1	84.6
October	154.7	93.7	72.4
Source: NRCS 2022.			

Figure 1. Location of Insect Traps Deployed at 'Uko'a Wetland in 2014, 2015, and 2021

2.2 Hydrology

ʻUkoʻa Wetland is situated in the watershed of Loko Ea (Parham et al. 2008). The wetland area historically comprised an estuary with two major ponds: ʻUkoʻa Pond at the northern end and Loko Ea fishpond at the southern end towards Waialua Bay. ʻUkoʻa Wetland is currently a freshwater system fed by basal, spring water and surface water in upper elevations, including Loko Ea Stream (Miller et al. 1989, WHALE 2010, SWCA 2012). The former channel that connected the wetland to Loko Ea and the ocean is overgrown with invasive vegetation. Recent studies have not found evidence of saltwater at ʻUkoʻa Wetland (WHALE 2010, SWCA 2012). Water depths vary spatially and temporality with depths recorded between 0.9 meters to 3.5 meters (Miller et al. 1989, WHALE 2010, SWCA 2012).

2.3 Flora

Previous vegetation surveys at ʻUkoʻa Wetland have documented nearly 100 plants species, 11 of which are native to the Hawaiian Islands (SWCA 2012). ʻUkoʻa Wetland is mainly dominated by large open areas of California grass (*Urochloa mutica*) and great bulrush/ ʻakaʻakai (*Schoenoplectus tabernaemontani*). Invasive water hyacinth (*Eichhornia crassipes*) has been removed from the open water area (beginning in January 2017). Upland areas are dominated by non-native trees, including paperbark (*Melaleuca quinquenervia*), Christmas berry (*Schinus terebinthifolius*), Java plum (*Syzygium cumini*), date palm (*Phoenix dactylifera*), and kiawe (*Neltuma pallida*). Sourbush (*Pluchea carolinensis*), Indian fleabane (*Pluchea indica*), and a hybrid of the two species (*Pluchea* x *fosbergii*), is common is some areas. The indigenous ground cover, ʻaeʻae (*Bacopa monnieri*), forms mats in marshy areas with shallow water.

2.4 Fauna

Although the area is fenced and invasive mammal control is conducted at ʻUkoʻa, feral pigs (*Sus scrofa*) are present in the fenced area due to fence vandalism. Rats (*Rattus* sp.), cats (*Felis catus*), mongoose (*Herpestes javanicus*), and house mice (*Mus musculus*) continue to be caught at ʻUkoʻa as part of the predator control program. Bullfrogs (*Rana catessbiana*) are regularly seen and heard around the open water areas of ʻUkoʻa Wetland. Mosquitofish (*Gambusia* sp.) and other non-native freshwater fish such as tilapia (*Tilapia* sp.) and platyfish (*Xiphophorus* sp.) can be regularly seen swimming in the waters of ʻUkoʻa. Tahitian prawns (*Macrobrachium lar*) and red-eared sliders (*Trachemys scripta elegans*) are also occasionally seen.

The endangered Hawaiian common gallinule/ ʻalae ʻula (*Gallinula chloropus sandvicensis*) is regularly seen at ʻUkoʻa Wetland, and nesting of this species has been documented. Endangered Hawaiian stilts/ aeʻo (*Himantopus mexicanus knudseni*) are occasionally seen foraging within the fenced area or flying over ʻUkoʻa Wetland.

Bat activity at ʻUkoʻa Wetland is monitored using 10 Song Meter SM2BAT+ acoustic recorders each equipped with two SMX-U1 ultrasonic microphones. The recorders were originally deployed between 2012 to 2015. Monitoring resumed in June 2017 following the removal of invasive vegetation in the open water areas and the construction of bat lanes. In December 2017, 16 bat lanes were created (Figure 1), and these lanes are maintained, as needed.

Annual bat detection rates have varied across sampling years (Table 2 and Figure 2). Comparison of detection rates for each month before (2012 to 2016 Sampling Period) and after (2018 to 2022 Sampling Period) management was implemented at ‘Uko‘a Wetland indicate an increase in the detection rates for several of the months throughout the year. In addition to observed increases in monthly detection rates, there has also been an observed increase in the mean proportion of nights with feeding buzzes recorded at several of the monitoring sites after management was implemented (Figure 3). A feeding buzz is classified as a burst of pulses at a very high rate with less than 11 milliseconds between pulses (Griffin et al. 1960) and are indicative of foraging behaviors. Additional details on the acoustic recorders at ‘Uko‘a and results are provided in Kawailoa Wind’s HCP annual reports (Tetra Tech 2021, 2022).

Table 2. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections at ‘Uko‘a Wetland from April 2012 to May 2022

Bat Sampling Period	Before or After Vegetation Removal	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2012 (April – May 2012)	Before	142	18	0.127
FY 2013 (June 2012 –May 2013)	Before	2,036	191	0.094
FY 2014 (June 2013 – May 2014)	Before	2,694	100	0.037
FY 2015 (June 2014 – May 2015)	Before	2,552	175	0.069
FY 2016 (June – October 2015)	Before	1,211	218	0.180
FY 2018 (June 2017 – May 2018)	After	3,248	444	0.137
FY 2019 (June 2018 – May 2019)	After	3,391	506	0.149
FY 2020 (June 2019 – May 2020)	After	3,339	650	0.195
FY 2021 (June 2020 – May 2021)[2]	After	3,182	613	0.193
FY 2022 (June 2021 – May 2022)	After	2,430	559	0.230

Notes:

The 2017 Sampling Period not included due to minimal number of detector-nights compared to other years; no detectors were deployed from November 2015 to May 2017.

Rows highlighted in yellow include months when insect sampling was conducted.

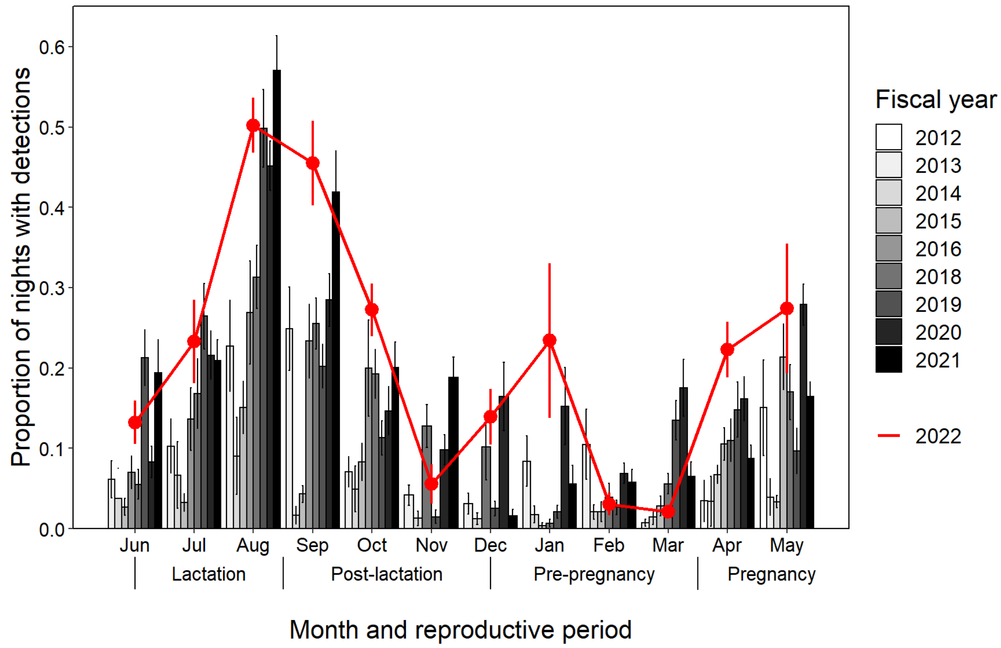

Figure 2. Monthly Bat Detection Rates at ‘Uko‘a Wetland for 2014 to 2022 Bat Sampling Periods with Corresponding Reproductive Periods

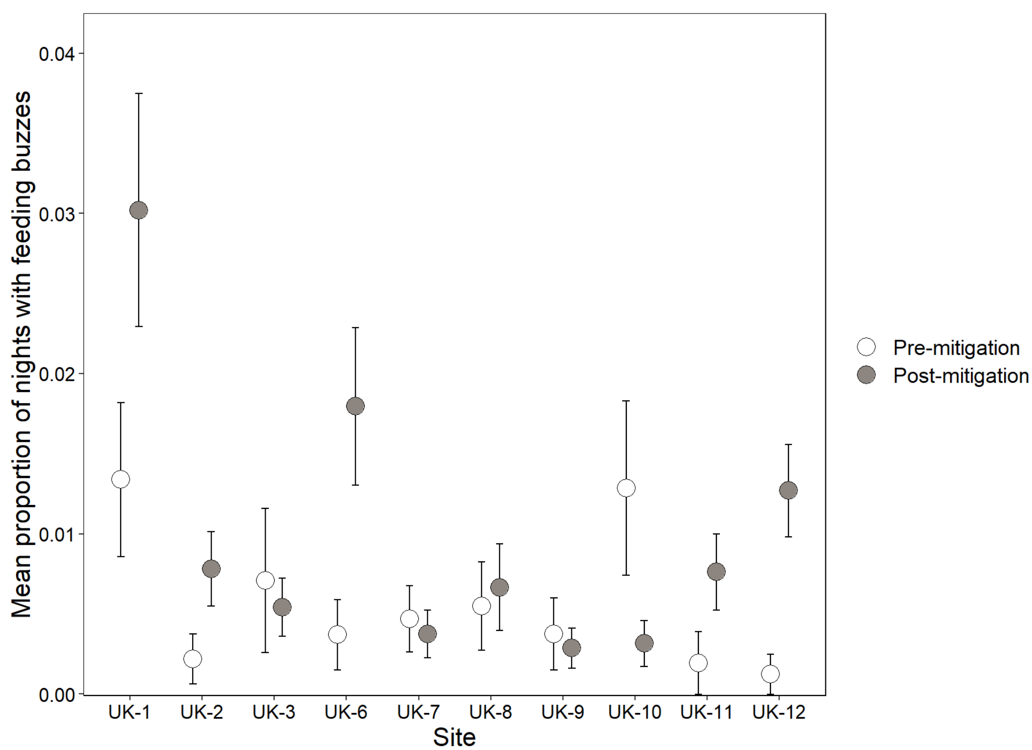

Figure 3. Mean and Standard Error for the Proportion of Feeding Buzzes for Each Monitoring Site at ‘Uko‘a Wetland Before (2012 – 2016 Sampling Period) and After (2018-2022 Sampling Period) Management

