

# **Kahuku Wind Power Habitat Conservation Plan FY 2025 Annual Report**



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**Incidental Take License ITL-10/ BO#2010-F-0190**

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## Executive Summary

This report summarizes work performed by Kahuku Wind Power, LLC (KAH) at the Kahuku Wind Power Project (Project) during the State of Hawai'i fiscal year (FY) 2025 (July 1, 2024 – June 30, 2025) under the terms of the approved Habitat Conservation Plan (HCP). The HCP is dated May 27, 2010, and describes KAH's compliance obligations under KAH's state Incidental Take License (ITL) ITL-10 and federal Incidental Take Statement (ITS) Biological Opinion (BO) 2010-F-0190. The HCP covers eight species: seven are federally and state-listed as threatened or endangered and one is exclusively a state-listed endangered species. The Project was constructed in 2010 and has been operating since March 23, 2011.

Wildlife fatality monitoring at the Project continued in FY 2025 within the 35-meter radius circular search plots centered on the wind turbine generators (WTGs). Plots were searched by canine-handler teams once per week, year-round. Bias correction trials were conducted quarterly to measure the probability that a carcass persists until the next search (carcass persistence) and the probability that an available carcass would be found (searcher efficiency). The results of these trials showed mean probabilities of persistence until the next search of 0.62 (bat surrogates) and 1.00 (medium-sized bird surrogates). Searcher efficiency was 0.86 for bat surrogates and 1.00 for medium bird surrogates.

Two 'ōpe'ape'a fatalities were found in FY 2025. A total of 12 bat fatalities have been observed as direct take at the Project since beginning operations on March 23, 2011. The cumulative fatality estimate using the Evidence of Absence estimator at the upper 80 percent credibility level is 24 bats, and the total indirect take for this estimate is 3 adult equivalents. Combining these values, there is an approximately 80 percent chance that cumulative take of the 'ōpe'ape'a from the start of operations through FY 2025 was less than or equal to 27 adults. KAH understands that take through FY 2025 has exceeded the permitted/authorized amount and the Project has initiated the development of an amendment to the state HCP and a new federal HCP, as well as the adaptive management action of acoustic bat deterrent installation and thermal camera monitoring in FY 2025. No fatalities of Covered Species other than 'ōpe'ape'a have been observed at the Project to date.

During FY 2025, KAH continued to monitor bat activity at the Project through four ground-based acoustic detectors located near Project WTGs. Between June 1, 2024 and May 31, 2025, the 'ōpe'ape'a were detected on 119 out of 1,386 detector nights (8.6 percent of detector-nights) using the SM4BAT-FS with SMM-U2 microphone. Activity levels and seasonal patterns of detection rate were comparable with previous years.

Mitigation obligations for baseline levels of take (Tier 1) of waterbirds, seabirds, the pueo and 'ōpe'ape'a were met prior to FY 2025. Implementation of mitigation for Higher Take (Tier 2) for the 'ōpe'ape'a commenced in FY 2025 and included the development of an Implementation Plan, continuing efforts to secure permitting and compliance for mitigation actions, creating additional bat foraging corridors by clearing vegetation and re-clearing vegetation within pre-existing bat

foraging corridors, and maintaining vegetation within the cleared corridors; 'ōpe'ape'a activity and insect composition/biomass baseline monitoring finished in July 2024 prior to the commencement of implementing mitigation activities.

KAH continued to communicate actively with USFWS and DOFAW throughout FY 2025 through the establishment of biweekly conference calls, submittal of quarterly reports, and e-mail communications related to the Project's HCP and associated mitigation. Communications included submittal of the final Tier 2 Mitigation Implementation Plan, as well as a preliminary HCP amendment concept document to address higher than anticipated take of 'ōpe'ape'a.

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## 1.0 Introduction

The Habitat Conservation Plan (HCP) for the Kahuku Wind Project (Project) was approved by the Hawai'i Division of Forestry and Wildlife (DOFAW) in 2010. Kahuku Wind Power, LLC (KAH) received a federal Biological Opinion (BO 2010-F-0190) and associated Incidental Take Statement (ITS) from the U.S. Fish and Wildlife Service (USFWS), and a state Incidental Take License (ITL; ITL-10) from DOFAW in May and June of 2010, respectively. The ITS and ITL cover the incidental take of eight species: seven federal and state-listed threatened or endangered species, and one exclusively state-listed endangered species (collectively referred to as the Covered Species) over a 20-year permit term.

The Covered Species include:

- 'Ōpe'ape'a (Hawaiian hoary bat; *Lasiurus semotus*);
- Ae'o (Hawaiian stilt; *Himantopus mexicanus knudseni*);
- 'Alae ke'oke'o (Hawaiian coot; *Fulica alai*);
- Koloa maoli (Hawaiian duck; *Anas wyvilliana*);
- 'Alae 'ula (Hawaiian common gallinule; *Gallinula galeata sandvicensis*);
- 'Ua'u (Hawaiian petrel; *Pterodroma sandwichensis*);
- 'A'o (Newell's shearwater; *Puffinus newelli*); and
- Pueo (Hawaiian short-eared owl; *Asio flammeus sandwichensis*); state-listed only.

The Project was constructed in 2010 and 2011 and commissioned for operation on March 23, 2011. The Project continues to be operated by KAH.

KAH and Tetra Tech, Inc (Tetra Tech) have collaborated to prepare this HCP annual report which describes work performed for the Project during the 2025 fiscal year for the State of Hawai'i (FY; July 1, 2024 – June 30, 2025) pursuant to the terms and obligations of the approved HCP, ITL, and ITS. Kahuku Wind submitted previous annual HCP progress reports for FY 2011 through FY 2023 to USFWS and DOFAW (Kahuku Wind 2011, Kahuku Wind 2012, Kahuku Wind 2013, Kahuku Wind 2014, Kahuku Wind 2015, Kahuku Wind 2016, Kahuku Wind 2017, Kahuku Wind 2018, Tetra Tech 2019, Tetra Tech 2020, Tetra Tech 2021, Tetra Tech 2022a, Tetra Tech 2023, Tetra Tech 2024a).

## 2.0 Fatality Monitoring

In consultation with USFWS, DOFAW, and the Endangered Species Recovery Committee (ESRC), fatality search areas and search frequency have evolved over time from the start of operations in 2011 through the initiation of the current approach in April 2015. Below is a summary of how fatality monitoring has evolved over time:

- In March 2011, the wildlife fatality monitoring effort involved twice weekly searches within a 64-meter circular radius monitoring plot centered on each WTG in addition to searches every other week within a larger 96-meter radius plot.
- In September 2014, the 96-meter radius plot searches every other week were suspended, but searches within the 64-meter radius plots continued twice weekly.
- In December 2014, plots were reduced in size to the current 35-meter radius (Figure 1). Search frequency was monthly from December 2014 through March 2015.
- In April 2015, the search frequency of the 35-meter radius plots was increased to a weekly interval. This search area and frequency has continued to be used for monitoring through FY 2025.

Weekly searches of the 35-meter radius plots (search area) were completed throughout FY 2025 for a total of 52 weekly searches. The plots were searched by trained detector dogs and their handlers (canine search teams). Weekly searches generally occur over 2 consecutive days, with searches conducted at six of the 12 WTGs on each day. The mean search interval achieved in FY 2025 was 6.91 days with a standard deviation of 0.6 days. All searches in FY 2025 were conducted by canine teams; should conditions have prevented the use of dogs (e.g., weather, injury, availability of canine search team, etc.), a qualified biologist would conduct transect-based visual searches within the search plots as a substitute.

Two individuals of one Covered Species, the 'ōpe'ape'a, were detected during fatality searches in FY 2025 (see Section 7.1). Other species fatalities are reported in Section 7.2, and no fatalities of other Covered Species have been observed at the Project since the start of operations.

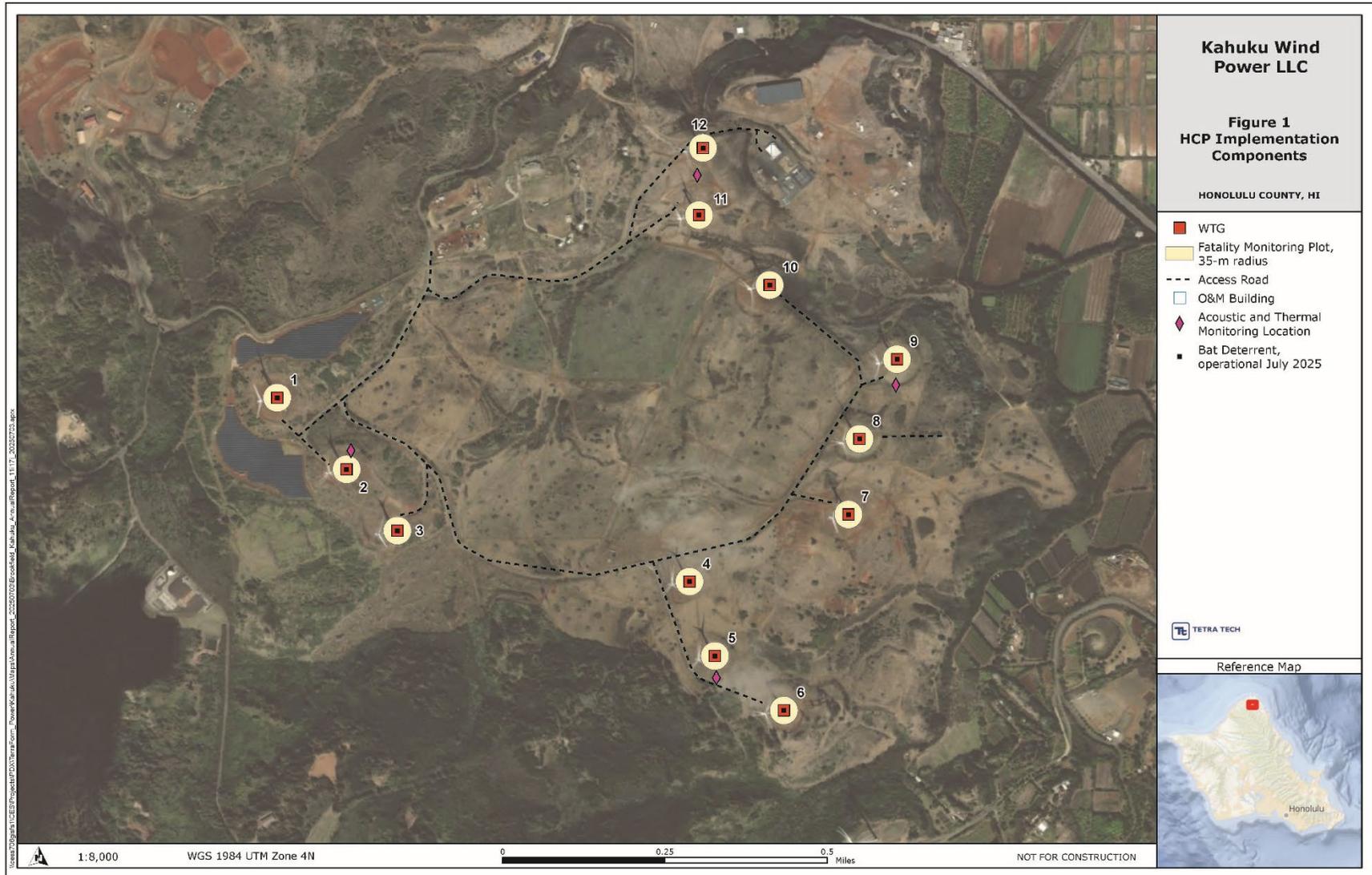


Figure 1. HCP Implementation Monitoring Locations

### 3.0 Carcass Persistence Trials

A 28-day carcass persistence trial was conducted in each quarter of FY 2025 for a total of four trials. These trials used carcasses of black rats (*Rattus rattus*) as surrogates for the 'ōpe'ape'a. Wedge-tailed shearwaters (*Ardenna pacifica*; obtained under the Project's Special Purpose Utility Permit [PER4839383<sup>1</sup>] and Protected Wildlife Permits [231228115819-WILD and 250122122859-WILD]) were used to represent medium-sized birds (surrogates for all avian Covered Species; see Section 1.0). In FY 2025, the mean probability that a bat surrogate carcass persisted until the next search was 0.62 (95 percent Confidence Interval [CI] = 0.5, 0.73; n=24). This represents an increase from the 0.55 reported in FY 2024 and was supported by the use of game cameras and trap protection from cattle. For medium-sized bird carcasses, the mean probability of persisting until the next search was 0.99 (95 percent CI = 0.93, 1.00; n=8).

### 4.0 Searcher Efficiency Trials

Searcher efficiency trials occurred throughout the year to test wildlife carcass detection of canine search teams (no un-aided, human only searches occurred in FY 2025). A total of 97 searcher efficiency trials (carcasses placed) were administered to canine search teams over 20 trial days during FY 2025. Carcasses of black rats were used as surrogates for the 'ōpe'ape'a. Carcasses of wedge-tailed shearwaters were used as surrogates for avian Covered Species. Of the 81 bat surrogate trial carcasses placed, 27 were lost to scavenging for a total of 54 carcasses available to be found. Sixteen wedge-tailed shearwater carcasses were placed; all were available to be found. The overall searcher efficiency in FY 2025 for bat surrogates was 0.83 (95 percent CI = 0.72, 0.91) and for medium-sized bird carcasses was 1.00 (95 percent CI = 0.85, 1.00).

### 5.0 Vegetation Management

Search plots include searchable area out to 35 meters from the base of each WTG. Search plots are comprised of bare ground and vegetation that is mowed when it reaches 4 to 6 inches in height. The search plots accommodate a relatively flat search area that is easily maintained; however, a small portion of one search plot (WTG 3) has a slope that precludes vegetation management and is consequently not searched. Vegetation within the plots consists mainly of Bermuda grass (*Cynodon dactylon*), sensitive plant (*Mimosa pudica*), and Guinea grass (*Megathyrsus maximus*).

Similar to past years, in FY 2025, all plots were mowed at regular intervals to maintain high visibility during fatality searches. Plots were checked weekly for vegetation conditions and

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<sup>1</sup> This permit expired March 31, 2025. However, a permit renewal application was submitted on February 25, 2025, more than 30 days prior to expiration, and therefore the activities authorized by the permit are allowed to continue per 50 CFR 13.22 until the USFWS acts on the renewal application. As of August 12, 2025, the renewal status remains "Application in Review".

generally mowed two to three times per month during the wetter months of the year and at least once per month during the drier months. Mowing consistently occurred immediately following the weekly fatality searches at the WTGs where needed. Livestock, primarily cattle, are grazed within search plot bounds, keeping vegetation low.

Additionally, the on-site biologist maintained communication with the canine searchers to ensure there were no impacts of invasive species (e.g., sensitive plant) on the canines.

## 6.0 Scavenger Trapping

In FY 2025, between 70 and 75 Doc-250s and 12 Trapinator traps were in use during trapping efforts at the Project. Trap set and check frequency was conducted every other week for a total of 26 site visits throughout FY 2025. This effort resulted in a total of 172 target animals being captured and removed including 131 mongooses (*Herpestes auropunctatus*), 35 rats (*Rattus* spp.), 2 mice (*Mus musculus*), and 4 feral cats (*Felis catus*). Other miscellaneous non-native, non-target captures during this timeframe included five species: cane toad (*Rhinella marina*), common myna (*Acridotheres tristis*), spotted dove (*Streptopelia chinensis*), red-crested cardinal (*Paroaria coronata*), and African snail (*Lissachatina fulica*).