3.0 Methods

This study used four different insect trap types (Townes-style Malaise, Aquatic Emergence, Universal Black Light, and Air Intercept Traps) distributed throughout ‘Uko‘a Wetland at 10 different locations (Figure 1). Trap locations were selected in 2014 based on accessibility and logistics, with a minimum distance of 60 meters separating any two traps. In addition, Universal Black Light Traps were placed a minimum distance of 80 meters from all bat detector microphones to avoid attracting insects, and therefore bats, to the detector sampling area. Traps were deployed in four different habitat types: ground upland, ground wetland, open water, and air upland (Table 3, Appendix A).

Table 3. Insect Trap Name, Type, and Habitat

Trap ID	Trap Type	Habitat
Up10	Townes-style Malaise Trap	Ground upland
UpDOT	Townes-style Malaise Trap	Ground upland
Wet1[1]	Townes-style Malaise Trap	Ground wetland
Wet2[2]	Townes-style Malaise Trap	Ground wetland
WaterKayak	Aquatic Emergence Trap	Open water
WaterRoad[3]	Aquatic Emergence Trap	Open water
Light 9	Universal Black Light Trap	Ground upland
Light 12	Universal Black Light Trap	Ground upland
Air12	Air Intercept Trap	Air upland
AirDOT	Air Intercept Trap	Air upland

1. Moved to a new location in 2021 due to change in vegetation conditions compared to 2014/2015 (2021 site roughly 290 meters from the 2014/2015 location).
2. Moved to a new location in 2021 due to change in vegetation conditions compared to 2014/2015 (2021 site roughly 220 meters from the 2014/2015 location).
3. Moved to a new location in 2021 because water levels at the 2014/2015 site were consistently dry making the trap non-functional.

Insect sampling in 2014 and 2015 was conducted by First Wind biologists, and sampling was conducted between June and October in 2014 and 2015 with some slight deviations due to trap availability, weather events, and trap site conditions. Insect sampling in 2021 was conducted by Tetra Tech biologists between June and September 2021 using the same number of traps and trap types. The 2021 trap locations were generally in the same locations used in 2014/2015, with the exception of three trap locations that required re-siting due to undesirable site conditions or trap functionality (Table 3, Figure 1). Additional trap details are discussed in Section 3.1.

During the sampling periods, the Townes-style Malaise Traps, Universal Black Light Traps, and Air Intercept Traps operated from sunset to sunrise, and the Aquatic Emergence Traps were run for 24 hours. For the 2014/2015 surveys, trap nights varied from 3 to 5 consecutive nights per month across all trap types (Table 4); this variation was due to weather events, trap malfunction, and abundance of insects collected. Notably, the protocol was altered in June 2015 to sample for 3 consecutive nights (rather than 5 nights) at both Universal Black Light Traps to reduce the sorting and identification effort involved with the large samples collected (Table 4). In 2021, all traps were set out from sunset to sunrise for 3 to 5 consecutive nights each month (similar to 2014/2015 to enable comparison of results). Each sample was collected daily within 1 hour of sunrise. Sampling was conducted during dry weather as much as possible and was timed around the new moon of each month.

The total number of nights sampled varied each year due to weather events and trap malfunctions. The number of trap nights ranged from 185 nights in 2014, to 210 nights in 2015, and 184 nights in 2021 (Table 4). Additionally, the number of trap nights per trap type varied within and between years.

In 2014 and 2015, samples of day flying mosquitoes were collected at all traps except for light traps. Day samples were not collected during the 2021 survey because mosquitofish removal was omitted from the management activities at ‘Uko‘a Wetland with agency approval. However, day samples of mosquitoes were collected at the two aquatic emergent traps in 2021. These traps ran for 24 hours per sample, so it is not possible to distinguish mosquitoes collected at day or night as part of these results.

3.1 Trap Deployment and Collection

3.1.1 Townes-style Malaise Traps

Four Townes-style Lightweight Malaise traps (Bioquip Products Inc., Compton, California, United States) were deployed each year to collect low-flying insects. In all sampling years, two malaise traps were deployed in the uplands (Up10 and UpDOT; Appendix A, Photos 3 and 4), and two malaise traps were deployed in the interior of the wetland (Wet1 and Wet2; Appendix A, Photos 1 and 2). These tent-like mesh traps intercept insects that fly close to the ground and trap a wide variety of insects, particularly Lepidopterans (moths) and Dipterans (flies). The collecting bottles for the malaise traps were furnished with enough denatured alcohol to last the sampling period. Denatured alcohol acted as both the killing agent and the preservative. The wetland Townes-style Malaise traps were moved to new locations in 2021 because vegetation conditions at the 2014/2015 sites had changed dramatically.

3.1.2 Aquatic Emergence Traps

Two Aquatic Emergence Traps (Bioquip Products Inc., Compton, California, United States) were deployed in open water areas (Appendix A, Photos 5 and 6) to capture aquatic emergent insects. These traps operated continuously for 24 hours per day, and the windows on the trap were left open between monthly samples to enable captured insects to escape. The location of one aquatic emergence trap location (WaterRoad) was changed in 2021 because water levels at the 2014/2015 location was often dry, resulting in inconsistent and minimal sampling.

Table 4. Number of Trap Nights by Sampling Period per Trap Type

Trap ID	June			July			August			September			October			Sum of Trap Nights
	2014	2015	2021	2014	2015	2021	2014	2015	2021	2014	2015	2021	2014	2015	2021	
Malaise	20	20	20	20	20	20	20	20	20	20	20	20	12	20	0	**272**
Aquatic Emergence	5	5	10	10	5	10	10	10	10	10	5	10	6	5	0	**111**
Universal Black Light	0	6	6	10	6	6	10	6	6	10	6	6	6	6	0	**90**
Air Intercept	0	10	10	0	10	10	0	10	10	10	10	10	6	10	0	**106**
Sum of Trap Nights by Month	**25**	**41**	**46**	**40**	**41**	**46**	**40**	**46**	**46**	**50**	**41**	**46**	**30**	**41**	**0**	**579**
Total Trap Nights (2014)																**185**
Total Trap Nights (2015)																**210**
Total Trap Nights (2021)																**184**

3.1.3 Universal Black Light Traps

Two universal black light funnel traps equipped with a 12-watt U-shaped black light (Bioquip Products Inc., Compton, California, United States) were deployed in the uplands (Light9 and Light12; Appendix A, Photos 7 and 8). Light traps utilize ultraviolet light to attract night-flying insects and are particularly effective at collecting Lepidopterans, Coleopterans (beetles), and Blattodea (termites). Universal black light traps were placed a minimum distance of 80 meters from all bat detector microphones to avoid attracting insects and, therefore bats, to the detector sampling area. The black light traps were run off one 12-volt battery, which was connected to solar panels for recharging during the day. Ammonium carbonate was used as a killing agent. Nightly samples were collected in 5-gallon elastic-top paint strainers or similar mesh bags, tied, labeled, and placed in the freezer for preservation.

3.1.4 Air Intercept Traps

Two land and air intercept traps (Air12 and AirDOT; Appendix A, Photos 9 and 10) with Malaise trap bottom collectors (Bioquip Products Inc., Compton, California, United States) were suspended from tree branches in the uplands approximately 4 meters above ground level (measured from the top of the trap). These traps are designed to collect higher flying insects, particularly Coleoptera, which dropped into collection tubes upon hitting the trap. Each suspended trap has a collection bottle at the top and a second collection bottle at the bottom. Bottom collection bottles were modified to allow water, but not captured insects, to escape during rain events. The collecting bottles for the air intercept traps were furnished with enough denatured alcohol to last the sampling period. Denatured alcohol acted as both the killing agent and the preservative.

3.2 Sorting and Identification

At the completion of each monthly sampling period, all wet samples were transferred to mason jars or whirl packs and dry samples were frozen. Each sample was delivered to entomologist Dr. Karl Magnacca in 2014 and 2015 and to entomologist Dr. Paul Krushelnycky in 2021 for sorting and identification. For all years sampled, insects between 3 and 25 millimeters in length were identified to the greatest taxonomic precision practical (generally order and family) and tallied. This size range represents the size class of typical prey items consumed by Hawaiian hoary bats (Jacobs 1999, Todd 2012, Pinzari et al. 2019). The entomologists also measured minimum and maximum lengths among all the individuals in a given taxon (of the insects collected within the 3-25 millimeters size range).

3.3 Data Analysis

Insects were classified as “known prey” if they were previously identified in the diet of Hawaiian hoary bats and classified as “potential bat prey” if they were available to bats (i.e., nocturnal, capable of sustained flight and between 3 and 24 millimeters in size). Insect taxa identified as unlikely bat prey were excluded from the analysis.

To account for differences in the number of nights sampled, a capture rate for each order or family was determined by dividing the total number of insects collected in each taxon by the number of trap nights in each year. The relative abundance of each order or family sampled was calculated by dividing the total number of insects collected within that order or family by the total number of insects collected for each sample year. Data was assessed collectively for the entire wetland rather than specific trap locations or habitats due to low sample sizes, changed trap locations, and differing number of trap nights.

4.0 Results

The total number of insects collected in each sampling year was 19,182 insects in 2014, 27,534 in 2015, and 17,501 in 2021 (Appendix B). Of these, the number of known or potential bat prey collected included 14,650 insects in 2014, 25,708 insects in 2015, and 17,204 insects in 2021 (Table 5, Appendix B). All analyses in this report refer only to the insect taxa classified as known or potential bat prey. Size ranges of the prey taxa collected are provided in Appendix C.

Table 5. Number of Insect Prey Collected by Order and Year

Order	2014 (N=185)	2015 (N=210)	2021 (N=184)
Blattodea (Termites)	500	649	899
Coleoptera (Beetles)	2,825	2,641	746
Diptera (Flies)	1,146	729	203
Embioptera (Webspinners)	72	127	194
Ephemeroptera (Mayflies)	0	0	13
Hemiptera (True Bugs)	1,278	2,775	910
Hymenoptera (Ants, Wasps)	1,745	1,197	8,704
Lepidoptera (Moths)	6,868	17,211	5,403
Neuroptera (Lacewings)	1	2	2
Orthoptera (Katydids)	127	27	13
Psocoptera (Barkflies)	0	0	48
Trichoptera (Caddisflies)	88	350	69
Total Insects Collected	**14,650**	**25,708**	**17,204**

N = The number of total trap nights in each year sampled.

4.1 Taxonomic Composition

Across all years, collected insects represented twelve orders. Lepidoptera (moths) was the most abundant order collected in 2014 and 2015, and Hymenoptera (ants, wasps) was the most abundant order collected in 2021 (Table 5). Lepidoptera, Hymenoptera, Coleoptera (beetles), Hemiptera (true bugs), Diptera (Flies), and Blattodea (Termites) made up 98 percent of all the insect prey collected. Two orders—Psocoptera (barkflies) and Ephemeroptera (mayflies)—were only recorded in 2021.

The total number of families identified each year is shown in Table 6. Across all years, Geometridae, Gelechioidea, and Tortricidae comprised 93.5 percent of all Lepidopterans collected. Formicidae comprised 96.3 percent of all Hymenopterans collected across all years. Of the beetles, the following six families made up 95.4 percent of all Coleopterans collected across all years: Elateridae, Scarabaeidae, Nitidulidae, Curculionidae, Bostrichidae, and Cerambycidae. Within Hemiptera, Cydnidae, Flatidae, Cicadellidae, and Lygaeidae comprised 94.4 percent of all individuals collected across all years.

Table 6. Number of Families Identified Each Year by Order

Order	2014 (N=185)	2015 (N=210)	2021 (N=184)
Blattodea (Termites)	1	1	2
Coleoptera (Beetles)	7	10	18
Diptera (Flies)	9	12	13
Embioptera (Webspinners)	1	1	1
Ephemeroptera (Mayflies)	0	0	1
Hemiptera (True Bugs)	8	8	13
Hymenoptera (Ants, Wasps)	3	3	5
Lepidoptera (Moths)	7	6	11
Neuroptera (Lacewing)	1	2	1
Orthoptera (Katydids)	2	3	2
Psocoptera (Barkflies)	0	0	3
Trichoptera (Caddisflies)	1	1	1
Total Number of Families Identified	**40**	**47**	**71**
N = The number of total trap nights in each year sampled.			

4.2 Capture Rates and Relative Abundance

Insect capture rates (total number collected/number of trap nights) varied across sampling years. The overall capture rate was highest in 2015 (122.4) compared to 2021 (93.5), and 2014 (79.2). Figure 4 shows the capture rate from all traps for each order by year. Lepidoptera had the highest capture rate among insect orders in 2014 and 2015 (37.1 and 82.0, respectively). Hymenoptera had the highest capture rate in 2021 (47.3), followed by Lepidoptera (29.4). The high capture rate of Hymenoptera in 2021 is mostly due to the large amount of alate (flying) ants (Hymenoptera: Formicidae) collected in light traps in 2021 versus previous years. Formicidae was the most abundant of all families in all years (Figure 5). Of the Lepidotpera, Geometridae were notably abundant in 2015, and Gelechioidea was the most abundant family in 2014 and 2021 (Figure 6). Coleoptera capture rates were lower than Lepidoptera; Elateridae was the most abundant of all Coleoptera in all three years, although the capture rate declined each sampling year (Figure 7). Hemiptera was many comprised of Cydnidae and Flatidae in all years (Figure 8).

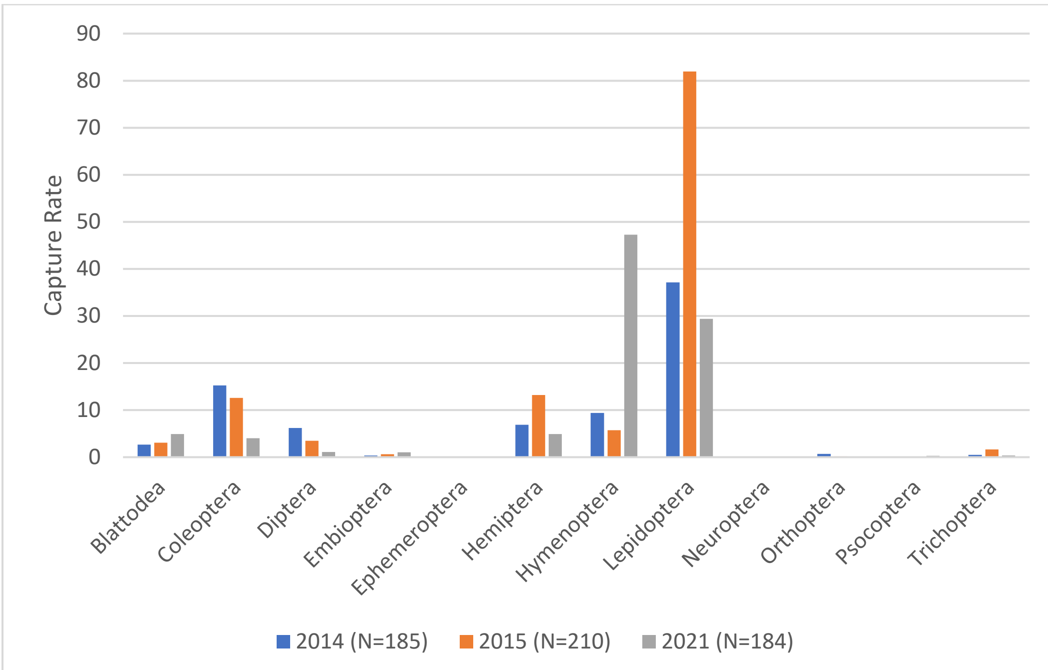

Figure 4. Capture Rates by Order for Each Sampling Year

Notes: Capture rate = Total number of insects collected/number of trap nights. N = Number of trap nights.