## 7.0 Documented Fatalities and Take Estimates

All downed wildlife observed during the fatality monitoring were handled and reported in accordance with the Downed Wildlife Protocol provided by USFWS and DOFAW (DOFAW and USFWS 2020). A single incident of downed (live) wildlife was observed at the Project in FY 2025 (Appendix 2).

Various factors affect how the number of observed fatalities is scaled to estimate the unobserved fatalities. Unobserved fatalities are due to three primary factors:

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

Sections 3.0 and 4.0 describe methods that are used to estimate the effect of the first two factors. The search area for fatalities at the Project has evolved over time; therefore, the proportion of the carcass distribution searched has varied. However, no changes to the size of the search area have been made since December 2014 (Section 2.0). Thus, the estimate of the proportion of the carcass distribution searched in FY 2025 remains the same as described in the FY 2018 annual report (Kahuku Wind 2018) and is presented in the context of take estimation in Appendix 1.

### 7.1 ‘Ōpe‘ape‘a

A total of 12 ‘ōpe‘ape‘a fatalities have been observed at the Project since operations began on March 23, 2011. Two ‘ōpe‘ape‘a fatalities were documented in FY 2025: one female detected on October 10, 2024 during regular searches at 25 meters from WTG 11’s base, and one male detected on December 9, 2024 during regular searches but outside of the search area at 39 meters from WTG 2’s base. Both fatalities were estimated to have occurred between 4-7 days prior to detection. Additionally, both carcasses were collected and transferred to the Bishop Museum, in coordination with USFWS, under the partnership established for genetic sexing. The resulting genetic sexing is included with the fatality description above.

Eleven bats have been detected inside of search plots; the December 9, 2024 detection was the first bat fatality to be detected outside of the designated search area. Table 1 lists the observed ‘ōpe‘ape‘a fatalities by fiscal year.

**Table 1. Observed ‘Ōpe‘ape‘a Fatalities at the Project through FY 2025**

Fiscal Year	Observed Direct Take	Incidental Fatality Observations	Total
2011	0	0	0
2012	3	0	3
2013	0	0	0
2014	0	0	0
2015	1	0	1
2016	0	0	0
2017	0	0	0
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	1	0	1
2022	1	0	1
2023	2	0	2
2024	2	0	2
2025	1	1	2
<b>Total</b>	<b>11</b>	<b>1</b>	<b>12</b>

Cumulative take is estimated from three components: (1) observed direct take (ODT) during protocol (standardized) fatality monitoring, (2) unobserved direct take (UDT), and (3) indirect take. The Evidence of Absence software program (EoA; Dalthorp et al. 2017), an agency-approved analysis tool for analyzing direct take, uses results from bias correction trials and ODT to generate an upper credible limit (UCL) of direct take (i.e., ODT + UDT). USFWS and DOFAW have requested that estimates of direct take for KAH be reported at the 80 percent UCL. Direct take values from this

analysis can be interpreted as: there is an 80 percent probability that actual direct take at the Project over the analysis period was less than or equal to the 80 percent UCL. Associated indirect take is estimated based on the sex and age characteristics of bat fatalities found at the Project, and the life history characteristics of (assumed to be representative of) the 'ōpe'ape'a, as described in the Project's approved HCP and current agency guidance (USFWS 2016).

The estimated direct take (ODT + UDT) between the start of operation (March 23, 2011) and end of FY 2025 (June 30, 2025) is less than or equal to 24 bats (80 percent UCL). Details of the estimated direct take parameters for 'ōpe'ape'a are in Appendix 1.

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

- The average number of offspring (pups) per female that survive to weaning is assumed to be 1.8.
- The sex ratio of the 'ōpe'ape'a taken through UDT is assumed to be 50 percent female unless there is evidence (10 or more bats) to indicate a different sex ratio (sexing results through FY 2025 indicate 7 of 10 bats with identifiable sex were female; therefore, KAH used a sex ratio of 70 percent female)
- The assessment of indirect take from the modeled UDT accounts for the fact that it is not known when the unobserved fatality may have occurred. The period from pregnancy to end of pup dependency for any individual 'ōpe'ape'a female 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 indirect take assessment uses a conversion of one juvenile bat as equal to 0.3 adults.

Based on the USFWS (2016) guidance, the estimate of cumulative indirect take as of the end of FY 2025 is calculated as:

- **Total Juvenile Take Calculated from Observed Female Take (April 1 – September 15)**
  - $3 \text{ (observed females)} * 1.8 \text{ (pups per female)} = 5.4 \text{ juveniles}^2$
- **Total Juvenile Take Calculated from Observed Unknown Sex Take (April 1 – September 15)**
  - $1 \text{ (observed unknown sex)} * 0.7 \text{ (sex ratio)} * 1.8 \text{ (pups per female)} = 1.26 \text{ juveniles}$

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<sup>2</sup> DNA results have identified the sex of 10 of the 12 bat fatalities detected at the Project, confirming that seven of the fatalities were female (Pinzari and Bonaccorso 2022; Bishop Museum results through 2025). Sex identification of two carcasses did not yield a confirmed sex.

- **Total juvenile Take Calculated from Unobserved Take**
  - $12$  (unobserved direct take) \*  $0.7$  (assumed sex ratio) \*  $0.25$  (proportion of calendar year females could be pregnant or have dependent pups) \*  $1.8$  (pups per female) =  $3.78$  juveniles
- **Total Calculated Juvenile Indirect Take** =  $10.44$  ( $5.4 + 1.26 + 3.78$ )
- **Total Adult Equivalent Indirect Take** =  $0.3$  (juvenile to adult conversion factor) \*  $10.44$  =  $3.13$

Therefore, cumulative indirect take through FY 2025 is 4 adults (rounded up from 3.13).

The UCL for cumulative Project take of the 'ōpe'ape'a at the 80 percent credibility level is 27 adult bats ( $24$  [estimated direct take] +  $4$  [estimated indirect take, measured in adult equivalents]). That is, there is an approximately 80 percent probability that actual take at the Project at the end of FY 2025 is less than or equal to 28 bats.

KAH understands that FY 2025 take has exceeded the fully permitted/authorized amount (Tier 2). Accordingly, the Project has implemented the adaptive management measure of installation acoustic bat deterrents at all turbines (see Section 10). Bat deterrents have proven effective at the neighboring Kawailoa Wind Project (Tetra Tech 2022b, Tetra Tech 2024b).

Additionally, KAH has initiated the development of an HCP amendment (state) and a new HCP (federal) with agencies to address the take exceedance and provided a letter of intent to the agencies on April 5, 2024. KAH has been working with USFWS and DOFAW on that amendment/new HCP since then and intends to submit a draft HCP/HCP amendment in FY 2027.

## 7.2 Fatalities of Non-Covered Species

Thirteen non-listed bird fatalities, representing seven species, were documented at WTGs at the Project site in FY 2025. Two of the species observed in FY 2025 are protected by the Migratory Bird Treaty Act (MBTA): wedge-tailed shearwater (five fatalities), and Pacific golden plover (*Pluvialis fulva*; one fatality). For a complete list of all fatalities detected in FY 2025, including Hawaiian (when applicable) and scientific names, see Appendix 2.

## 8.0 Wildlife Education and Observation Program

Wildlife Education and Observation Program trainings continue to be conducted on an as-needed basis to provide on-site personnel with the information to respond appropriately if they observe a Covered Species or encounter downed wildlife while on-site. Wildlife Education and Observation Program trainings were provided to 73 individuals over 24 dates in FY 2025.

## 9.0 Mitigation

The Project's mitigation requirements are described in Section 7.6 of the approved HCP.

### 9.1 'Ōpe'ape'a

#### 9.1.1 *On-Site Acoustic Monitoring*

The HCP commits to acoustically monitoring for bat activity during years when systematic fatality monitoring is conducted. Acoustic monitoring has been conducted continuously at the Project since the start of operations in 2011. Over the course of this long-term monitoring effort, the number of monitoring locations and type of monitoring equipment has changed. Between FY 2014 and FY 2017, monitoring was conducted at 12 locations, including ground and nacelle-based, distributed across the Project. However, due to the low frequency in the number of nights with recorded bat activity, monitoring efforts were reduced to seven ground-based locations beginning in FY 2018 (Kahuku Wind 2018), and then to four ground-based locations (WTGs 2, 5, 9, and 12; Figure 1) beginning in FY 2019 (Tetra Tech 2019). Anabat acoustic bat detectors (models SD1 and SD2) were deployed during the first 2 years of bat acoustic monitoring. In FY 2014 (July 2013) Anabat detectors were replaced with Song Meter SM2BAT+ ultrasonic recorders equipped with SM3-U1 microphones (Wildlife Acoustics, Maynard, MA, USA). In FY 2017, SM3-U1 microphones were replaced with SMX-U1 microphones. In FY 2023, the Song Meter SM2BAT+ acoustics recorders and SMX-U1 microphones were replaced with the newest models available, the Song Meter SM4BAT-FS and SMM-U2 microphones.

The objective of monitoring is to better understand the annual and seasonal variations in bat activity at the project. Analysis of variance (ANOVA) and a Tukey's HSD test were used to determine if there any differences in detection rates between FY 2014 and FY 2025 monitoring years<sup>3</sup>. To test for a change in detection rates across all monitoring years, we used a linear mixed-effect model (LMM) with year, sampling effort (i.e., the number of monitoring locations), and microphone model as predictor variables, with interactions between these variables and included site location as a random effect. Data were normalized with an Ordered Quantile Normalization transformation using the 'bestNormalize' package in R (Peterson 2021). The distribution of residuals from the LMM 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 4.4.2 (R Core Team 2024). The characterization of Hawaiian hoary bat reproductive seasons corresponds approximately to Gorresen et al. (2013).

Bat activity at the Project has remained generally low over the 12-year monitoring period. In FY 2025, 'ōpe'ape'a were detected on 119 out of 1,385 detector-nights (8.6 percent) across the four

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<sup>3</sup> The reporting period spans the months June 2024 to May 2025. All previous sampling years have been adjusted to reflect this same sampling period. This change was made in FY 2021 to allow adequate time for review of the annual dataset and analyses.

monitoring locations (Table 2). This was the highest detection rate recorded since monitoring using the Song Meters began, representing an increase from the 6.3 percent detection rate in FY 2024; however, the difference is not statistically significant (Tukey’s HSD:  $P = 1.00$ ).

Annual detection rates across all monitoring years remained consistently low, below 9.0 percent (Table 2). The observed annual detection rates over the past 3 monitoring years (FY 2023 - FY 2025) were significantly higher than those recorded prior to FY 2022, excluding FY 2019 (Table 3). While the increases in detection rates demonstrated in FY 2023 through FY 2025 are likely attributed to updated microphone sensitivity, the annual detection rates across all monitoring years appear to be stable, with no significant increasing or decreasing trend, regardless of the variation in the sampling effort or microphone model used (LMM; Year:  $t_{12,83} = -0.07, P > 0.945$ ; Year\*sampling effort:  $t_{12,83} = -0.74, P > 0.459$ ; Year\*detector/microphone model:  $t_{12,83} = 1.45, P > 0.145$ ).

**Table 2. Number of Detector-Nights Sampled and Proportion of Detector-Nights with Bat Detections Between FY 2014 and FY 2025**

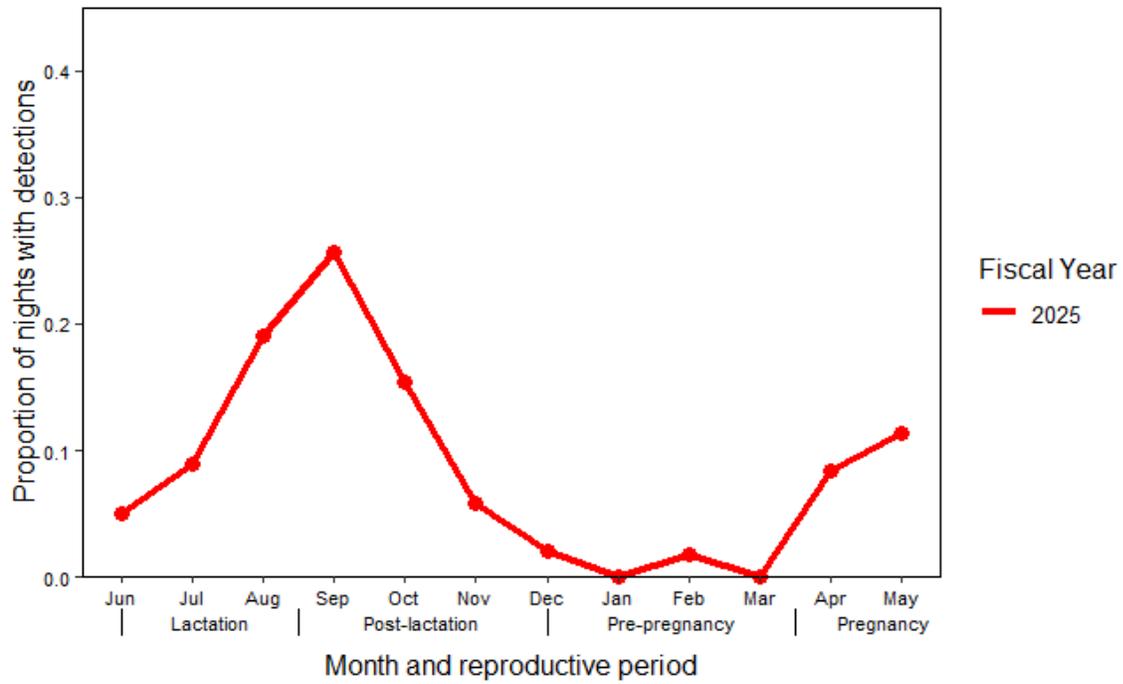
Sampling Period <sup>1,2</sup>	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2014 (July 2013 - May 2014)	3,146	31	0.010
FY 2015 (June 2014 - May 2015)	3,113	12	0.004
FY 2016 (June 2015 - May 2016)	3,030	28	0.009
FY 2017 (June 2016 - May 2017)	3,093	15	0.005
FY 2018 (June 2017 - May 2018)	1,458	10	0.007
FY 2019 (June 2018 - May 2019)	1,046	12	0.011
FY 2020 (June 2019 - May 2020)	1,413	6	0.004
FY 2021 (June 2020 - May 2021)	1,283	9	0.007
FY 2022 (June 2021 - May 2022)	1,225	32	0.026
FY 2023 (June 2022 - May 2023)	1,458	98	0.067
FY 2024 (June 2023 - May 2024)	1,440	91	0.063
FY 2025 (June 2024 - May 2025)	1,385	119	0.086

1. Number of monitoring sites: FY 2014 - 2017 ( $n = 12$ ), FY 2018 ( $n = 7$ ), FY 2021 - 2025 ( $n = 4$ ).  
 2. Acoustic recorder and microphone model: FY 2014 - 2016 (SM2Bat+ with SM3-U1), FY 2017 - 2022 (SM2BAT+ with SMX\_U1), FY 2023 - 2025 (SM4BAT-FS with SMM-U2).