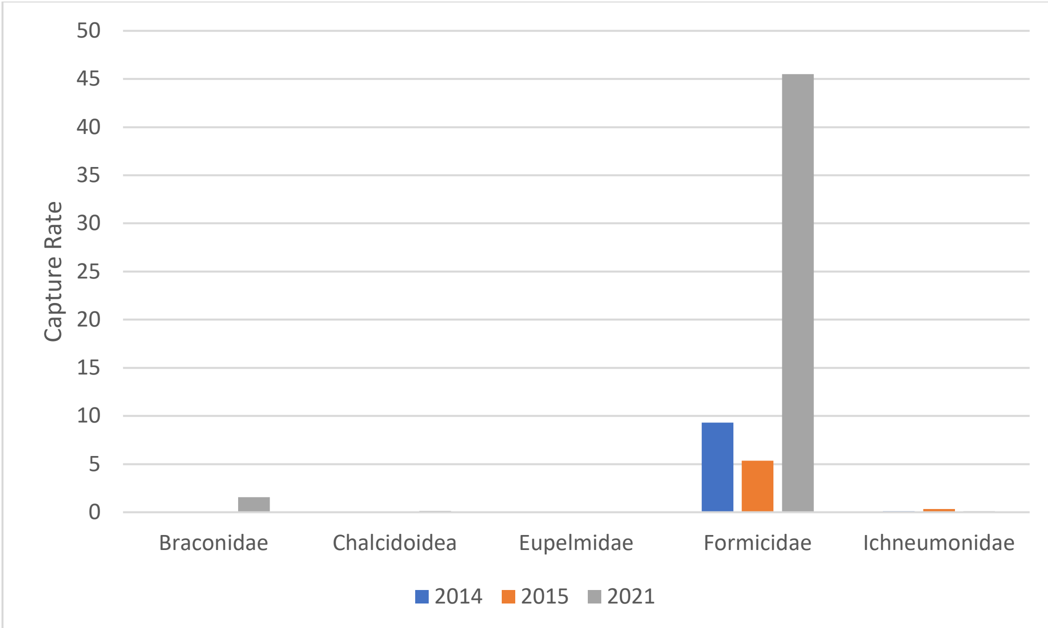

Figure 5. Hymenoptera Capture Rates by Family for Each Year

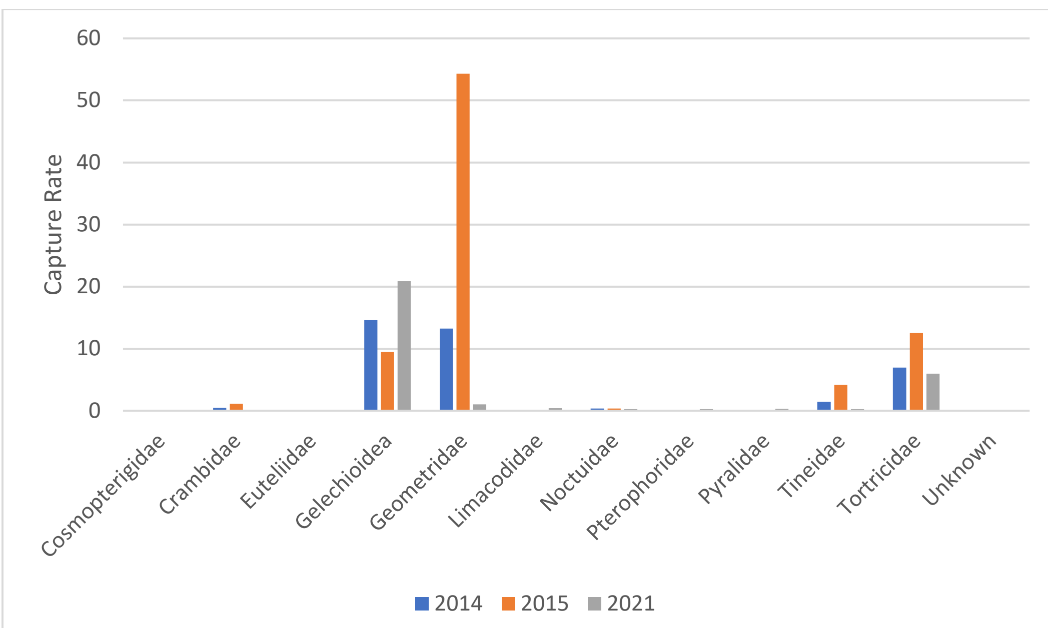

Figure 6. Lepidoptera Capture Rates by Family for Each Year

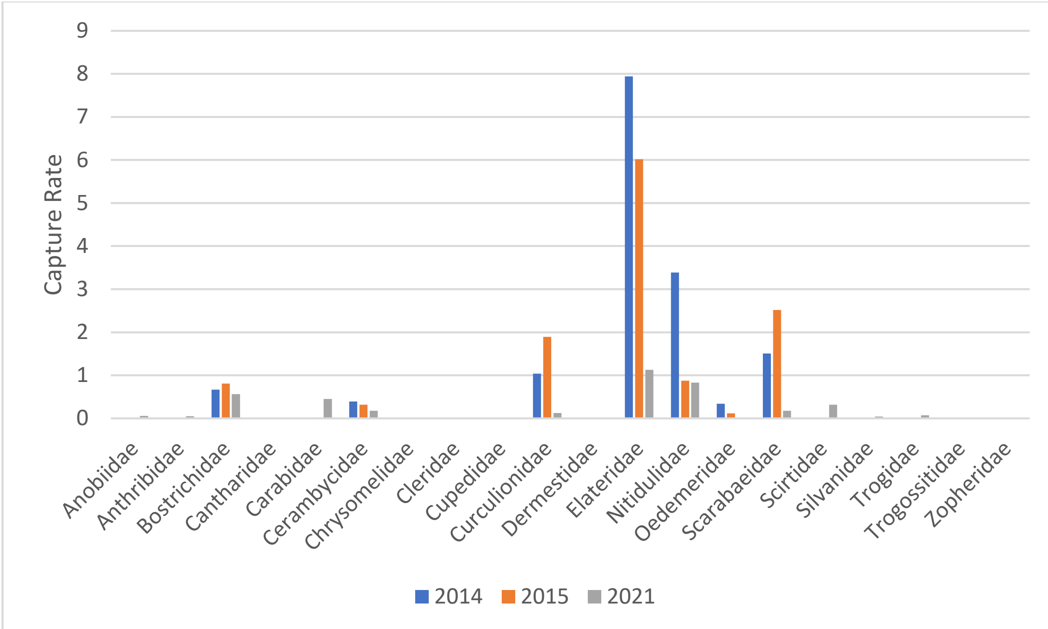

Figure 7. Coleoptera Capture Rates by Family for Each Year

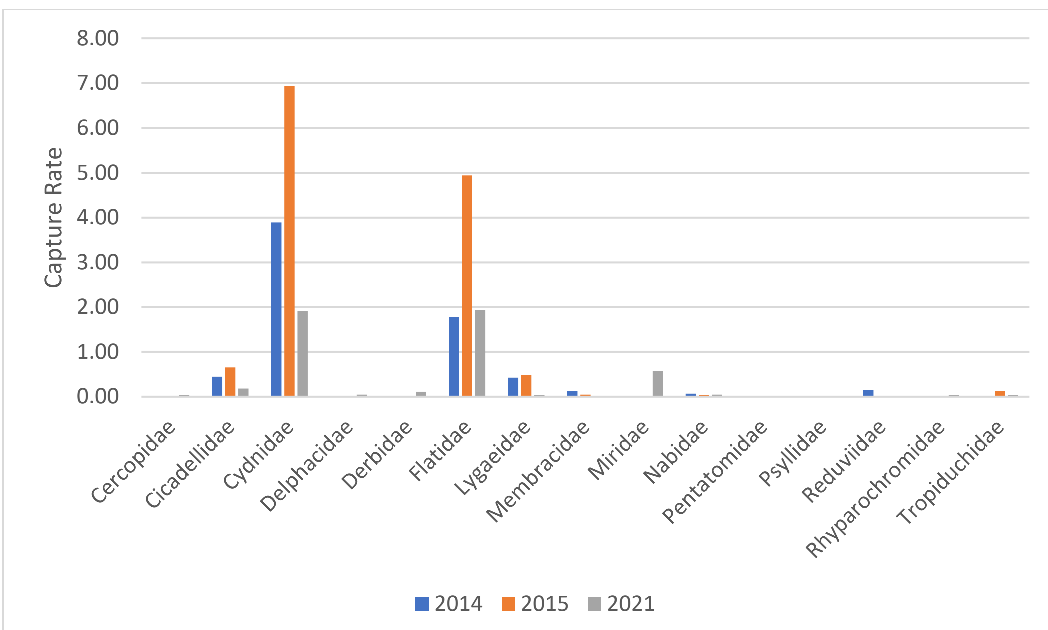

Figure 8. Hemiptera Capture Rates by Family for Each Year

The relative abundance of prey collected follows similar patterns as the capture rate (Figure 8). Lepidoptera had the greatest relative abundance among insect orders in 2014 (46.9 percent) and 2015 (66.9 percent), followed by Coleoptera in 2014 (19.3 percent) and Hemiptera in 2015 (10.8 percent). Hymenoptera had the greatest relative abundance among insect orders in 2021 (50.6 percent), followed by Lepidoptera (31.4 percent).

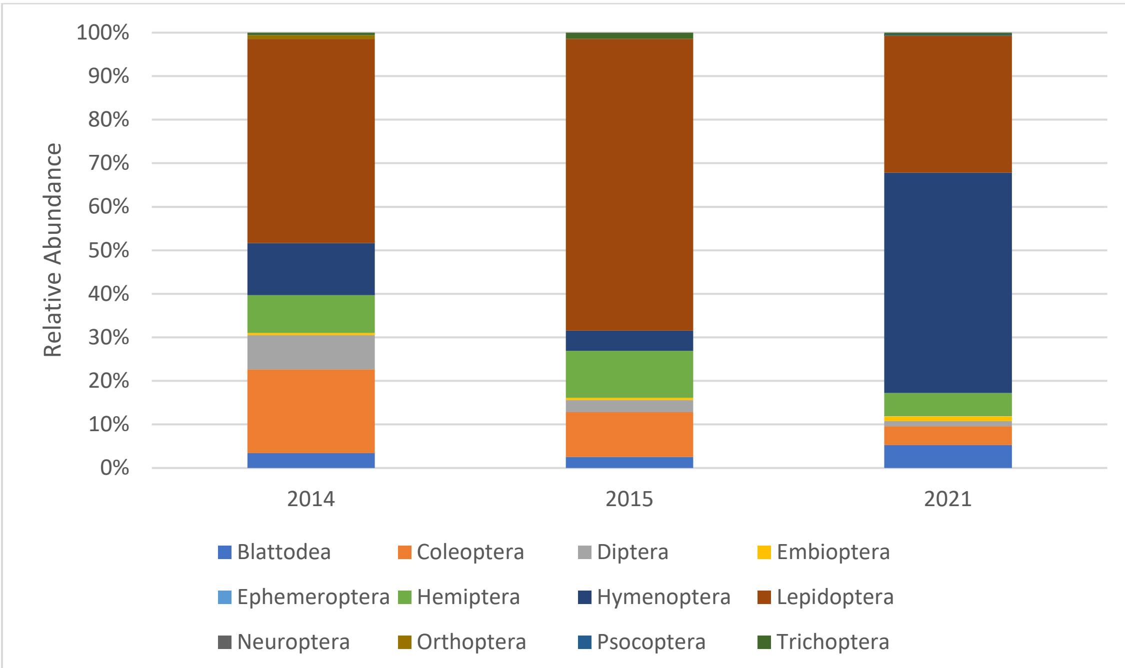

Figure 9. Relative Abundance by Order for Each Sampling Year

4.3 Trap Type

The two light traps collected the highest number of insects of all the trap types. Light traps collected 88.2 percent of all insect prey across years and collected all 12 insect orders. The malaise traps collected 11 of the 12 insect prey orders, and collected 8.9 percent of all collected insects across all years. Air intercept traps collected 1.5 percent of the total collected insects in all years (representing 8 insect orders), and aquatic emergence traps collected 1.4 percent (representing 8 insect orders) of the insect prey across all years.