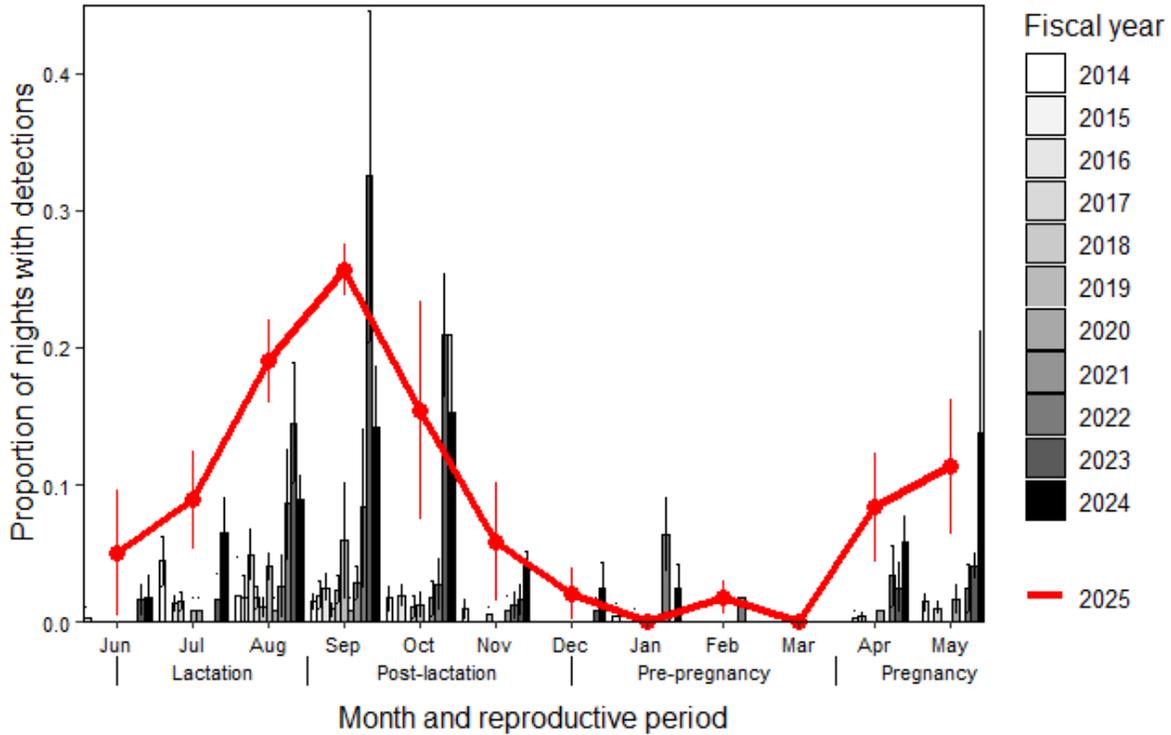
**Table 3. Results of a Tukey’s Honest Significant Difference (HSD) Test on the Annual Detection Rates for each of the sampling years at Kahuku between FY 2014 – FY 2025**

Sampling Years	Difference in Means	Lower 95% CI	Upper 95% CI	P-value
2014 - 2023	1.56	0.27	2.84	0.006
2014 - 2024	1.49	0.20	2.77	0.010
2014 - 2025	1.78	0.50	3.07	0.001
2015 - 2022	1.47	0.18	2.75	0.012
2015 - 2023	2.08	0.80	3.37	0.000
2015 - 2024	2.01	0.73	3.30	0.000
2015 - 2025	2.31	1.03	3.59	0.000
2016 - 2023	1.87	0.59	3.15	0.000
2016 - 2024	1.80	0.52	3.08	0.001
2016 - 2025	2.10	0.82	3.38	0.000
2017 - 2022	1.39	0.11	2.68	0.022
2017 - 2023	2.01	0.73	3.29	0.000
2017 - 2024	1.94	0.66	3.22	0.000
2017 - 2025	2.24	0.96	3.52	0.000
2018 - 2023	1.63	0.24	3.03	0.009
2018 - 2024	1.56	0.17	2.96	0.015
2018 - 2025	1.86	0.47	3.25	0.001
2020 - 2023	2.02	0.45	3.59	0.003
2020 - 2024	1.95	0.38	3.52	0.004
2020 - 2025	2.25	0.68	3.82	0.000
2021 - 2023	1.67	0.10	3.24	0.027
2021 - 2024	1.60	0.03	3.17	0.041
2021 - 2025	1.90	0.33	3.47	0.006

In FY 2025, bat detections peaked in September, corresponding with the early post-lactation reproductive period, with 29 detections recorded (26 percent of detector-nights). Following this peak, detection rates declined in October and November and remained low through March. No detections were recorded in January and March, aligning with the pre-pregnancy period. Activity resumed in April and May, with 10 and 14 detections, respectively, during the pregnancy period (Figure 2). This seasonal pattern mirrors trends observed in prior years, indicating consistency in bat activity patterns relative to reproductive cycles (Figure 3).



**Figure 2. Monthly Bat Acoustic Activity at Kahuku for FY 2025 with Corresponding Reproductive Periods**



**Figure 3. Monthly Bat Acoustic Activity at Kahuku for FY 2023 through FY 2025 with Corresponding Reproductive Periods**

**9.1.2 On-Site Thermal Image Monitoring**

With the goals of providing data on ‘ōpe‘ape‘a behavior at turbines with deterrents and supplementing acoustic monitoring data, KAH deployed thermal imaging cameras at the same turbines where acoustic monitoring has been ongoing (WTGs 2, 5, 9, and 12; Figure 1) in March 2025. Data analysis is currently ongoing, and results will be included in the FY 2026 annual report.

**9.1.3 Tier 1 Mitigation**

The Baseline (Tier 1) mitigation obligation for the ‘ōpe‘ape‘a is complete. Kahuku Wind paid the full obligation of \$150,000 for Tier 1 bat mitigation conducted by DOFAW at the Kahikinui Forest Reserve on Maui in September 2011 (Kahuku Wind 2012). These funds were used for 2,500 meters of ungulate fencing around a 280-acre enclosed restoration area (Landon 2015).

**9.1.4 Tier 2 Mitigation**

Tier 2 Mitigation is occurring over 176 acres within four fenced cattle grazing parcels at the Helemano Section of the ‘Ewa Forest Reserve (Helemano Mitigation Area) on O‘ahu. KAH is working

with DOFAW O'ahu to conduct management actions beneficial to bats. In FY 2025, KAH and DOFAW signed a memorandum of understanding (MOU) and DOFAW issued a Forest Reserve Special Use Permit (SUP) to allow KAH to begin implementation of the Tier 2 Mitigation Plan in the Helemano Mitigation Area. Implementation activities in FY 2025 included the development of an Implementation Plan (Tetra Tech 2024c), continuing to secure permitting and compliance for mitigation actions, creating additional bat foraging corridors by clearing vegetation and re-clearing vegetation within pre-existing bat foraging corridors, and maintaining vegetation within the cleared corridors (Appendix 3). Additional details on some of these actions taken in FY 2025 are provided below.

#### *9.1.4.1 Foraging Corridors*

A total of 37.19 acres of non-native vegetation was cleared within the mitigation area for the development of bat foraging corridors between December 2024 and March 2025 (Appendix 4). Bat foraging corridors previously created by O'ahu DOFAW in 2022 were re-cleared in two of the parcels, starting at the end of December 2024 and finishing in February 2025. This re-cleared a total of 16.73 acres of non-native vegetative regrowth. New bat foraging corridors were created in the two other parcels during the months of January 2025 and March 2025, involving clearing a total of 20.46 acres of non-native vegetation. Vegetation clearing activities for bat foraging corridors fully concluded in March 2025 (Appendix 4). Vegetation management of woody regrowth within the bat foraging corridors began in April 2025 involving spot spray herbicide treatments; this activity is still in progress at the time of annual report submission. No vegetation clearing of vegetation greater than 15 feet in height will occur during the bat pupping season (June 1 – September 15).

#### *9.1.4.2 Fencing Replacement and Water Tank Installation*

As part of permitting and compliance, on March 14, 2025, KAH submitted to the State Historic Preservation Division (SHPD) for HRS Chapter 6E-42 Historic Preservation Review for moderate ground disturbance activities associated with fence removal and replacement, installation of a water tank, and installation of underground piping to the water tank (Appendix 3). A response from SHPD was anticipated 45 days after submission (i.e., May 1, 2025) per Hawaii Administrative Rules (HAR) 13-275 and HAR-284; KAH is awaiting SHPD review at the time of annual report submission. KAH anticipates the commencement of fence removal and replacement actions after receiving a response of concurrence from SHPD; this action is targeted for the end of October 2025 and anticipated to run through May 2026, however actions are dependent on SHPD review timeline. KAH expects to secure permitting for the water tank and begin installation by June 2026, with the development and permitting of a ditch water draw system to refill the water tank anticipated in FY 2027. Anticipated timelines for mitigation activities are presented in Appendix 3.

### 9.1.4.3 *Bat Acoustic Monitoring*

#### **Baseline Monitoring Results**

Baseline acoustic monitoring for bat activity began in March 2023 with the deployment of 15 SM4BAT-FS detector units each with an SMM-U2 microphone placed at randomly selected locations throughout the Helemano Mitigation Area. To ensure a wide sampling effort, these monitoring units were moved monthly to different randomly selected sampling locations, evenly distributed throughout the four mitigation parcels and control site. This monitoring effort was completed in July 2024. In addition to and separate from the primary baseline acoustic monitoring effort, one acoustic monitor (SM2BAT+ with SMX-U1 microphone) was deployed at the site of a proposed water feature installation within the Helemano Mitigation Area to capture baseline activity at the location prior to mitigation action of above-ground water tank installation.

Between April 2023 and July 2024, 'ōpe'ape'a were detected on 4.7 percent of monitoring nights across the Helemano mitigation parcels and control site. Bat activity peaked in late summer and early fall and declined in winter months with significant variation in bat activity between mitigation parcels. Parcel 4 consistently exhibited the highest levels of bat activity, particularly during peak activity season, followed by Parcel 3. Parcels 1 and 2 showed lower and relatively stable bat activity throughout the year, and the control site showed a short spike in activity during late summer before dropping off sharply. Behavioral call analysis mirrored these patterns, with the highest rates of search-phase and approach-phase calls recorded in Parcels 3 and 4. Feeding buzzes, indicative of foraging, were rare and also concentrated in Parcels 3 and 4. At the proposed water feature site, bat activity followed similar seasonal trends with bat detections occurring on 11.7 percent of sampling nights.

#### **Year One Monitoring**

Year one monitoring commenced on July 1, 2025 and will occur over the course of FY 2026. Similar to baseline monitoring, this effort involves the deployment of 15 SM4BAT-FS detector units each with an SMM-U2 microphone placed at and moved to randomly selected locations within the mitigation area monthly. In addition to and separate from the year one acoustic monitoring effort, one acoustic monitor (SM2BAT+ with SMX-U1 microphone) will also be redeployed at the site of the proposed water feature installation. Year one insect sampling will begin in August 2025. This year one monitoring effort will be compared to the baseline monitoring results as the first assessment of the Mitigation Plan's success criteria.

### 9.1.4.4 *Insect Sampling*

Baseline insect sampling began in August 2023 and was completed in July 2024. Insect sampling revealed 77 arthropod species from 11 orders, with the Lepidoptera and Coleoptera families showing the greatest diversity. Native insects consisted of 36 species of Lepidoptera from 30 genera and 13 families. Insect biomass was highest in September and December 2023, particularly in Parcels 2 and 3, and declined in spring 2024. Statistical models confirmed significant differences

in both bat activity and insect biomass across parcels and time, suggesting that habitat quality and prey availability vary seasonally and spatially within the Helemano Mitigation Area. Detailed results of the insect sampling are presented in Appendix 5.

## **9.2 Other Covered Species**

Mitigation efforts for waterbirds were completed as of FY 2015 and no further reporting is required (Kahuku Wind 2016). All mitigation efforts for 'a'o and 'ua'u were completed as of FY 2017; no further reporting is required (Kahuku Wind 2017, Pacific Cooperative Studies Unit and DOFAW 2017). Mitigation efforts for the pueo were completed as of FY 2017 and no further reporting is required (Kahuku Wind 2017).

## **10.0 Adaptive Management**

KAH has implemented adaptive management steps in accordance with the adaptive management framework in Section 8.3 of the approved HCP to understand and reduce the risk to the 'ōpe'ape'a. Adaptive management measures that have been and continue to be implemented include implementing a Project-wide low wind-speed curtailment (LWSC) regime and adjustments in scavenger control efforts to maintain a high probability of detecting Project-related wildlife fatalities.

The Project initiated LWSC at all turbines at wind speeds of up to 5 meters per second on April 27, 2012. LWSC is currently implemented between sunset and sunrise from April through November. Curtailment is achieved by feathering blades to minimize rotation. KAH monitors the turbines on a nightly basis to confirm the LWSC programming is operating as intended.

Nine bat fatalities have been observed over approximately 13 years since the initiation of LWSC implementation at KAH. In comparison, three bat fatalities were found across two calendar years prior to the initiation of LWSC.

In FY 2025 KAH worked with NRG Systems to install 12 tower-mounted ultrasonic acoustic deterrent systems across the Project, with one system (each consisting of four deterrent units) at each turbine. Deterrents were installed on the turbine towers (approximately 4 meters above ground level), facing up towards the rotor-swept area, and each of the four deterrent units broadcasts a wide spectrum of sound to deter bats within the 20 to 50 kilohertz (kHz) range.

The deterrents were installed in June 2025 and were all operational by July 3, 2025, and are complimented by the thermal image monitoring program which commenced in March of 2025 (see Section 9.1.2). To the extent possible, based on small mortality sample sizes across years of operation, and considering deterrents are installed on all turbines (i.e., no control), data from post-construction mortality monitoring and thermal camera imaging will be used to inform the effectiveness of deterrents, potentially in conjunction with results of deterrent effectiveness from other studies.

KAH is in the process of data review for and determination of whether implementation of an alternative Smart Curtailment program is justified. Data are being analyzed in two ways:

- (1) Using acoustic data correlated with wind speed, time of night, time of year, and other variables to develop a Smart Curtailment program that would reduce risk to bats.
- (2) Using thermal imaging data from when deterrents were active to design a Smart Curtailment program that pairs with the deterrents to reduce risk to bats.

KAH is continuing to work with DOFAW and USFWS on an HCP amendment and full draft federal HCP. The HCP amendment/new Federal HCP will include the proposed LWSC regime.

## 11.0 Agency Meetings, Consultations, and Visits

KAH communicated actively with USFWS and DOFAW throughout FY 2025 through video teleconference, conference calls, quarterly reports, and e-mail communications related to the Project’s HCP (Table 4). These communications included focused discussions of ‘ōpe‘ape‘a Tier 2 mitigation planning and the finalization of the Mitigation Plan.

**Table 4. Summary of Agency Coordination and Communication in FY 2025 or related to FY 2025 reporting**

Date	Communication	Participants
July 1 – June 30 (biweekly)	Recurring check-in calls	KAH, Tetra Tech, DOFAW, USFWS
July 17, 2024	Submission of the Helemano Implementation Plan	Tetra Tech, on behalf of KAH
July 22, 2024	Revised KAH HCP Concept	To: DOFAW, USFWS From: KAH
July 31, 2024	Submission of FY 2024 annual report	To: DOFAW, USFWS From: KAH
August 8, 2024	Helemano MOU – KAH comments and edits	To: DOFAW From: KAH
August 20, 2024	DOFAW comments on KAH HCP Concept	TO: KAH From: DOFAW
August 21, 2024	KAH HCP Amendment Concept Review – in person	KAH, Tetra Tech, USFWS, DOFAW
August 30, 2024	USFWS comments on annual report	To: KAH From: USFWS
September 5, 2024	DOFAW comments on annual report	To: KAH From: DOFAW
September 13, 2024	Meeting to Plan Bat Mitigation Implementation Timeline	KAH, Tetra Tech, DOFAW

<b>Date</b>	<b>Communication</b>	<b>Participants</b>
September 23, 2024	Call to discuss Helemano MOU	DOFAW, KAH
September 25, 2024	DOFAW comments on Helemano MOU and Implementation Plan	To: KAH From: DOFAW
September 27, 2024	Kahuku HCP Concept presentation to ESRC	KAH, Tetra Tech
October 10, 2024	Notification of downed wildlife: 'ōpe'ape'a	To: DOFAW and USFWS From: Tetra Tech
October 10, 2024	Submitted final Helemano Implementation Plan and signed MOU	To: DOFAW and USFWS From: KAH
October 11, 2024	Final annual report submission	To: DOFAW, USFWS From: KAH
October 30, 2024	Q1 report	To: DOFAW, USFWS From: KAH
October 31, 2024	Final executed MOU for Helemano	To: KAH From: DOFAW
November 19, 2024	HEPA exemption notice	To: KAH From: DOFAW
December 5, 2024	Submission of DWP Approach Memo	To: USFWS From: Tetra Tech on behalf of KAH
December 9, 2024	Carcass Distribution and Density Weighted Proportions discussion	Tetra Tech, KAH, USFWS
December 11, 2024	Downed wildlife report: 'ōpe'ape'a	To: DOFAW, USFWS From: Tetra Tech on behalf of KAH
December 17, 2024	Request to thin the density of kukui and African tulip individuals within the Helemano Mitigation Area (email)	To: DOFAW, USFWS From: Tetra Tech on behalf of KAH
January 6, 2025	Submission of raw PCM data spreadsheet for FY 2019- FY 2024	To: USFWS From: KAH
January 9, 2025	Project updates/questions provided via email.	To: USFWS and DOFAW From: KAH
January 16, 2025	USFWS email concurrence with Request to thin the density of kukui and African tulip individuals within the Helemano Mitigation Area	To: Tetra Tech and KAH From: USFWS
January 31, 2025	Clarifications: Request to thin the density of kukui and African tulip individuals within the Helemano Mitigation Area (email)	To: DOFAW, USFWS From: Tetra Tech on behalf of KAH

<b>Date</b>	<b>Communication</b>	<b>Participants</b>
January 31, 2025	Q2 report submission	To: DOFAW, USFWS From: KAH
February 3, 2025	DOFAW email concurrence with Request to thin the density of kukui and African tulip individuals within the Helemano Mitigation Area	To: Tetra Tech and KAH From: DOFAW
February 20, 2025	Request to change approach for clearing the vegetation encasing the fence line at the Helemano Mitigation Area (email)	To: DOFAW, USFWS From: Tetra Tech on behalf of KAH
March 19, 2025	DOFAW email concurrence with Request to change approach for clearing the vegetation encasing the fence line at the Helemano Mitigation Area	To: Tetra Tech and KAH From: DOFAW
March 19, 2025	USFWS email concurrence with Request to change approach for clearing the vegetation encasing the fence line at the Helemano Mitigation Area	To: Tetra Tech and KAH From: USFWS
April 16, 2025	Re-submission of Kahuku Tier 2 Bat Mitigation Plan and Implementation Plan updated to memorialize agency approved variances.	To: USFWS and DOFAW From: Tetra Tech on behalf of KAH
April 30, 2025	Q3 Report submission	To: DOFAW, USFWS From: Tetra Tech on behalf of KAH
May 15, 2025	Communication to inform agencies about Kahuku District Park baseball field lights on before sunrise (email)	To: USFWS, DOFAW From: Tetra Tech
June 12, 2025	Meeting to discuss the introduction of a honeybee operation to the HMA	DOFAW, KAH, Tetra Tech
June 13, 2025	Communication to confirm honeybees will not be introduced to the HMA during the Year One monitoring effort at the HMA	To: Tetra Tech and KAH From: DOFAW
August 15, 2025	Draft annual report submitted	To: DOFAW and USFWS From: KAH
September 26, 2025	Comments on draft annual report	To: KAH From: USFWS
January 29, 2026	Comments on draft annual report	To: KAH From: DOFAW
February 12, 2026	FY 2025 annual review meeting	DOFAW, KAH, Tetra Tech

## 12.0 Expenditures

Total HCP-related expenditures for the Project in FY 2025 were \$1,419,300 (Table 5).

**Table 5. HCP-Related Expenditures at the Project in FY 2025**

Category <sup>1</sup>	Amount
Permit compliance	\$100,000
Fatality monitoring	\$70,000
Acoustic monitoring for bats	\$17,500
Thermal monitoring for bats	\$32,000
Smart Curtailment Data Analysis	\$14,900
Scavenger control	\$28,300
Vegetation management	\$21,800
Tier 2 Bat Mitigation	\$821,600
Adaptive Management (bat deterrents)	\$313,200
<b>Total Cost for FY 2025</b>	<b>\$1,419,300</b>
1. Staff labor and equipment costs are included in the overall costs for each category.	

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# **Appendix 1. Dalthorp et al. (2017) Fatality Estimation for 'Ōpe'ape'a at the Project through FY 2025**

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Modelling Parameter		Modelling Period															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 (current)
LWSC		N/A	N/A	Partial	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s
Date Range of Modelling Period	Begin	1/1/2011	10/1/2011	4/1/2012	9/1/2013	8/1/2014	11/1/2014	4/1/2015	7/1/2016	7/1/2017	7/1/2018	7/1/2019	7/1/2020	7/1/2021	7/1/2022	7/1/2023	7/1/2024
	End	10/1/2011	3/31/2012	8/1/2012	7/31/2124	10/31/2014	3/31/2015	6/30/2016	6/30/2017	6/30/2018	6/30/2019	6/30/2020	6/30/2021	6/30/2022	6/30/2023	6/30/2024	6/30/2025
Period length (days)		273	182	122	333	91	150	456	364	364	364	364	364	364	364	364	364
Percent of Year		0.75	0.5	0.33	0.91	0.25	0.41	1.25	1	1	1	1	1	1	1	1	1
Search Interval (days)		3.5	2.5	3.5	3.5	3.5	30	7	7	7	7	7	7	7	7	7	7
Number of Searches in Modelling period		77	72	34	94	25	4	64	51	51	52	52	52	52	52	52	52
Observed fatalities (X)		1	0	2	0	1	0	0	0	0	0	0	1	1	2	2	1
K		0.7	0.7	0.7	0.7	0.7	0.7	1 <sup>1</sup>									
DWP		1	1	1	1	1	1	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
ĝ	Ĝ	0.464	0.796	0.746	0.83	0.67	0.347	0.565	0.53	0.535	0.411	0.527	0.632	0.519	0.589	0.385	0.378
	95% LCI	0.262	0.675	0.611	0.647	0.46	0.166	0.486	0.465	0.464	0.326	0.434	0.549	0.421	0.521	0.29	0.3
	95% UCI	0.672	0.894	0.861	0.955	0.85	0.554	0.642	0.595	0.605	0.618	0.618	0.714	0.616	0.659	0.485	0.46
B	Ba	9.841	39.66	33.65	17.27	13.94	7.456	87.01	119.5	101.7	50.73	58.89	86.42	51.85	99.82	36.1	52.59
	Bb	11.38	10.18	11.43	3.528	6.853	14.05	67.09	105.8	88.6	72.82	52.93	50.4	48.05	70.31	57.67	86.38
M* <sup>3</sup>		4	3	7	6	7	8	8	9	9	9	9	11	13	17	22	24

1. Searches performed by canine teams which have a high probability of detecting a carcass during a subsequent search if initially missed.
2. Reduced search area (See FY 2017 Annual Report for detailed analysis).
3. Cumulative value representing estimate of total direct take from the start of operations through the identified monitoring period at the 80 percent UCL.

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## **Appendix 2. Documented Fatalities at the Project during FY 2025**

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Species	Date Documented	WTG	Distance to WTG (meters)	Bearing from WTG (degrees)	Search/ Incidental <sup>1</sup>
<i>Lasiurus semotus</i> ('ōpe'ape'a/Hawaiian hoary bat) <sup>2</sup>	10/10/2024	11	25	315	Search
<i>Columba livia</i> (rock pigeon)	10/13/2024	10	31	260	Incidental
<i>Pluvialis fulva</i> (kōlea/Pacific golden plover) <sup>3</sup>	11/18/2024	11	47	290	Incidental
<i>Ardenna pacifica</i> ('ua'u kani/wedge-tailed shearwater) <sup>3,4</sup>	11/26/2024	7	0	315	Search
<i>Ardenna pacifica</i> ('ua'u kani/wedge-tailed shearwater) <sup>3</sup>	11/26/2024	12	28	300	Search
<i>Ardenna pacifica</i> ('ua'u kani/wedge-tailed shearwater) <sup>3</sup>	11/26/2024	12	72	250	Incidental
<i>Lasiurus semotus</i> ('ōpe'ape'a/Hawaiian hoary bat) <sup>2</sup>	12/09/2024	2	39	285	Incidental
<i>Acridotheres tristis</i> (common myna)	2/10/2025	2	22	2	Search
<i>Estrilda astrild</i> (common waxbill)	2/14/2025	4	25	215	Incidental
<i>Estrilda astrild</i> (common waxbill)	2/17/2025	4	22	210	Search
<i>Estrilda astrild</i> (common waxbill)	3/14/2025	10	23	315	Search
<i>Spilopelia chinensis</i> (spotted dove)	4/11/2025	12	2	180	Incidental
<i>Paroaria coronata</i> (red crested cardinal)	4/30/2025	7	35	170	Search
<i>Ardenna pacifica</i> ('ua'u kani/wedge-tailed shearwater) <sup>3</sup>	5/13/2025	9	90	254	Incidental
<i>Ardenna pacifica</i> ('ua'u kani/wedge-tailed shearwater) <sup>3</sup>	6/30/2025	9	30	220	Search

1. Incidental equates being found outside of the searched area and/or outside of the regularly scheduled search time.  
 2. Federally and State endangered species.  
 3. Species protected under the MBTA.  
 4. This individual was injured and transported to Hawaii Wildlife Center staff at Feather and Fur Animal Hospital, where it was later euthanized due to injuries.

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**Appendix 3. Tier 2 Bat Mitigation  
Implementation Timeline, June 2024 to  
May 2025**

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Helemano Bat Mitigation Actions FY 2025 Timeline

Habitat Improvement Actions Period													
Task	2024 - 2025												
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
Implementation Plan and MOU	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Permits	Blue	Yellow	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Barbed Wire Removal and Replacement	Orange	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Vegetation: Bat Corridor Development	Blue	Orange	Blue	Blue	Blue	Green	Blue						
Vegetation Monitoring and Management	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Cattle/Ranch Land Management Planning and Actions	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Water Resources	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Invasive Species Monitoring	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Acoustic/Insect Monitoring and Analysis	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Reporting	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Adaptive Management <sup>2</sup>	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

Planning/Coordination/Work Period
Agency Interface including DOFAW O'ahu
OnSite Action
DOFAW O'ahu Interface
TBD

		Year 1											
		2025 - 2026											
Task		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Implementation Plan and MOU													
Permits		■	■	■	■	■	■	■	■				
Barbed Wire Removal and Replacement													
Vegetation: Bat Corridor Development													
Vegetation Monitoring and Management		■	■	■	■	■	■	■	■	■	■	■	■
Cattle/Ranch Land Management Planning and Actions							■	■	■	■	■	■	■
Water Resources		■	■	■	■	■	■	■	■	■	■	■	■
Invasive Species Monitoring			■	■	■	■	■	■	■	■	■	■	■
Acoustic/Insect Monitoring and Analysis		■	■	■	■	■	■	■	■	■	■	■	■
Reporting		■	■	■	■								
Adaptive Management <sup>2</sup>			■	■	■	■	■	■	■	■	■	■	■

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

■	Planning/Coordination/Work Period
■	Agency Interface including DOFAW O'ahu
■	OnSite Action
■	DOFAW O'ahu Interface
■	TBD

		Year 2											
		2026 - 2027											
Task		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Implementation Plan and MOU													
Permits													
Barbed Wire Removal and Replacement													
Vegetation: Bat Corridor Development													
Vegetation Monitoring and Management													
Cattle/Ranch Land Management Planning and Actions													
Water Resources													
Invasive Species Monitoring													
Acoustic/Insect Monitoring and Analysis													
Reporting													
Adaptive Management <sup>2</sup>													

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

- Planning/Coordination/Work Period
- Agency Interface including DOFAW O'ahu
- OnSite Action
- DOFAW O'ahu Interface
- TBD

Year 3													
Task	2027 - 2028												
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
Implementation Plan and MOU													
Permits													
Barbed Wire Removal and Replacement													
Vegetation: Bat Corridor Development													
Vegetation Monitoring and Management	OnSite Action												
Cattle/Ranch Land Management Planning and Actions	OnSite Action												
Water Resources	OnSite Action								OnSite Action				
Invasive Species Monitoring	OnSite Action												
Acoustic/Insect Monitoring and Analysis		OnSite Action	OnSite Action	OnSite Action	OnSite Action					OnSite Action	OnSite Action	OnSite Action	OnSite Action
Reporting													
Adaptive Management <sup>2</sup>	TBD												

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

- Planning/Coordination/Work Period
- Agency Interface including DOFAW O'ahu
- OnSite Action
- DOFAW O'ahu Interface
- TBD

		Year 4											
		2028 - 2029											
Task		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Implementation Plan and MOU													
Permits													
Barbed Wire Removal and Replacement													
Vegetation: Bat Corridor Development													
Vegetation Monitoring and Management		OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action
Cattle/Ranch Land Management Planning and Actions		OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action
Water Resources		OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action							OnSite Action
Invasive Species Monitoring		OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action	OnSite Action
Acoustic/Insect Monitoring and Analysis		OnSite Action	OnSite Action	Agency Interface including DOFAW O'ahu									
Reporting				Agency Interface including DOFAW O'ahu									
Adaptive Management <sup>2</sup>		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

Planning/Coordination/Work Period
Agency Interface including DOFAW O'ahu
OnSite Action
DOFAW O'ahu Interface
TBD