The number of trap nights per trap type varied within and between years. Capture rates (total number collected/number of trap nights) per trap type (Figures 9-12) further show that light traps caught the most insects compared to the other trap type even though light traps had the lowest trap nights of all the trap types. Excluding aquatic emergence traps, the various traps had a high capture high of Lepidoptera compared to other orders, except for light traps in 2021 which had the highest capture rate for Hymenoptera. Light traps also had the highest capture rate for Coleoptera compared to the other trap types. The aquatic emergence traps had the lowest capture rates, except for a peak of Diptera in 2014 (see Figure 13).

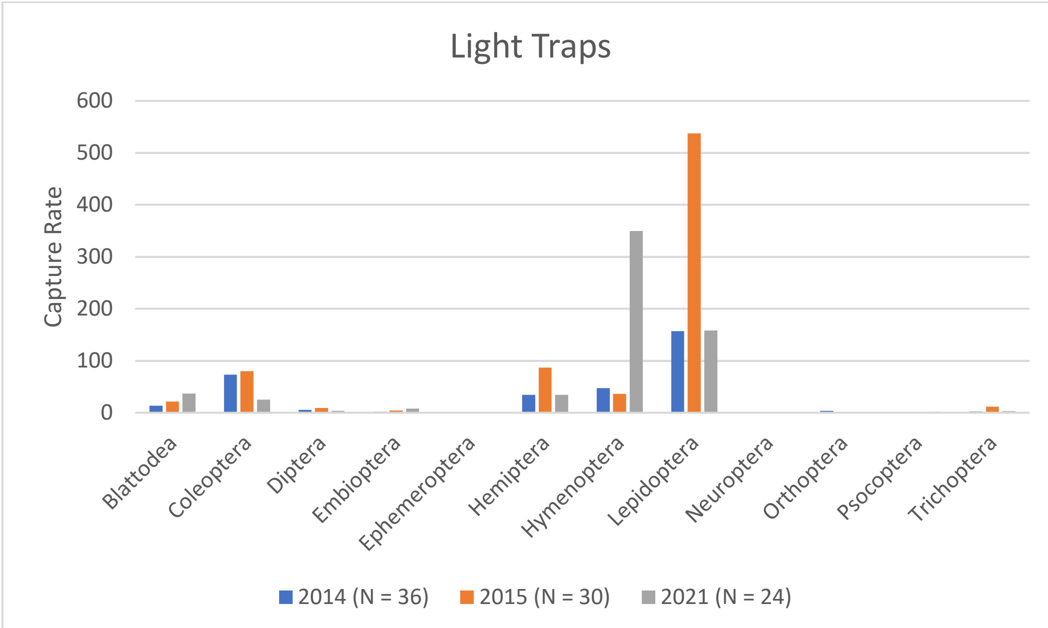

Figure 10. Capture Rate for Light Traps by Year per Order

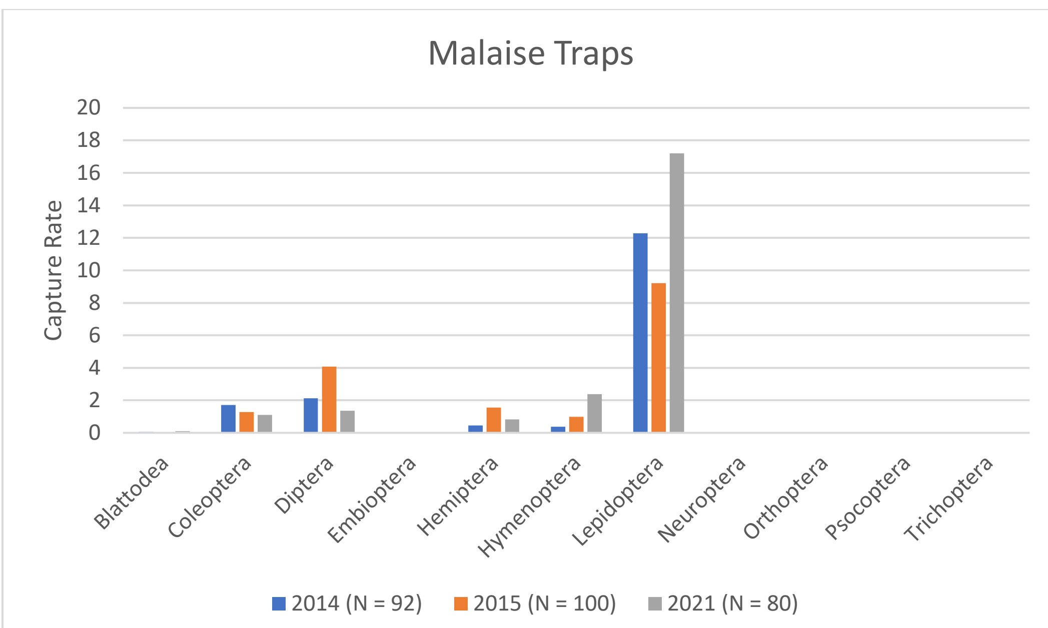

Figure 11. Capture Rate for Malaise Traps by Year per Order.

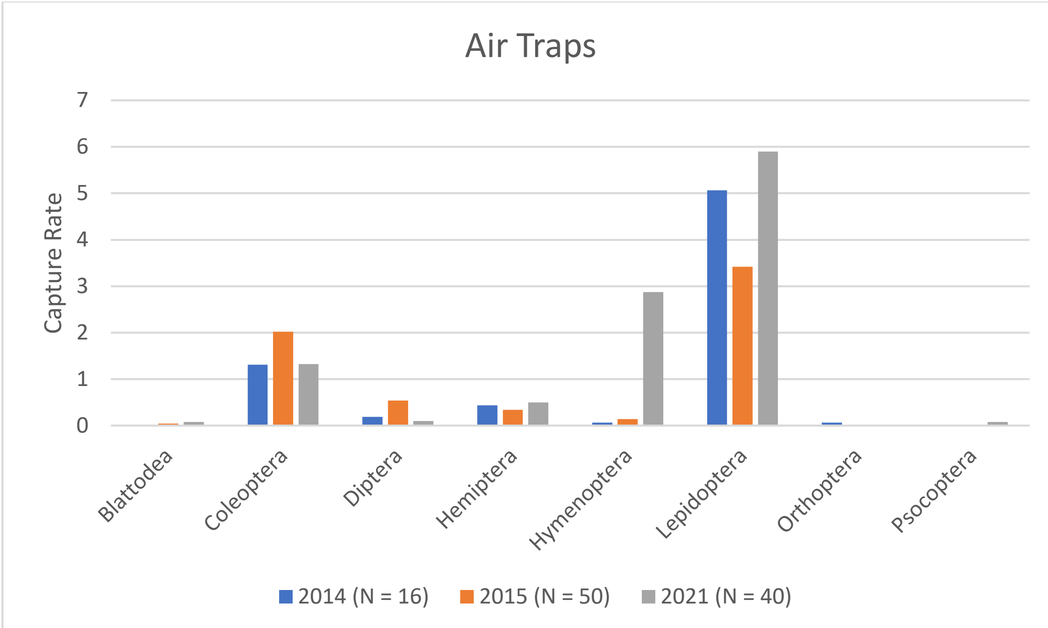

Figure 12. Capture Rate for Air Intercept Traps by Year per Order

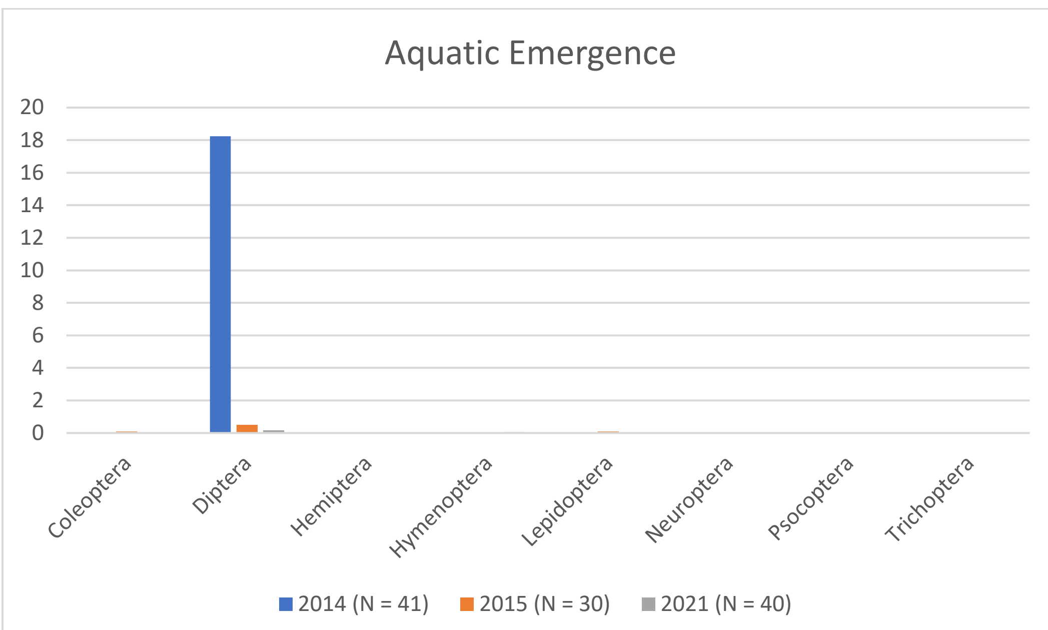

Figure 13. Capture Rate for Aquatic Emergence Traps by Year per Order

5.0 Discussion

This insect assessment fulfills the insect monitoring obligation outlined in the Kawailoa Wind HCP for Tier 1 mitigation for the Hawaiian hoary bat. This study used four trap types to sample insects throughout ʻUkoʻa Wetland in three different years to assess prey availability for the Hawaiian hoary bat. While this study provides insight into the potential prey types and amounts available to Hawaiian hoary bats at ʻUkoʻa Wetland, comparative and statistical data analysis is not appropriate due to limitations in the original study design, changes in site management activities, and differences in trap locations and trap nights across sampling years. Between-year comparisons (mostly measured by capture rates) demonstrate that the types and abundance of available insect prey changed throughout the study; however, results from this study have not been tested for statistical significance. Removal of invasive water hyacinth in the open water area and removal of non-native trees and grasses within the bat lanes at ʻUkoʻa Wetland in 2017 could have influenced prey availability during this study. However, it is not possible to attribute any observed changes in insect prey availability between years to the management activities due to unrelated, naturally occurring interannual variation in insect populations and the original study design.

Hawaiian hoary bats are considered feeding generalists, but Lepidoptera (moths) and Coleoptera (beetles) are considered the most important prey for the Hawaiian hoary bat (Jacobs 1999, Todd 2012, Pinzari et al. 2019, DLNR 2021). The results of this study show that Lepidoptera and Coleoptera are present at ʻUkoʻa Wetland. Overall, Lepidoptera may be more abundant at ʻUkoʻa Wetland compared to other insects, with a total of 29,482 moths collected over the study. Other insects that are known to be consumed by the Hawaiian hoary bat, such as Diptera (flies) and Blattodea (termites) (Jacobs 1999, Todd 2012, Pinzari et al. 2019) are also present at ʻUkoʻa Wetland.

This study also found that light traps were the most effective at collecting insects at ʻUkoʻa Wetland. This result is not surprising given that light traps actively draw insects into the traps. Light traps were particularly effective at collecting Lepidopterans compared to other trap types. In contrast, aquatic emergence traps generally had the lowest capture rates of all trap types.

Acoustic detectors at ʻUkoʻa Wetland have documented year-round use of the area by Hawaiian hoary bats. Insect sampling coincided with the Hawaiian hoary bat lactation and early post-lactation reproductive periods, when elevated detection rates have been detected at ʻUkoʻa Wetland compared to other times of the year (Tetra Tech 2022). Feeding buzzes have also been recorded at every detector location throughout ʻUkoʻa Wetland. Additional dietary studies would be needed to determine what prey items are being consumed by Hawaiian hoary bats at ʻUkoʻa Wetland, but since known and potential Hawaiian hoary bat prey is present and feeding buzzes have been recorded, it is assumed that ʻUkoʻa Wetland is providing foraging habitat for the Hawaiian hoary bat.

6.0 Literature Cited

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.L. Chen, P.S. Chu, J.K. Eischeid, and D.M. Delparte. 2013. Online Rainfall Atlas of Hawai‘i. Bull. Amer. Meteor. Soc. 94, 313–316, doi: 10.1175/BAMS-D-11-00228.1. Available at: http://rainfall.geography.hawaii.edu/. Accessed March 2022.

Gorresen, P.M., K.W. Brinck, M.A. DeLisle, K. Montoya-Aiona, C.A. Pinzari, and F.J. Bonaccorso. 2018. Multi-state occupancy models of foraging habitat use by the Hawaiian hoary bat (*Lasiurus cinereus semotus*). PLoS ONE 13(10): e0205150. https://doi.org/10.1371/journal.pone.0205150.

Griffin, D.R., F.A. Webster, and C.R. Michael. 1960. The echolocation of flying insects by bats. Animal Behavior 8:141-154.

H.T. Harvey and SWCA (H. T. Harvey and Associates and SWCA Environmental Consultants). 2014. ‘Uko‘a Wetland Hawaiian Hoary Bat Mitigation Management Plan. Prepared for First Wind. Approved by USFWS and DOFAW 2014.

Jacobs, D.S. 1999. The diet of the insectivorous Hawaiian hoary bat (*Lasiurus cinereus semotus*) in an open and a cluttered habitat. *Canadian Journal of Zoology*, *77*(10), 1603–1608. https://doi.org/10.1139/z99-110.

Miller, J.N., S.S. Armann, S.S.C. Chan-Hui, and J. Chiang. 1989. Ecologically sensitive wetlands on Oahu: groundwater protection strategy for Hawai‘i. Environmental Center Water Resources Research Center, University of Hawai‘i at Mānoa.

NRCS. 2022. NRCS National Water and Climate Center Monthly Total Precipitation for Waimea Valley. Available at: https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/agAcisClimateData/. Accessed November 2022.

Parham, J.E., G.R. Higashi, E.K. Lapp, D.G. K. Kuamoo, R.T. Nishimoto, S. Hau, J.M. Fitzsimons, D.A. Polhemus, and W.S. Devick. 2008. Atlas of Hawaiian Watersheds & Their Aquatic Resources. Copyrighted website published by the Hawaii Division of Aquatic Resources, Department of Land and Natural Resources. Available at: www.hawaiiwatershedatlas.com. Accessed June 7, 2022.

Pinzari, C.R,. T. Peck, D. Zinn, D. Gross, K. Montoya-Aiona, K.W. Brinck, P.M. Gorresen, and F.J. Bonaccorso. 2019. Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) activity, diet, and prey availability at the Waihou Mitigation Area, Maui. Hawaii Cooperative Studies Unit Technical Report HCSU-090.

Price, J.P., Jacobi, J.D., Gon, S.M., III, Matsuwaki, D., Mehrhoff, L., Wagner, W., Lucas, M., and Rowe, B., 2012. Mapping plant species ranges in the Hawaiian Islands—Developing a methodology and associated GIS layers: U.S. Geological Survey Open-File Report 2012–1192, 34 p. Available at http://pubs.usgs.gov/of/2012/1192/.

SWCA (SWCA Environmental Consultants). 2011. Kawailoa Wind Power Habitat Conservation Plan. Prepared for Kawailoa Wind Power. Dated October 2011.

SWCA. 2012. ‘Uko‘a Wetland Management Plan for Waterbirds 2012 – 2032. Prepared for First Wind. Approved by USFWS and DOFAW 2012.

Tetra Tech. 2021. Kawailoa Wind Power Habitat Conservation Plan, FY 2021 Annual Report.

Tetra Tech. 2022. Kawailoa Wind Power Habitat Conservation Plan, FY 2022 Annual Report.

Todd, C.M. 2012. Effects of prey abundance on seasonal movements of the Hawaiian hoary bat *(Lasiurus cinereus semotus)*. University of Hawai’i at Hilo.

WHALE (WHALE Environmental Services, LLC). 2010. ‘Uko‘a Wetlands Management Plan. Prepared for Pono Pacific and the Kamehameha Schools.

APPENDIX A

PHOTOGRAPHS OF THE INSECT TRAP LOCATIONS AT ‘UKO‘A WETLAND

Photo 1. Trap “Wet1”, a Townes-style Malaise Trap in wetland habitat in 2014 (top photo) and 2021 (bottom photo). Note: This trap was re-sited in 2021 (roughly 290 meters from the 2014/2015 location) due to a change in vegetation at the original trap location.

Photo 2. Trap “Wet2”, a Townes-style Malaise Trap in wetland habitat in 2014 (top photo) and 2021 (bottom photo). Note: This trap was re-sited in 2021 (roughly 220 meters from the 2014/2015 location) to a new location with same habitat type as the 2014/2015 location.

Photo 3. Trap "Up10", a Townes-style Malaise Trap in upland habitat in 2014 (top) and 2021 (bottom). Note: This trap was re-sited in 2021 (roughly 14 meters) because the 2014/2015 location was within private property.

Photo 4. Trap "UpDOT", a Townes-style Malaise Trap in upland habitat in 2014 (top) and 2021 (bottom).

Photo 5. Trap “WaterKayak”, an Aquatic Emergence Trap in open water habitat in 2014 (top) and 2021 (bottom). Note: Water hyacinth removed from open water in January 2017.

Photo 6. Trap “WaterRoad”, an Aquatic Emergence Trap in 2014 (top) and 2021 (bottom). This trap was re-sited in 2021 to a new location due to lack of consistent surface water at the 2014/2015 site.

Photo 7. Trap "Light9", a Universal Black Light Trap in upland habitat in 2014 (top) and 2021 (bottom).