		Year 5											
		2029 - 2030											
Task		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Implementation Plan and MOU													
Permits													
Barbed Wire Removal and Replacement													
Vegetation: Bat Corridor Development													
Vegetation Monitoring and Management		■	■	■	■	■	■	■	■	■	■	■	■
Cattle/Ranch Land Management Planning and Actions		■	■	■	■	■	■	■	■	■	■	■	■
Water Resources		■	■	■	■	■							■
Invasive Species Monitoring		■	■	■	■	■	■	■	■	■	■	■	■
Acoustic/Insect Monitoring and Analysis		■	■	■	■	■	■	■	■	■	■	■	■
Reporting													
Adaptive Management <sup>2</sup>		■	■	■	■	■	■	■	■	■	■	■	■

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

Planning/Coordination/Work Period
Agency Interface including DOFAW O'ahu
OnSite Action
DOFAW O'ahu Interface
TBD

Post-Mitigation Actions Period

Task	2030											
	Jun	Jul	Aug	Sep	Oct	Nov	Dec					
Implementation Plan and MOU												
Permits												
Barbed Wire Removal and Replacement												
Vegetation: Bat Corridor Development												
Vegetation Monitoring and Management	OnSite Action	OnSite Action										
Cattle/Ranch Land Management Planning and Actions	OnSite Action	OnSite Action	OnSite Action	OnSite Action								
Water Resources												
Invasive Species Monitoring	OnSite Action	OnSite Action	OnSite Action	Agency Interface								
Acoustic/Insect Monitoring and Analysis	OnSite Action	OnSite Action	OnSite Action	Agency Interface								
Reporting				Agency Interface								
Adaptive Management <sup>2</sup>	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

1 SHPD Submittal; Mitigation Actions dependent upon SHPD determination are planned to occur in FY 2026.

2 No adaptive management was necessary in FY 2025.

Planning/Coordination/Work Period
Agency Interface including DOFAW O'ahu
OnSite Action
DOFAW O'ahu Interface
TBD

## **Appendix 4. Tier 2 Helemano Mitigation Area Bat Foraging Habitat Corridors**

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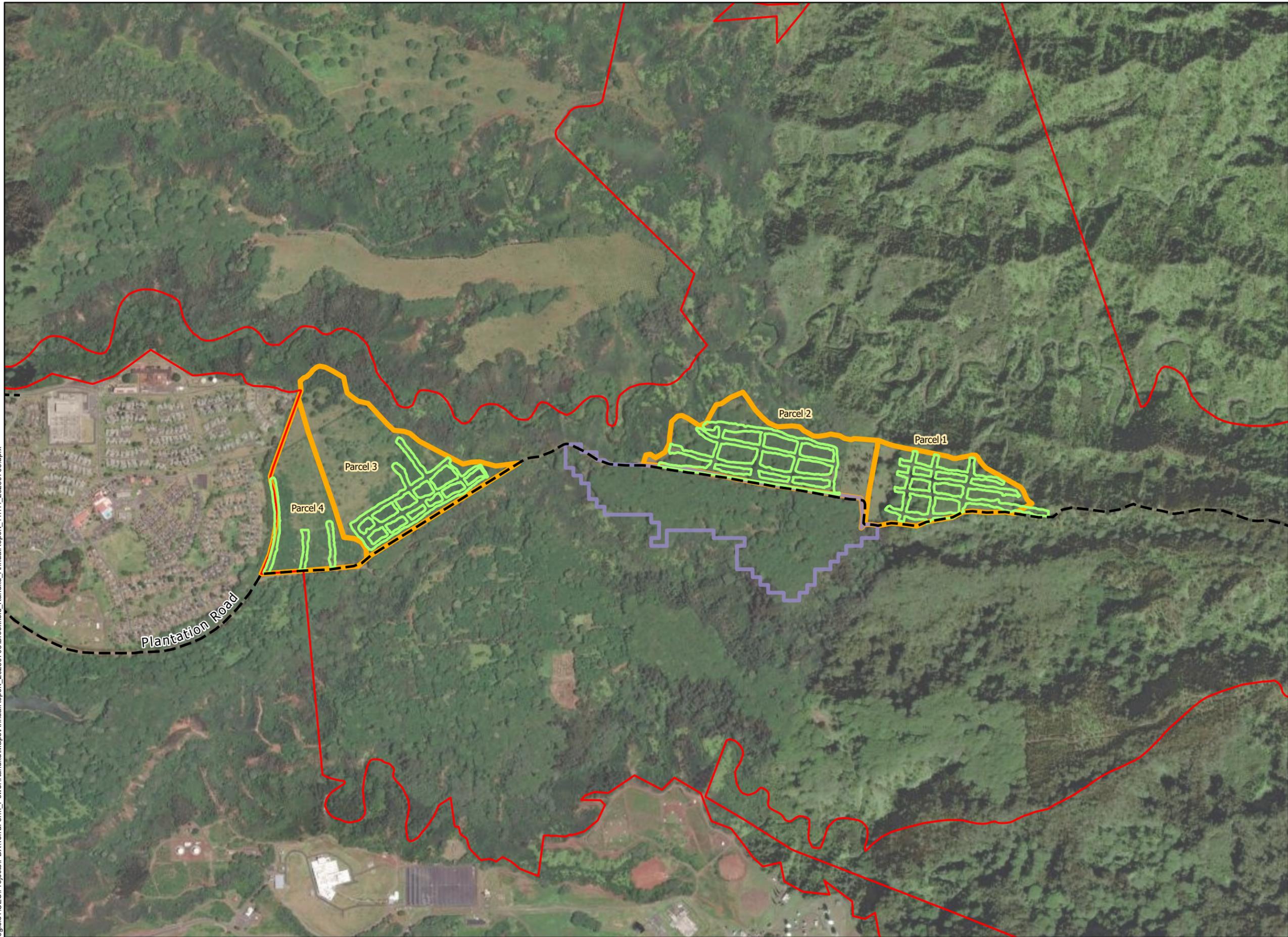
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# Kahuku Wind Power LLC

## Tier 2 Helemano Mitigation Area Bat Foraging Corridors

HONOLULU COUNTY, HI

-  Helemano Section
-  Helemano Mitigation Area (HMA)
-  Corridors Re-cleared/  
Created by KAH (37.2 acres)
-  Control Area
-  Access Road



Reference Map

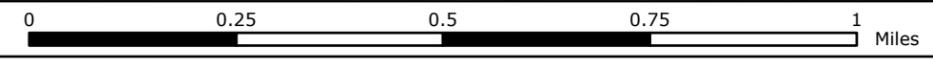


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# **Appendix 5. Tier 2 Helemano Mitigation Area Baseline Report**

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# Kahuku Wind Project

## Hawaiian Hoary Bat Tier 2 Mitigation Baseline Monitoring Report



July 2025

**Prepared for**

Kahuku Wind Power LLC/Terraform Power

**Prepared by**



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- Appendix B: Hawaiian Hoary Bat Diet
- Appendix C: Insect Monitoring Results

## Acronyms and Abbreviations

AICc	Akaike’s Information Criterion corrected
EMM	estimated marginal means
GLMM	generalized linear mixed-effects model
HMA	Helemano Mitigation Plan
KAH	Kahuku Wind Power, LLC
LM	linear model
LMM	linear mixed-effects model
SLAM	Sea Land and Air Malaise
SM4	Song Meter SM4BAT

## 1.0 INTRODUCTION

Kahuku Wind Power, LLC (KAH) initiated a baseline monitoring program in 2023 as part of the Tier 2 mitigation efforts outlined in the *Kahuku Wind Project Hawaiian Hoary Bat Tier 2 Mitigation Plan* (Mitigation Plan; Tetra Tech 2024), occurring in the Helemano Section of the 'Ewa Forest Reserve. The biological goal of this mitigation is to fully offset and provide a net benefit for the incidental take of eight Hawaiian hoary bats (*Lasiurus semotus*) through habitat enhancement and management.

To achieve this goal, the mitigation plan is structured around three primary objectives: 1) enhance, manage, and protect 176 acres of foraging and roosting habitat within the Helemano Mitigation Area (HMA); 2) demonstrate an increase in bat activity as an indicator of improved resource availability; and 3) establish a link between habitat enhancement efforts and increased availability of bat prey resources.

As part of this effort, KAH began acoustic monitoring for Hawaiian hoary bats in the HMA in April 2023 and initiated passive and active insect sampling in August 2023 to assess baseline prey biomass and diversity. This report presents the results of the baseline monitoring period conducted between March 2023 and June 2024, providing a foundation for future evaluation of the effectiveness of habitat enhancement measures on bat activity and insect prey availability.

## 2.0 METHODS

### 2.1 Data Collection

#### 2.1.1 Bat Acoustic Monitoring

Acoustic monitoring for Hawaiian hoary bats was conducted across the four mitigation parcels between April 2023 and July 2024, and across the control site between August 2023 and July 2024. Nightly monitoring was conducted using Song Meter SM4BAT-FS (SM4) ultrasonic recorders equipped with a high frequency SMM-U2 microphone (Wildlife Acoustics, Inc., Maynard, MA). Within each mitigation parcel and the control site, SM4 units were deployed at three randomly selected locations and moved monthly to a new, random location. A total of 180 unique random locations were selected for sampling across the four mitigation parcels ( $n = 144$  locations) and the control site ( $n = 36$  locations). Additionally, the proposed location of the water feature was monitored using a Song meter SM2BAT+ acoustic recorder equipped with high frequency SMX-U1 microphone (Wildlife Acoustics, Inc., Maynard, MA) between April 2023 and July 2024 (Figure 1).

Acoustic recordings were processed in Kaleidoscope PRO version 5.4.0 (Wildlife Acoustics, Inc., Maynard, Massachusetts) using the Bats of North America 5.1.0 AutoID classifier for Hawai'i to identify potential bat calls. All calls were then manually reviewed and classified by a single analyst to reduce observer bias. Bat activity was quantified using multiple acoustic metrics, including detection rate, number of call files, call type classification, foraging duration, and the timing of nightly activity. Detection rate was calculated as the proportion of sampling nights with at least one confirmed bat detection relative to the total number of sampling nights.

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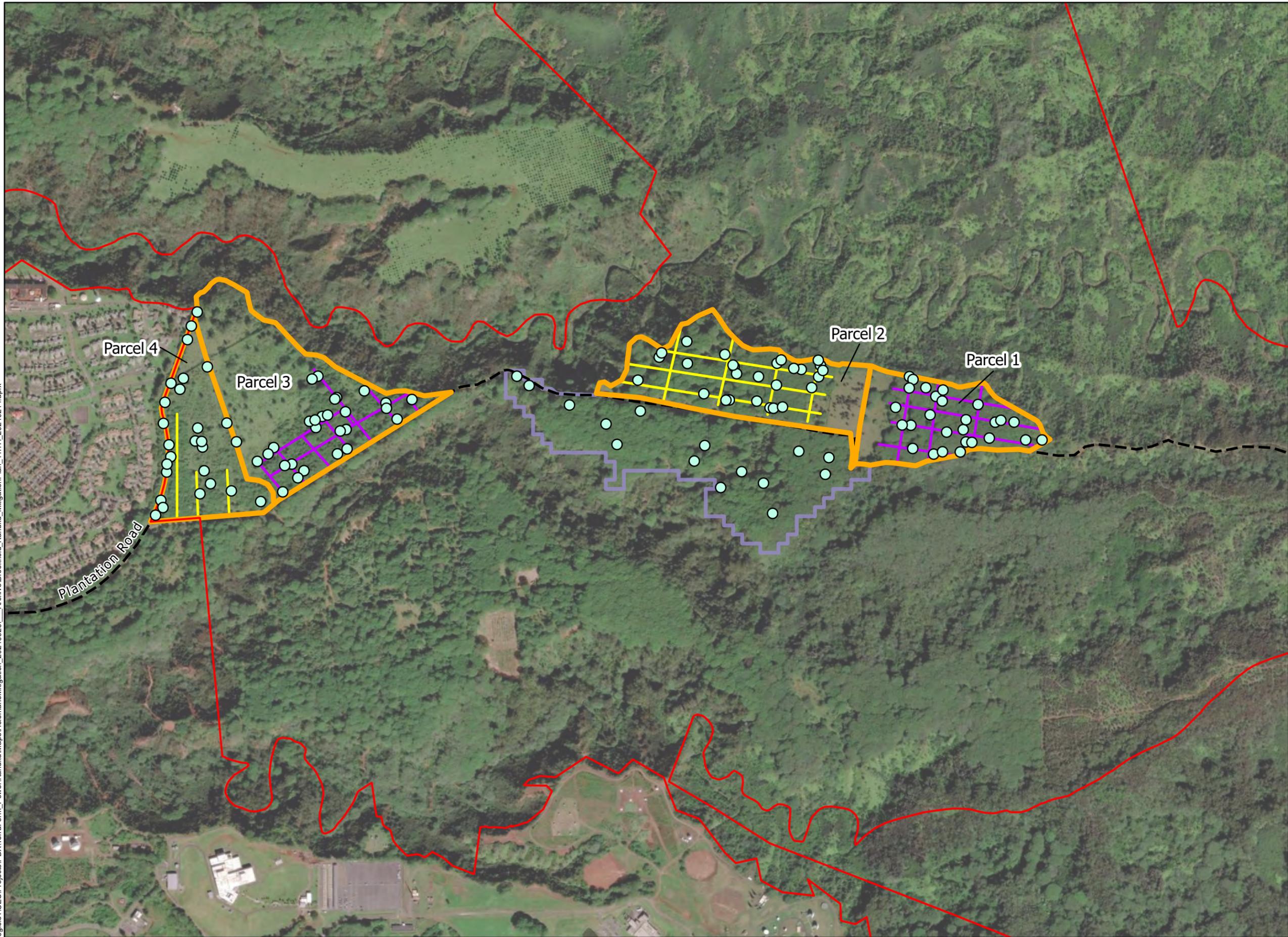
## Figure 1 Helemano Mitigation Area Bat Monitor Locations

HONOLULU COUNTY, HI

- Helemano Section
- Helemano Mitigation Area (HMA)
- Control Area
- KAH-proposed Corridors (2023)
- DOFAW-created Corridors (2022): To Be Maintained by KAH
- Acoustic Monitoring Stations
- Access Road



### Reference Map

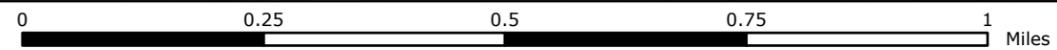


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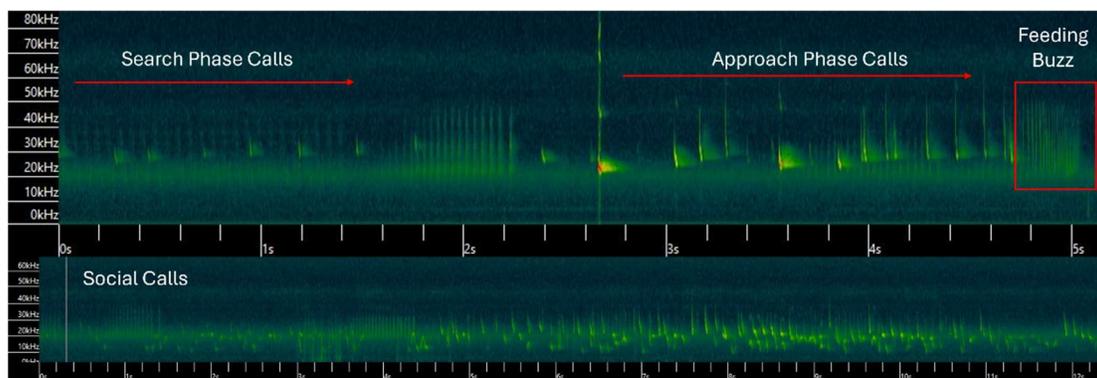
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Call types were categorized into four behavioral classes (Figure 2) and are defined as follows (Pfalzer and Kusch 2003, Gager et al. 2016, Fraser et al. 2020, and Kohles et al. 2020):

- Search phase calls – Echolocation call emitted as a bat is commuting or looking for food; characterized by regular consistent call characteristics with a narrower bandwidth, longer duration and inter-pulse interval, and a weaker harmonic, ranging between 35 and 20 kHz,
- Approach phase calls – Steep broadband pulses of short duration and inter-pulse interval with a prominent harmonic, typically ranging between 80 and 20 kHz.
- Feeding buzzes – The terminal phase of an echolocation sequence that results in numerous rapidly produced calls during the approach to a potential prey,
- Social calls – vocalizations produced in addition to echolocation calls to transfer information to conspecifics related to agonistic encounters and territoriality, mate attraction, and parental care.