Photo 8. Trap "Light12", a Universal Black Light Trap in upland habitat in 2014 (top) and 2021 (bottom).

Photo 9. Trap "Air12", an Air Intercept Trap in upland habitat in 2014 (top) and 2021 (bottom).

Photo 10. Trap “AirDOT”, an Air Intercept Trap in upland habitat in 2014 (top) and 2021 (bottom).

APPENDIX B

LIST AND COUNTS OF ALL INSECT TAXA COLLECTED AT ‘UKO‘A WETLAND IN 2014, 2015, AND 2021 (INCLUDING NON-PREY TAXA)

Table B-1. Insect Taxa Counts by Year

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
Blattodea (Termites)						
Blaberidae	*Pycnoscelus indicus*	No	179	145	22	346
Blatellidae		No	46	37	28	111
	Balta notulata	*No*	*8*	*4*	*0*	
	Balta sp.	*No*	*0*	*0*	*4*	
	Blatella sp.	*No*	*38*	*33*	*0*	
	Blattella germanica	*No*	*0*	*0*	*24*	
Blattidae		No	72	23	3	98
	Periplaneta sp.	*No*	*36*	*13*	*0*	
	Platyzosteria soror	*No*	*36*	*10*	*3*	
Kalotermitidae		Yes	500	649	768	1,917
	Incisitermes immigrans	*Yes*	*500*	*649*	*760*	
	Cryptotermes brevis	*Yes*	*0*	*0*	*8*	
Rhinotermitidae	*Coptotermes* sp.	Yes	0	0	131	131
Coleoptera (Beetles)						
Anobiidae	Unknown	Yes	0	0	11	11
Anthribidae		Yes	0	0	9	9
	Araeocerus sp.	*Yes*	*0*	*0*	*4*	
Bostrichidae	Unknown	Yes	123	170	104	397
Bruchidae	Unknown	No	6	0	3	9
Cantharidae	*Caccodes oceaniae*	Yes	0	0	3	3
Carabidae	Unknown	Yes	0	4	83	87
Cerambycidae	Unknown	Yes	72	67	32	171

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
Chrysomelidae	Unknown	Yes	0	1	0	1
Cleridae	Unknown	Yes	0	0	1	1
Coccinellidae	Unknown	No	9	14	7	30
Cupedidae	Unknown	Yes	0	1	0	1
Curculionidae		Yes	192	397	23	612
	Crossotarsus externedentatus	*Yes*	*0*	*0*	*3*	
Dermestidae	Unknown	Yes	0	0	3	3
Dytiscidae	Unknown	No	0	0	3	3
Elateridae		Yes	1,469	1,264	207	2,940
	Conoderus exsul	*Yes*	*0*	*0*	*180*	
Helodidae	Unknown	No	1,384	587		1,971
Hydrophilidae		No	12	169	45	226
	Dactylosternum abdominale	*No*	*0*	*0*	*3*	
Nitidulidae		Yes	627	184	153	964
	Phenolia limbata	*Yes*	*601*	*182*	*0*	
	Phenolia limbata tibialis	*Yes*	*0*	*0*	*153*	
Oedemeridae		Yes	63	24	1	88
	Thelyphassa apicala	*Yes*	*0*	*0*	*1*	
Scarabaeidae		Yes	279	529	33	841
	Ataenius puncticollis	*Yes*	*0*	*0*	*22*	
Scirtidae	*Scirtes* sp.	*Yes*	*0*	*0*	*58*	*58*
Silvanidae	Unknown	Yes	0	0	8	8
Staphylinidae	Unknown	No	71	90	99	260
Tenebrionidae		No	2,513	676	4	3,193
	Eutochia lateralis	*No*	*0*	*0*	*1*	

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
	Uloma sp.	*No*	*0*	*0*	*1*	
Trogidae	*Trox suberosus*	Yes	0	0	13	13
Trogossitidae	*Tenebroides nanus*	Yes	0	0	1	1
Zopheridae	*Colobicus parilis*	Yes	0	0	3	3
Dermaptera (Earwigs)						
Labiduridae	*Labidura riparia*	No	0	0	2	2
Labiidae	Unknown	No	0	0	1	1
Unknown	Unknown	No	203	28		231
Diptera (Flies)						
Asilidae	*Leptopteromyia mexicanae*	No	0	0	2	2
Calliphoridae	Unknown	Yes	54	46	9	109
Ceratopogonidae	Unknown	No	0	0	1	1
Chironomidae	Unknown	Yes	802	65	71	938
Culicidae	Unknown	Yes	3	14	6	23
Dolichopodidae	Unknown	No	16	18	10	44
Drosophilidae		Yes	1	0	13	14
	Drosophila sp.	*Yes*	*0*	*0*	*12*	
Lauxaniidae	Unknown	Yes	1	10	0	11
Limoniidae		Yes	243	282	0	525
	Dicranomyia sp.	*Yes*	*74*	*74*	*0*	
	Erioptera sp.	*Yes*	*16*	*5*	*0*	
	Styringomyia sp.	*Yes*	*151*	*203*	*0*	
Micropezidae	*Taeniaptera angulata*	Yes	0	0	1	1
Muscidae		Yes	39	87	18	144
	Lispocephala sp.	*Yes*	*1*	*0*	*0*	

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
Otitidae		Yes	0	2	4	6
	Euxesta annonae	*Yes*	*0*	*0*	*4*	
Sarcophagidae	Unknown	Yes	1	3	7	11
Scenopinidae	Unknown	Yes	0	2	3	5
Sciaridae	Unknown	Yes	0	216	7	223
Stratiomyidae		Yes	2	1	**0**	**3**
	Hermetia illucens	*Yes*	*0*	*1*	*0*	
Syrphidae		No	3	14	5	22
	Allograpta sp.	*No*	*1*	*12*	*0*	
	Volucella sp.	*No*	*2*	*0*	*0*	
Tachinidae	Unknown	Yes	0	1	3	4
Tephritidae	Unknown	Yes	0	0	3	3
Tipulidae	Unknown	Yes	0	0	58	58
Embioptera (Webspinners)						
Oligotomidae	Unknown	Yes	72	127	194	393
Ephemeroptera (Mayflies)						
Caenidae	Unknown	Yes	0	0	13	13
Hemiptera (True Bugs)						
Cercopidae	Unknown	Yes	0	0	6	6
Cicadellidae	Unknown	Yes	83	137	33	253
Cydnidae		Yes	720	1,457	351	2,528
	Geotomus pygmaeus	*Yes*	*0*	*0*	*285*	
Delphacidae	Unknown	Yes	0	0	9	9
Derbidae	*Cedusa* sp.	Yes	0	0	20	20
Flatidae		Yes	328	1,037	355	1,720

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
	Melormenis basalis	*Yes*	*0*	*0*	*355*	
Lygaeidae		Yes	79	101	6	186
	Nysius sp.	*Yes*	*8*	*0*	*0*	
	Remaudiereana sp.	*Yes*	*71*	*95*	*0*	
Membracidae	Unknown	Yes	25	9	0	34
Miridae	Unknown	Yes	0	0	106	106
Nabidae	Unknown	Yes	13	6	8	27
Notonectidae	Unknown	No	3	4	1	8
Pentatomidae		Yes	0	2	1	3
	Plautia stali	*Yes*	*0*	*2*	*0*	
Psyllidae	Unknown	Yes	0	0	2	2
Reduviidae	Unknown	Yes	29	0	0	29
Rhyparochromidae	Unknown	Yes	0	0	7	7
Tropiduchidae		Yes	1	26	6	33
	Kallitaxila granulata	*Yes*	*0*	*0*	*6*	
Hymenoptera (Ants, Wasps)						
Apidae		No	1	3	4	8
	Apis sp.	*No*	*1*	*3*	*0*	
	Apis mellifera	*No*	*0*	*0*	*4*	
Braconidae	Unknown	Yes	3	3	286	292
Chalcidoidea	Unknown	Yes	0	0	24	24
Eupelmidae	Unknown	Yes	0	0	1	1
Formicidae		Yes	1,721	1,126	8,372	11,219
	Camponotus alate	*Yes*	*186*	*50*	*0*	
	Camponotus variegatus	*Yes*	*0*	*0*	*13*	

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
	Myrmecine alate	*Yes*	*1,261*	*603*	*0*	
	Pheidole megacephala majors	*Yes*	*0*	*0*	*14*	
Halictidae	*Lasioglossum* sp.	No	3	11	1	15
Ichneumonidae	Unknown	Yes	21	68	21	110
Lepidoptera (Moths)						
Cosmopterigidae	*Hyposmocoma* sp.	Yes	0	0	3	3
Crambidae	Unknown	Yes	82	235	15	332
Euteliidae	Unknown	Yes	0	0	1	1
Gelechioidea	Unknown	Yes	2,709	1,987	3,845	8,541
Geometridae		Yes	2,448	11,404	185	14,037
	Macaria abydata	*Yes*	*2,413*	*11,063*	*141*	
Limacodidae	*Darna pallivitta*	Yes	0	0	78	78
Noctuidae	Unknown	Yes	65	73	41	179
Pterophoridae	Unknown	Yes	4	0	44	48
Pyralidae	Unknown	Yes	0	0	51	51
Tineidae		Yes	265	871	45	1,181
	Opogona sp.	*Yes*	*265*	*871*	0	
Tortricidae	Unknown	Yes	1,285	2,636	1,095	5,016
Unknown ("long palpi”)	Unknown	Yes	10	5	0	15
Unknown (“immature”)	Unknown	No	0	0	11	11
Neuroptera (Lacewing)						
Chrysopidae	Unknown	Yes	0	1	0	1
Hemerobiidae	Unknown	Yes	1	1	2	4