**Figure 2. Spectrogram Showing the Various Call Type Categories of the Hawaiian Hoary Bat**

### 2.1.2 Insect Monitoring

Tetra Tech conducted quarterly sampling of insects throughout the HMA in August and November of 2023, and March and June of 2024. Three Sea Land and Air Malaise (SLAM) traps and one ultraviolet (UV) light trap (Australian Entomological Supplies, NSW, AUS) were deployed at fixed locations in each of the four mitigation parcels and the control site (15 SLAM traps and five UV lights; Figure 3). Random sampling of cattle dung was also conducted in the mitigation parcels, excluding the control site. During each quarterly sampling event, SLAM traps were deployed for 30 days, and light traps were deployed for 3 consecutive nights coinciding with the period of the new moon. Light trap sampling consisted of 3-hour-long sampling periods per sampling night. All potential bat prey insects with a body length 3 millimeters or greater were identified to the lowest taxonomic level possible, as well as counted and measured to the nearest millimeter.

Biomass of collected insects was calculated using the weight-length relationship determined by Gruner (2003):

$$y = a(x)^b$$

Where  $y$  = dry biomass,  $x$  = size measurement, either length or length \* width;  $a$  and  $b$  are coefficients estimated through linear regression procedures for each taxon.

# Kahuku Wind Power LLC

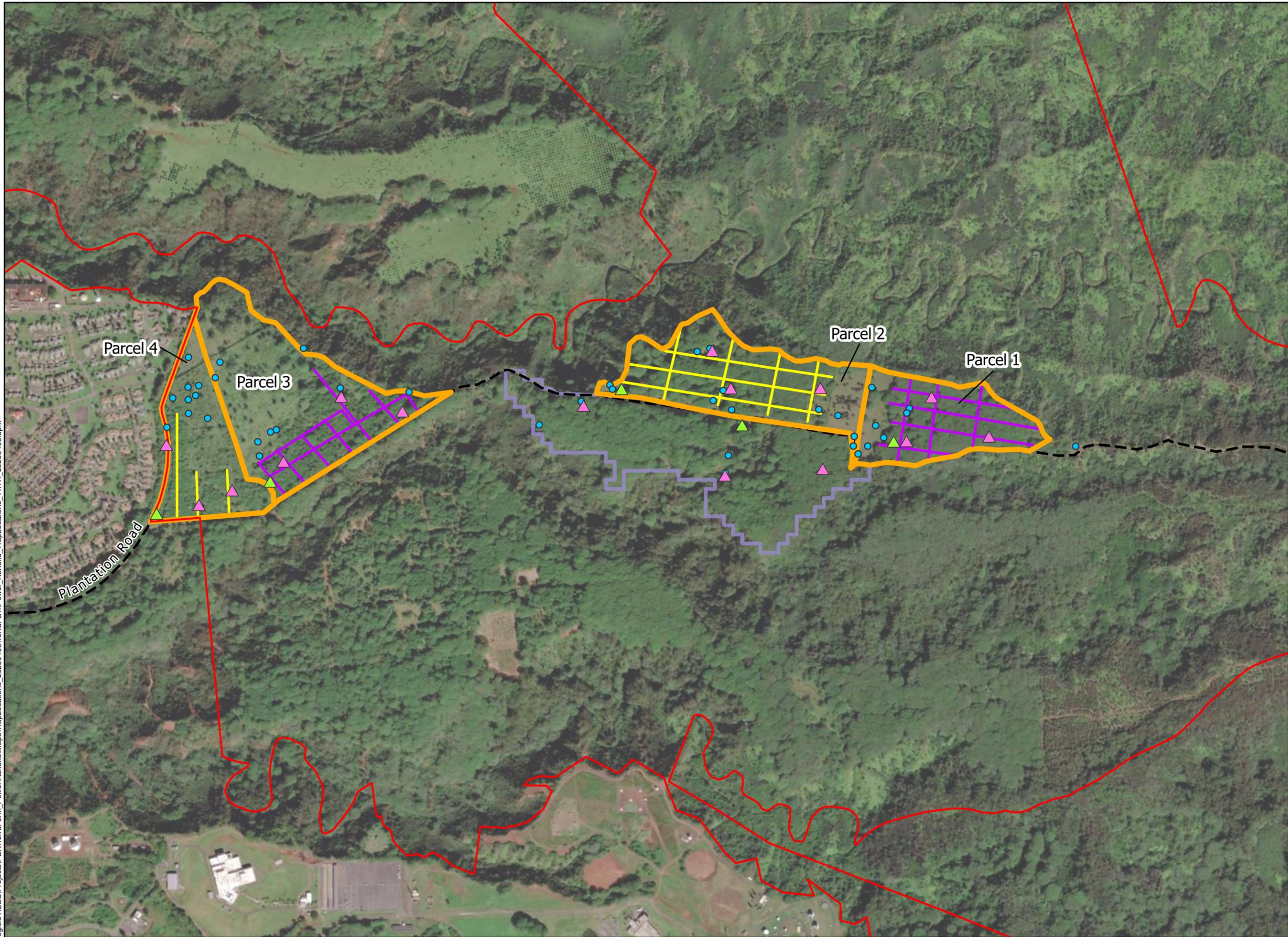
## Figure 3 Helemano Mitigation Arthropod Sampling Locations

HONOLULU COUNTY, HI

- Helemano Section
- Helemano Mitigation Area (HMA)
- Control Area
- KAH-proposed Corridors (2023)
- DOFAW-created Corridors (2022): To Be Maintained by KAH
- Malaise Traps
- Light Traps
- Dung Samples
- Access Road



Reference Map

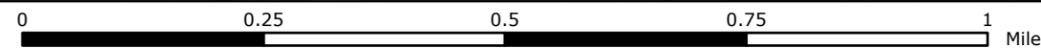


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## 2.2 Statistical Analysis

To best understand baseline conditions of bat and insect activity at the HMA, three separate but complementary analyses were conducted, each aligned with the structure, temporal resolution, and objectives of the respective datasets. First, nightly bat acoustic detections were analyzed over a full year to evaluate spatial and seasonal variation in the proportion of nights with detections and to characterize behavioral call types, including search phase calls, approach phase calls, and feeding buzzes. Second, insect biomass was assessed across mitigation parcels and quarterly sampling periods to quantify seasonal trends in prey availability. Third, the relationship between insect biomass and bat detection rates was examined to determine whether bat activity corresponded with fluctuations in insect abundance across parcels and reproductive periods.

Each analysis is described in detail in Sections 2.2.1 through 2.2.3. These distinct analytical approaches allowed us to fully utilize each dataset within its appropriate context while providing a comprehensive assessment of the baseline conditions prior to mitigation implementation.

### 2.2.1 Bat Acoustic Data

To evaluate differences in the proportion of nights with bat detections across mitigation parcels and monthly sampling periods, we fit a generalized linear mixed-effects model (GLMM) with a binomial error structure using the ‘lme4’ package (Bates et al. 2015) in R version 4.4.2 (R Core Team 2024). The model included mitigation parcel and sampling month as fixed effects, and Site ID was included as a random intercept to account for repeated measures within sites. Model optimization was performed using the “bobyqa” optimizer with increased iteration limits to ensure convergence. Type III ANOVA tests were used to assess the significance of fixed effects using the ‘car’ package (Fox 2019). Model residuals were checked for overdispersion. Post-hoc pairwise comparisons among parcels and months were conducted using estimated marginal means (EMMs) on the logit scale with Tukey-adjusted p-values using the ‘emmeans’ package (Lenth 2025).

To assess spatial and seasonal variation in bat behavioral activity, three binomial GLMMs were fitted for search phase calls, approach phase calls, and feeding buzzes. For each call type model mitigation parcel and sampling month were included as fixed effects and Site ID as a random intercept. Model fitting, optimization, diagnostics, and post-hoc pairwise comparisons followed the procedures as described above. Type III ANOVA tables were used to evaluate the significance of predictors, and overdispersion was checked using the same custom function.

Due to low call frequency, especially for approach phase and feeding buzz events, convergence warnings and singular fits were encountered in some models. These results were interpreted with caution. All models employed an alpha value of 0.05 and were conducted in R version 4.2.2 (R Core Team 2024).

### 2.2.2 Insect Data

To evaluate differences in insect biomass across mitigation parcels and quarterly sampling periods, we used GLMM with a Gamma distribution and log-link function to account for the continuous and right-skewed nature of the biomass data (Zuur et al. 2009). The model included mitigation parcel, sampling period, and their interaction as fixed effects and trap ID as a random effect to account for

repeated measures within traps over time. Model fit was evaluated using residual diagnostics and posterior predictive checks. Type III ANOVA tests were used to assess the significance of fixed effects in the model. We calculated the EMMs of insect biomass for each mitigation parcel within each sampling period and back-transformed these estimates to the original biomass scale for interpretability. A pairwise comparison between mitigation parcels was conducted within each sampling period using Tukey's method for multiple comparisons and we provide the ratios of means (i.e., fold changes) along with corresponding p-values to indicate the magnitude and significance of differences in estimated mean insect biomass between parcels for each sampling period. All analyses were conducted in R version 4.2.2 (R Core Team 2024) using the 'glmmTMB', 'car', 'emmeans', and 'performance' packages (Fox 2019, Lenth 2025, McGillicuddy et al. 2025, Lüdtke et al. 2021), with significance assessed at  $\alpha = 0.05$ .

### 2.2.3 Bat and Insect Activity

To examine the effects of insect biomass, mitigation parcel, and reproductive period on bat activity at the HMA, a linear model (LM) was constructed in R version 4.4.2 (R Core Team 2024). Bat detection rates and insect biomass were standardized by summarizing means within each mitigation parcel and reproductive period. A linear mixed-effects model (LMM) which included mean bat detection rates as the response, and mean insect biomass (log-transformed), mitigation parcel, and reproductive period as predictors with site as a random effect was initially constructed using the 'lme4' package (Bates et al. 2015) in R to account for repeated sampling across sites. However, the variance component for the site random intercept was estimated as zero, indicating singularity issues and suggesting that the random effect did not contribute to explaining variance in the data. Unlike in Section 2.2.1, where convergence warnings were retained and results interpreted with caution due to sparse event data, the random effect was excluded here after a likelihood ratio test showed no improvement in model fit ( $\chi^2 = 1, p = 1$ ). This justified the use of the simpler linear model for interpretation.

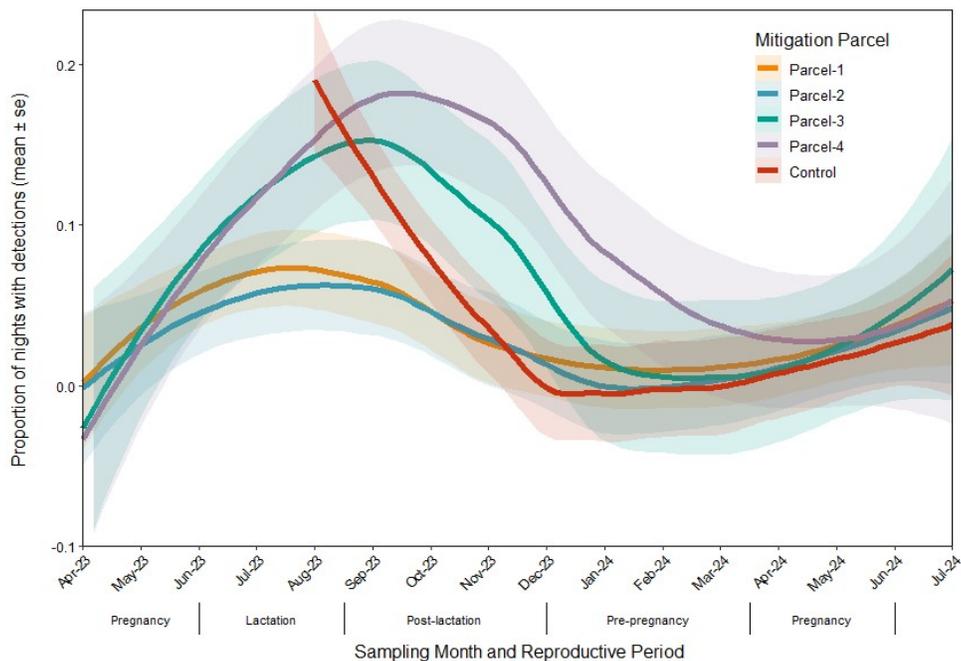
A global LM was constructed that included mean bat detection rates as the response variable and mean insect biomass (log-transformed), mitigation parcel, and reproductive period as explanatory variables, and included all additive effects, two-way, and three-way interactions to assess context-dependent effects of insect biomass across parcels and seasonal reproductive periods (Appendix C, Table 3). To identify the most parsimonious model, we used the 'MuMIn' package (Barton 2025) in R to conduct model selection based on Akaike's Information Criterion corrected for small sample sizes (AICc). The dredge function was applied to the global model to generate all possible subset models, which were then ranked according to their AICc values. The top-ranked model was selected for further interpretation and summary. Model diagnostics, including residual plots and Q-Q plots, were reviewed to assess homoscedasticity and assumptions of normality for the final model.

## 3.0 RESULTS

### 3.1 Bat Activity

Between April 2023 and July 2024, Hawaiian hoary bats were detected on 287 out of 6,172 monitoring nights (4.7 percent) across the four mitigation parcels and the control site. Bat activity exhibited a strong seasonal pattern, with detection rates increasing through the pregnancy and lactation reproductive periods (April – July 2023) and peaking during the late lactation and early post-lactation reproductive periods (August and September 2023), followed by a sharp decline during the late post-

lactation and pre-pregnancy reproductive periods (October – February). A modest resurgence in detections was observed beginning at the end of the pre-pregnancy reproductive period (March 2024) and continuing into the pregnancy reproductive period (Figure 4).

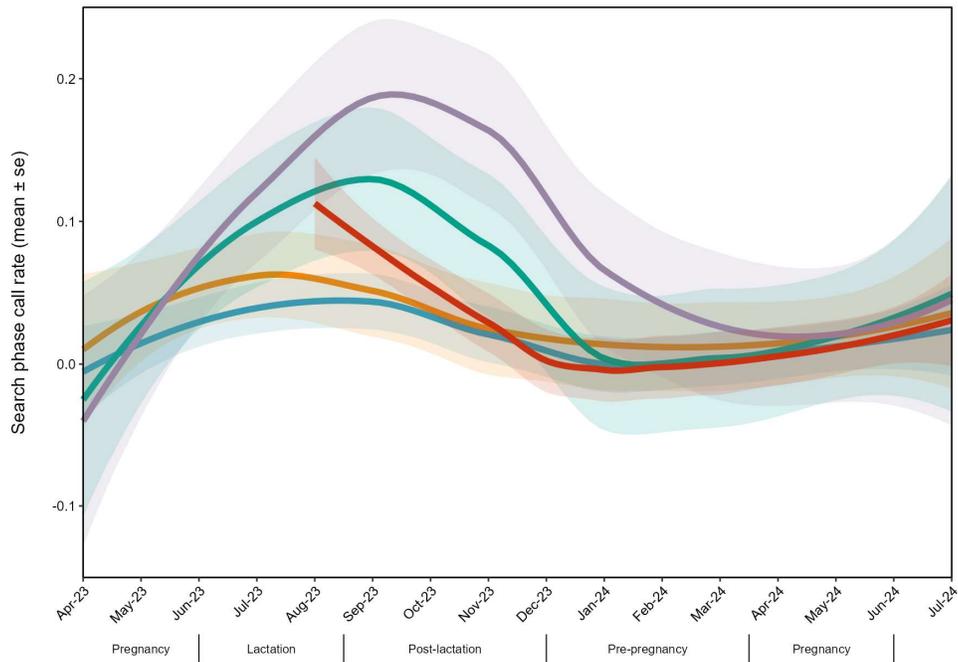


**Figure 4. Monthly Mean Detection Rates with Standard Error at Each Mitigation Parcel and the Control Site**

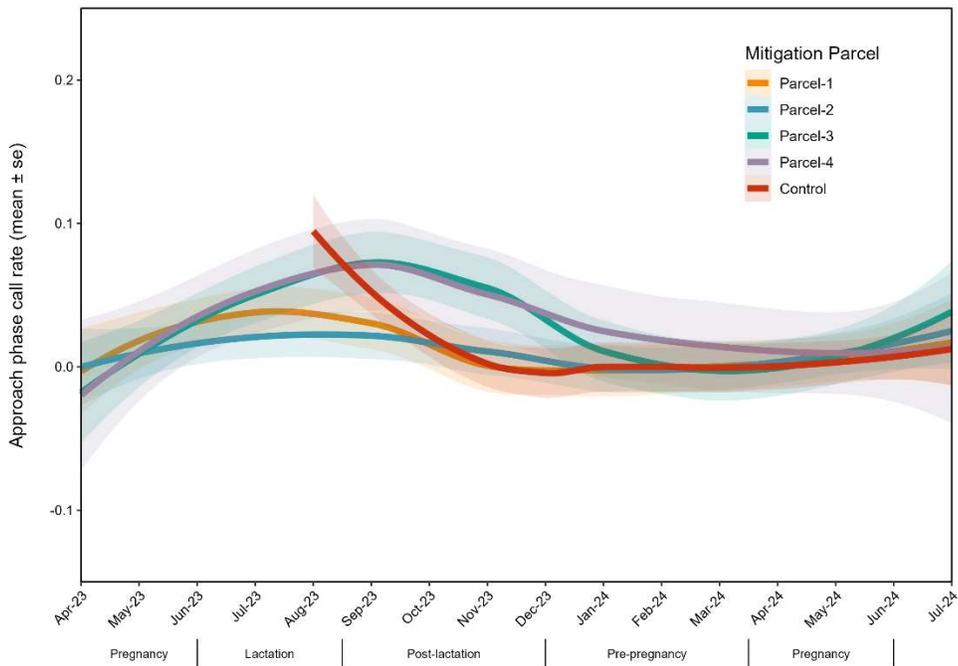
Bat detection rates varied significantly across mitigation parcel and reproductive period (GLMM; Parcel:  $\chi^2 = 30.80$ ,  $p < 0.001$ ; Reproductive Period:  $\chi^2 = 104.33$ ,  $p < 0.001$ ). Parcel 4 consistently exhibited the highest detection rates, particularly during the late lactation and post-lactation reproductive periods and was significantly higher compared to Parcel 1 ( $p < 0.001$ ), Parcel 2 ( $p < 0.001$ ), and the control site ( $p < 0.002$ ). Parcel 3 also demonstrated elevated activity similar to Parcel 4 but declined more sharply in October of the post-lactation reproductive period. Parcels 1 and 2 maintained low and relatively stable bat activity throughout the year, indicating limited use. The control site showed a distinct but short-lived spike in detections during the late lactation reproductive period (August 2023) before dropping off sharply (Figure 4 and Appendix A, Table 1).

The seasonal and spatial patterns observed in bat detection rates were also reflected in the behavioral call data (Figures 5, 6, and 7), with mitigation parcel and reproductive period significantly influencing both search phase calls (GLMM; Parcel:  $\chi^2 = 37.70$ ,  $p < 0.001$ ; Reproductive Period:  $\chi^2 = 96.37$ ,  $p < 0.001$ ; Figure 5) and approach phase calls (GLMM; Parcel:  $\chi^2 = 13.60$ ,  $p = 0.009$ ; Reproductive Period:  $\chi^2 = 44.01$ ,  $p < 0.001$ ; Figure 6). Search phase calls, which indicated general movement and exploration, were the most frequently detected behavioral call type and were significantly higher in Parcel 4 compared to Parcel 1 ( $p < 0.001$ ), Parcel 2 ( $p < 0.001$ ) and the Control site ( $p < 0.001$ ). Approach phase calls, associated with more targeted flight, were detected less frequently and occurred primarily in Parcels 4 and 3 and at the Control site. Approach phase calls were significantly higher in Parcel 4 compared to Parcel 1 ( $p < 0.046$ ) and Parcel 2 ( $p = 0.050$ ). The Control site was the only site in which approach phase calls were greater than search phase calls. Feeding buzzes, indicative of active foraging, occurred at much lower rates overall. Parcel 4 and Parcel 3 again recorded the highest

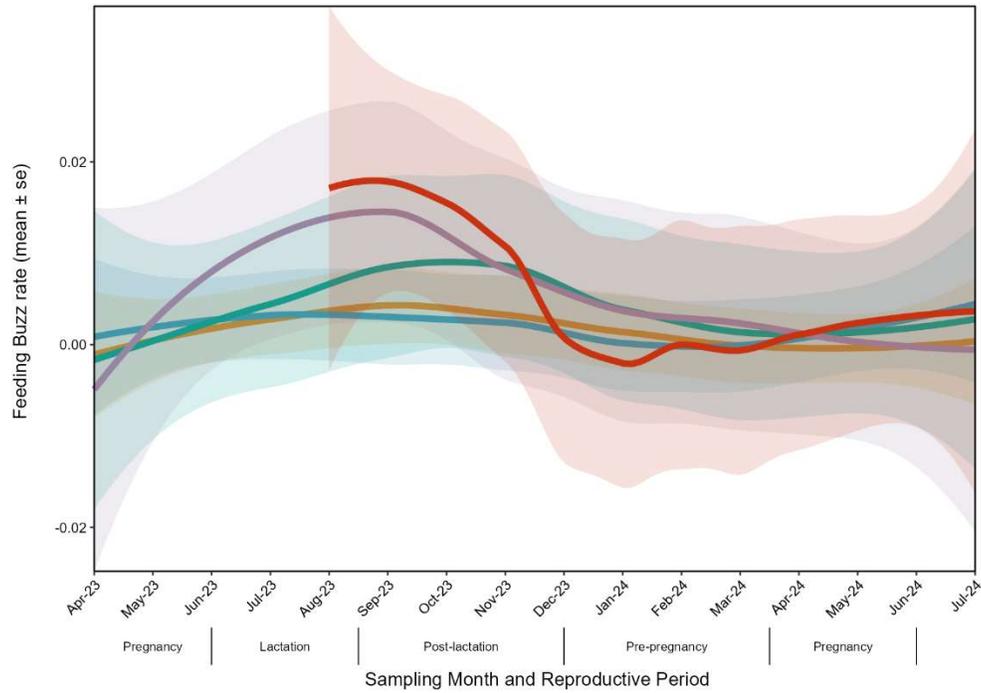
feeding buzz activity (Figure 8). Only two social calls were observed across the entire baseline monitoring year: one at Parcel 2 on August 22, 2023, and one at the control site on August 23, 2023.



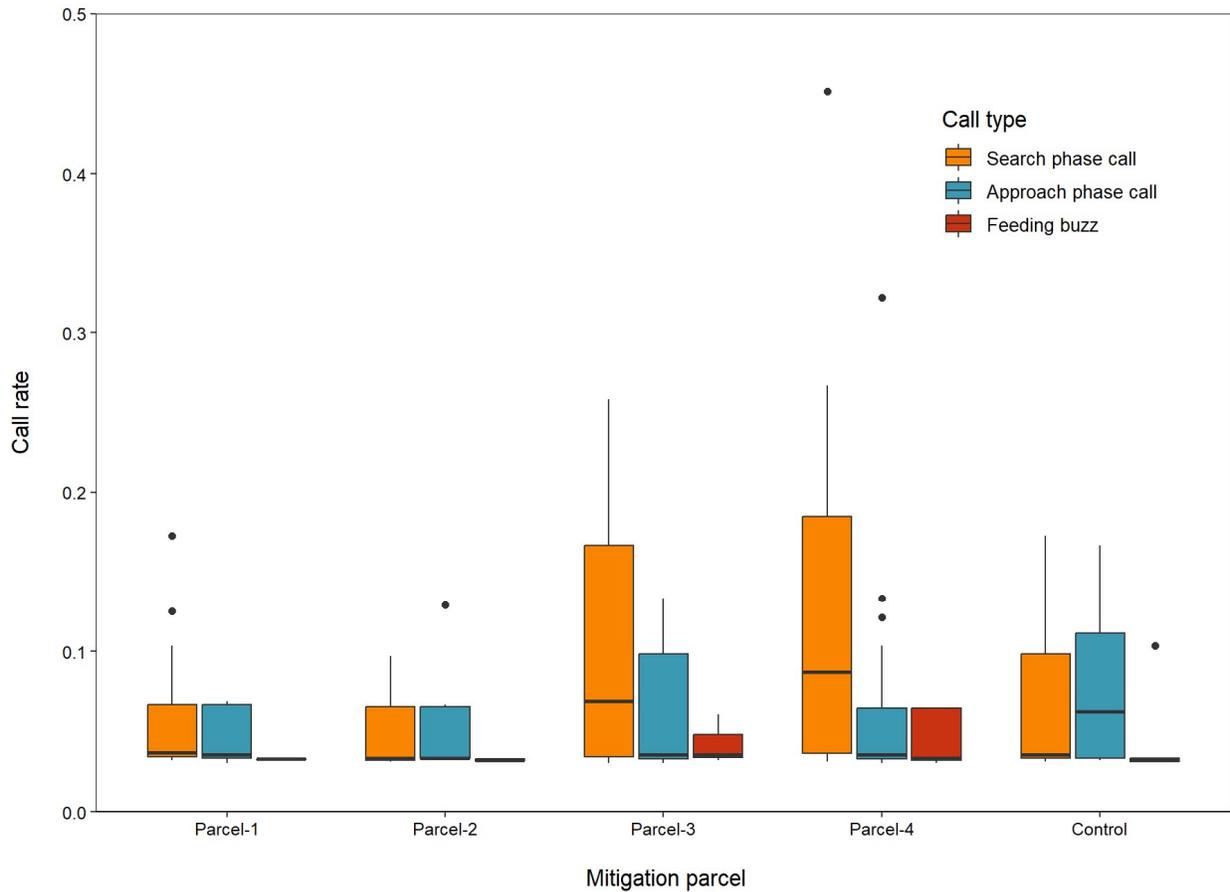
**Figure 5. Monthly Mean Detection Rates with Standard Error for Search Phase Calls at Each Mitigation Parcel and the Control Site**



**Figure 6. Monthly Mean Detection Rates with Standard Error for Approach Phase Calls at each Mitigation Parcel and the Control Site**

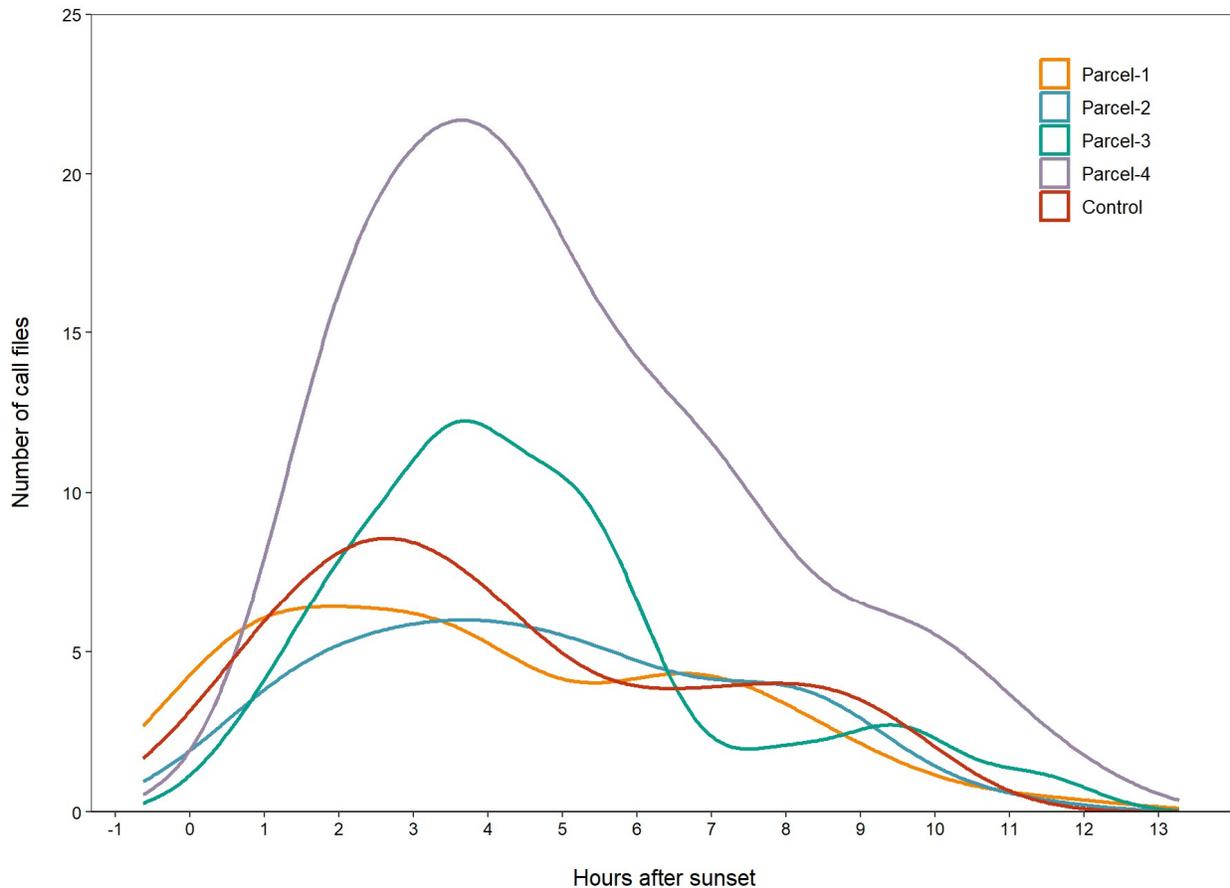


**Figure 7. Monthly Mean Detection Rates with Standard Error for Feeding Buzzes at Each Mitigation Parcel and the Control Site**



**Figure 8. Distribution of Behavioral Call Rates Across Mitigation Parcel and the Control Site**

Bat activity also varied by hour of the night (Figure 9). The earliest bat activity occurred 36 minutes after sunset, typically peaking between 2 to 5 hours after sunset. The latest bat activity was recorded 51 minutes prior to sunrise. Parcel 4 showed the highest and most sustained levels of acoustic activity, maintaining elevated call rates through most of the night. Parcel 3 exhibited a sharp peak approximately 4 hours after sunset followed by a rapid decline, while Parcels 1 and 2 showed more modest and stable levels of nightly activity. The Control site had a prominent peak early in the night, approximately 3 hours after sunset, and a more gradual tapering pattern, suggesting temporal differences in bat foraging behavior among parcels.