Family	Genus or Species	HHB Prey[1]	2014 Total	2015 Total	2021 Total	Grand Total
Odonata (Dragonflies)						
Aeschnidae	*Anax* sp.	No	3	0	0	3
Coenagrionidae		No	8	7	2	17
	Enallagma civile	*No*	*8*	*7*	*0*	
	Ishnura ramburii	*No*	*0*	*0*	*2*	
Orthoptera (Katydids)						
Acrididae	Unknown	Yes	0	2	0	2
Gryllidae	Unknown	Yes	117	10	12	139
Tettigoniidae	Unknown	Yes	10	15	1	26
Polyxenida (Millipedes)						
Polyxenidae	*Polyxenus* sp.	No	0	0	42	42
Psocoptera (Barkflies)						
Ellipsocidae	Unknown	Yes	0	0	1	1
Lepidopsocidae	Unknown	Yes	0	0	1	1
Psocidae		Yes	0	0	46	46
	Ptycta sp.	*Yes*	*0*	*0*	*37*	
Spirobolida (Millipedes)						
Spirobolidae	*Spirobolellus* sp.	No	0	0	1	1
Trichoptera (Caddisflies)						
Hydropsychidae	*Cheumatopsyche pettiti*	Yes	0	0	69	69
Hydroptilidae	Unknown	Yes	88	350	0	438
Grand Total			**19,182**	**27,534**	**17,501**	**64,217**

1. Insects were classified as “known prey” if they were previously identified in the diet of Hawaiian hoary bats and classified as “potential bat prey” if they were available to bats (i.e., nocturnal, capable of sustained flight and between 3-24 millimeters in size). All analyses in this report refer only to the insect taxa labeled “yes” in this column.
2. Grand totals are only calculated for the highest level taxa for each family.

APPENDIX C

TOTAL COUNTS AND SIZE RANGES OF INSECT PREY TAXA COLLECTED AT 'UKO'A WETLAND

Table C-1. Insect Prey Taxa Counts and Size Ranges Across all Sampling Years

Family	Genus or Species	Total Count (2014, 2015, 2021)	Size Range (millimeters)
Blattodea (Termites)			
Kalotermitidae	All	1,917	5-7
	Incisitermes immigrans	*1,909*	*5-7*
	Cryptotermes brevis	*8*	*6-7*
Rhinotermitidae	*Coptotermes* sp.	131	6-7
Coleoptera (Beetles)			
Anobiidae	All (Unknown)	11	3-5
Anthribidae	All	9	3-5
	Araeocerus sp.	*4*	*4-5*
	Unknown	*5*	*3-4*
Bostrichidae	All (Unknown)	397	5.9-13
Cantharidae	*Caccodes oceaniae*	3	3.5
Carabidae	All (Unknown)	87	3-10
Cerambycidae	All (Unknown)	171	5.8-25
Chrysomelidae	All (Unknown)	1	4
Cleridae	All (Unknown)	1	14
Cupedidae	All (Unknown)	1	4.1
Curculionidae	All	612	3-11.8
	Crossotarsus externedentatus	*3*	4.5
	Unknown	*609*	3-11.8
Dermestidae	All (Unknown)	3	3
Elateridae	All	2,940	6-15.4
	Conoderus exsul	*180*	9-12
	Unknown	*2,760*	6-15.4
Nitidulidae	All	964	4.4-7
	Phenolia limbata	783	5.6-6.5
	Phenolia limbata tibialis	*151*	7
	Unknown	*30*	4.4-6.8
Oedemeridae	All	88	8.1-12
	Thelyphassa apicala	1	12
	Unknown	87	8.1-8.9
Scarabaeidae	All	841	3-17
	Ataenius puncticollis	22	3-4
	Unknown	819	4.1-17
Scirtidae	*Scirtes* sp.	58	3.5-4

Family	Genus or Species	Total Count (2014, 2015, 2021)	Size Range (millimeters)
Silvanidae	All (Unknown)	8	3
Trogidae	*Trox suberosus*	13	14
Trogossitidae	*Tenebroides nanus*	1	8
Zopheridae	*Colobicus parilis*	3	3.5
Diptera (Flies)			
Calliphoridae	All (Unknown)	109	7.4-9
Chironomidae	All (Unknown)	938	3.4-7
Culicidae	All (Unknown)	23	3.7-4.3
Drosophilidae	All	14	3-5
	Drosophila sp.	12	3-4
	Unknown	2	3.6-5
Lauxaniidae	All (Unknown)	11	3.6-4
Limoniidae	All	525	3.7-7.1
	Dicranomyia sp.	*148*	4-4.9
	Erioptera sp.	*21*	3.7-4.4
	Styringomyia sp.	*354*	4.6-5.6
	Unknown	*2*	5.9-7.1
Micropezidae	*Taeniaptera angulata*	1	9
Muscidae	All	144	4-6.7
	Lispocephala sp.	*1*	6.1
	Unknown	*143*	4-6.7
Otitidae	All	6	4.3-5
	Euxesta annonae	*4*	5
	Unknown	*2*	4.3
Sarcophagidae	All (Unknown)	11	4-9.2
Scenopinidae	All (Unknown)	5	4-5
Sciaridae	All (Unknown)	223	3-4.4
Stratiomyidae	All	3	9.9-14.8
	Hermetia illucens	*1*	14.8
	Unknown	*2*	9.9
Tachinidae	All (Unknown)	4	6-13.2
Tephritidae	All (Unknown)	3	4
Tipulidae	All (Unknown)	58	4-9
Embioptera (Webspinners)			
Oligotomidae	All (Unknown)	393	5.2-8
Ephemeroptera (Mayflies)			
Caenidae	All (Unknown)	13	4

Family	Genus or Species	Total Count (2014, 2015, 2021)	Size Range (millimeters)
Hemiptera (True Bugs)			
Cercopidae	All (Unknown)	6	3-3.5
Cicadellidae	All (Unknown)	253	3-11
Cydnidae	All	2,528	3.7-7.5
	Geotomus pygmaeus	285	4
	Unknown	2,243	3.7-7.5
Delphacidae	All (Unknown)	9	3-5
Derbidae	*Cedusa* sp.	20	3-4
Flatidae	All	1,720	4-6
	Melormenis basalis	355	6
	Unknown	1,365	4-4.9
Lygaeidae	All	186	3.8-6.8
	Nysius sp.	8	3.8-4
	Remaudiereana sp.	166	5-5.6
	Unknown	12	5.9-6.8
Membracidae	All (Unknown)	34	3.7-4.1
Miridae	All (Unknown)	106	4-6
Nabidae	All (Unknown)	27	6.7-8.5
Pentatomidae	All	3	9.6-17
	Plautia stali	2	9.6
	Unknown	1	17
Psyllidae	All (Unknown)	2	3
Reduviidae	All (Unknown)	29	9.6
Rhyparochromidae	All (Unknown)	7	5
Tropiduchidae	All	33	3.6-6
	Kallitaxila granulata	*6*	6
	Unknown	*27*	3.6-4.4
Hymenoptera (Ants, Wasps)			
Braconidae	All (Unknown)	292	3-4.4
Chalcidoidea	All (Unknown)	24	3-4
Eupelmidae	All (Unknown)	1	4
Formicidae	All	11,219	3.5-11.2
	Camponotus alate	236	10.2-11.2
	Camponotus variegatus	13	6-8
	Myrmecine alate	1,864	6.7-7.1
	Pheidole megacephala majors	14	3.5
	Unknown	9,092	4-7

Family	Genus or Species	Total Count (2014, 2015, 2021)	Size Range (millimeters)
Ichneumonidae	All (Unknown)	110	4-8.6
Lepidoptera (Moths)			
Cosmopterigidae	*Hyposmocoma* sp.	3	4-5
Crambidae	All (Unknown)	332	5.6-13
Euteliidae	All (Unknown)	1	15
Gelechioidea	All (Unknown)	8,541	3-11
Geometridae	All	14,037	6-22
	Macaria abydata	13,617	6-13
	Unknown	420	6-22
Limacodidae	*Darna pallivitta*	78	8
Noctuidae	All (Unknown)	179	11-25
Pterophoridae	All (Unknown)	48	6-6.7
Pyralidae	All (Unknown)	51	5-11
Tineidae	All	1,181	5.5-15
	Opogona sp.	1,136	5.6-8.9
	Unknown	45	5.5-15
Tortricidae	All (Unknown)	5,016	4.6-10
Unknown	All (Unknown)	15	4.9-5
Neuroptera (Lacewing)			
Chrysopidae	All (Unknown)	1	7.3
Hemerobiidae	All (Unknown)	4	4.9-9
Odonata (Dragonflies)			
Acrididae	All (Unknown)	2	21.3-25
Gryllidae	All (Unknown)	139	5-20
Tettigoniidae	All (Unknown)	26	7-15.5
Psocoptera (Barkflies)			
Ellipsocidae	All (Unknown)	1	3
Lepidopsocidae	All (Unknown)	1	4
Psocidae	All	46	3-4
	Ptycta sp.	37	3-4
	Unknown	9	3-4
Trichoptera (Caddisflies)			
Hydropsychidae	*Cheumatopsyche pettiti*	69	7-8
Hydroptilidae	All (Unknown)	438	3.9-5.3