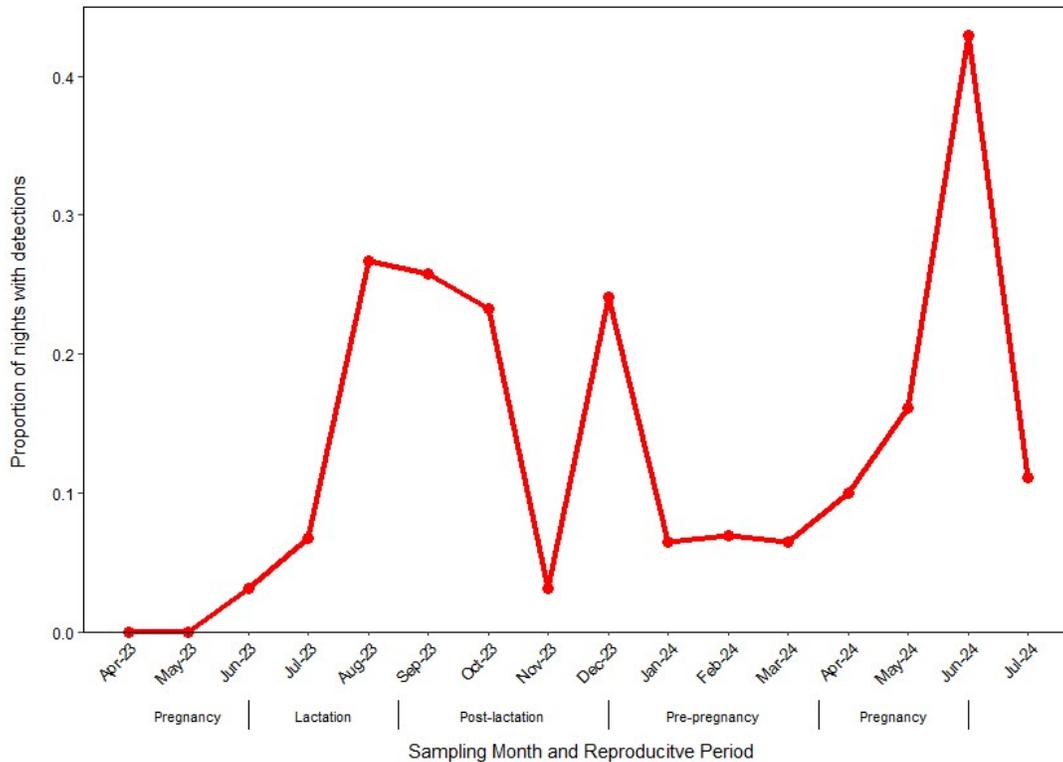


**Figure 9. Hourly Distribution of Hawaiian Hoary Bat Activity After Sunset Across the Four Mitigation Parcels and Control Site**

**3.1.1 Bat Activity at the Water Feature**

At the proposed water feature location, Hawaiian hoary bats were detected on 53 of 453 monitoring nights (11.7 percent). Bat activity was initially low in the beginning during the first monitored pregnancy reproductive period (April and May 2023), with nearly zero detections. Detection rates began to increase at the end of the pregnancy reproductive period (June 2023), peaking in the late lactation and early post-lactation reproductive periods (August and September 2023). Activity declined sharply during middle to late post-lactation reproductive period (November 2023), followed by a brief resurgence at the cusp of the post-lactation and pre-pregnancy reproductive periods (December 2023). Detection rates remained low for the remainder of the pre-pregnancy reproductive period (January – March 2024). A second, more pronounced increase in activity occurred during the

climax of the pregnancy and lactation reproductive periods (June 2024), before declining again in July 2024. However, the largest peak in June 2024 may be a misrepresentation of the true detection rates as there was a substantial loss of data due to detector malfunction (Figure 10; Appendix A, Table 2). Currently no water feature exists at this location.



**Figure 10. Monthly Detection Rates at the Proposed Water Tank Location**

## 3.2 Insect Monitoring

### 3.2.1 Insect Diversity

Over the course of the baseline monitoring year (August 2023 to June 2024), a total of 118 insect sampling events occurred (SLAM,  $n = 60$ ; light traps,  $n = 20$ ; dung,  $n = 38$ ). A total of 77 species of insects were identified, representing 84 genera, 73 families, and 11 orders. There are several insects that remain unidentified at the family ( $n = 39$ ), genus ( $n = 146$ ), and species ( $n = 165$ ) levels. The greatest insect diversity was observed among the orders Lepidoptera (15 families) and Coleoptera (15 families), followed by Diptera (13 families), Hemiptera (10 families) and Hymenoptera (10 families) (Table 1). Native insects consisted of 36 species of Lepidoptera from 30 genera and 13 families; this includes 10 unidentified insects at the species level that were determined to be unique (Table 1).

Comparison of insect prey captured at the HMA to known insect identified in the diet of Hawaiian hoary bats (Appendix B, Table 1) indicates 9 species from 14 Genera and 25 families found in the diet of Hawaiian hoary bats were present at the HMA over the course of this study (Appendix C, Table 1). If Hawaiian hoary bats consume all insect species from the families identified at the HMA this would result in minimum of 84 different species available to Hawaiian hoary bats.

**Table 1. Summary Detailing Number of Insects Collected**

Order	Family	Genus	Species
Blattodea	3	4	4
Coleoptera	15	22	20
Dermaptera	1	1	1
Diptera	13	3	3
Hemiptera	10	10	10
Hymenoptera	10	4	4
Lepidoptera	15	36	31
Neuroptera	2	0	0
Orthoptera	2	3	3
Psocodea	1	0	0
Trichoptera	1	1	1
Unidentified	39	146	165

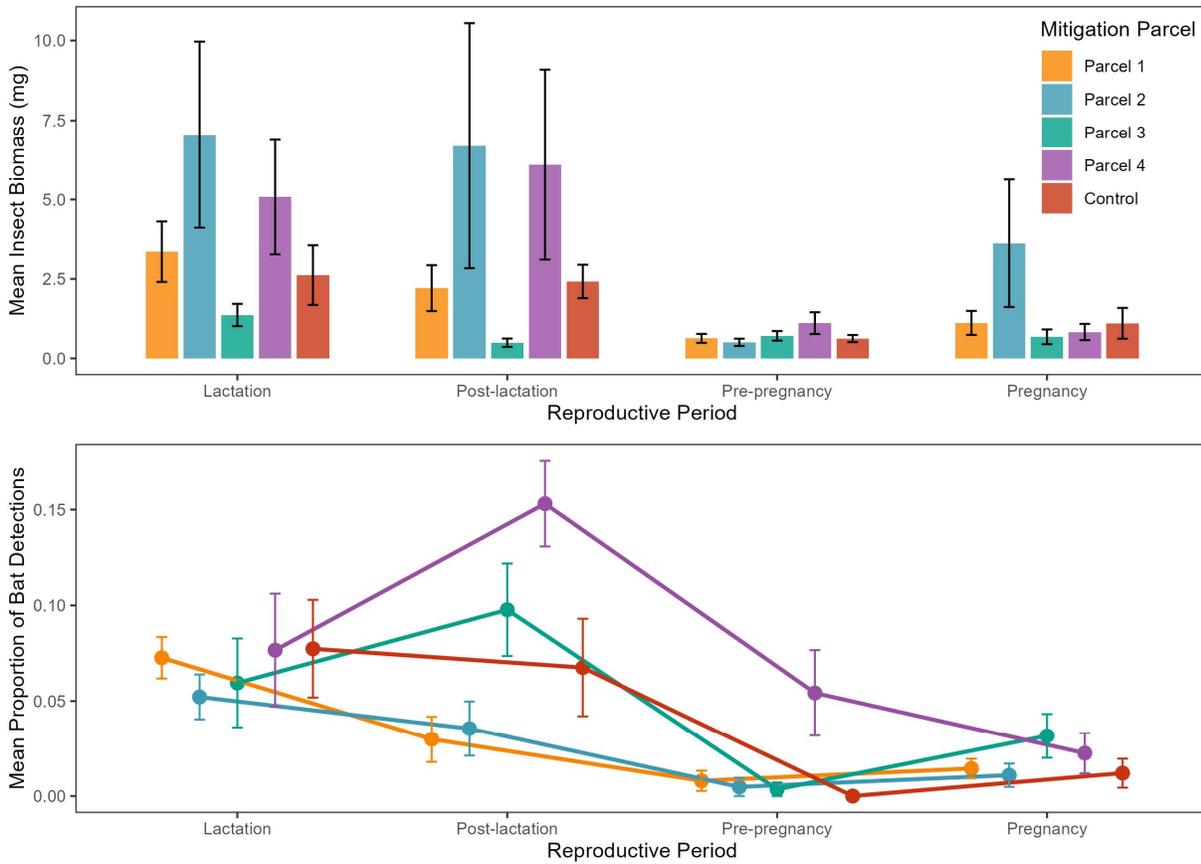
### 3.2.2 Insect Biomass

Estimated mean insect biomass varied significantly across mitigation parcels and bat reproductive periods (GLMM:  $R^2 = 24.5$  percent; Parcel:  $\chi^2 = 91.04$ ,  $df = 4$ ,  $p < 0.001$ ; Reproductive Period:  $\chi^2 = 83.81$ ,  $df = 3$ ,  $p < 0.001$ ). The highest amounts of insect biomass were observed during the bat lactation and post-lactation reproductive period for all parcels and the control site, excluding Parcel 3. In Parcel 3, mean insect biomass decreased in the post-lactation reproductive period. In the lactation reproductive period mean insect biomass at Parcel 2 was between 2.13 and 5.11 times greater compared to Parcels 1 (2.13x,  $p < 0.001$ ), Parcel 3 (5.11x,  $p < 0.001$ ), and the Control site (2.68x,  $p < 0.001$ ), and at Parcel 4 insect biomass was between 1.9 and 3.6 times greater than Parcels 3 (3.60x,  $p < 0.001$ ) and the Control site (1.89x,  $p < 0.006$ ) (Figure 11 and Appendix C, Table 2).

In the post-lactation reproductive period, mean insect biomass remained high across most parcels and the control site, except for Parcel 3, which showed relatively lower values. At Parcel 2, mean insect biomass was between 2.7 and 13.1 times greater compared to Parcel 1 (2.96x,  $p < 0.001$ ), Parcel 3 (13.07x,  $p < 0.001$ ), and the control site (2.68x,  $p < 0.001$ ). Parcel 4, which showed an increase in mean insect biomass from the lactation reproductive period, had values between 2.5 and 12.1 times higher compared to Parcel 1 (2.74x,  $p < 0.001$ ), Parcel 3 (12.07x,  $p < 0.001$ ), and the Control site (2.49x,  $p < 0.001$ ) (Figure 11 and Appendix C, Table 2).

Overall, mean insect biomass significantly decreased across all parcels and the control site in the pre-pregnancy reproductive period (GLMM:  $z = -7.860$ ,  $p < 0.001$ ). During the pre-pregnancy reproductive period, mean insect biomass was significantly higher at Parcel 4 and between 1.7 and 2.2x greater compared to Parcel 1 (1.74x,  $p < 0.021$ ), Parcel 2 (2.17x,  $p < 0.001$ ), and the Control site (1.75x,  $p < 0.020$ ). Parcel 2 demonstrated the lowest level of mean insect biomass in the pre-pregnancy reproductive period and the second lowest mean insect biomass across mitigation parcels and reproductive periods (Figure 11 and Appendix C Table 2).

In the pregnancy reproductive period, mean insect biomass increased at Parcels 1, 2 and the Control site but remained relatively stable at Parcels 3 and 4. The most significant increase in mean insect biomass was observed at Parcel 2 which ranged between 3.3 and 5.3 times higher compared to Parcel 1 (3.34x,  $p < 0.001$ ), Parcel 3 (5.43x,  $p < 0.001$ ), Parcel 4 (4.40x,  $p < 0.001$ ), and the control site (3.30x,  $p < 0.001$ ) (Figure 11 and Appendix C Table 2).



**Figure 11. Mean Insect Biomass (Top) and Mean Proportion of Bat Detections (Bottom) With Standard Error Across Reproductive Periods by Mitigation Parcel and Control Site**

### 3.3 Bat Activity and Insect Biomass

The best model predicting bat activity included mean insect biomass, parcel, and reproductive period without any interactions ( $\Delta AICc \leq 2$ , weight of 0.67; Appendix C, Table 1) and explained approximately 59% of the variance in mean detections rates of bats at the HMA (Multiple  $R^2 = 59.1$  percent, Adjusted  $R^2 = 52.7$  percent).

Mean insect biomass had a significant positive effect on mean bat detection rates (LM:  $t_{8,51} = 2.24, p = 0.029$ ), indicating that higher insect biomass was associated with increased bat activity. This relationship was most evident at Parcels 1, 4, and at the Control site (Figure 11). Parcel 2 had high mean insect biomass and low mean bat detection rates, however the general trend in mean insect biomass and bat detection rates across reproductive season was apparent (Figure 11). Parcel 3 had some of the highest bat detections, especially during the post-lactation and pregnancy reproductive periods. However, it had the lowest mean insect biomass (Figure 11).

## 4.0 DISCUSSION

The baseline monitoring study conducted from March 2023 to June 2024 at the HMA provided useful insight into Hawaiian hoary bat activity and insect prey availability across mitigation parcels and reproductive seasons. Overall, bat activity across the HMA was relatively low, with an annual detection rate of only 4.7 percent of sampling nights across all sites. However, when compared to

results from an island-wide survey on O‘ahu, detection rates at the HMA were well above the median (1.9 percent) and slightly below the mean (5.7 percent) reported across 86 sites (Thompson and Starcevich 2022). A higher annual detection rate (11.7 percent) was observed at the proposed water feature location, which was monitored using a less sensitive SMM-U1 microphone. This higher detection rate may reflect the microphone’s proximity to the large gulch adjacent to the HMA to the north (within 50 feet) and water troughs to the south (within 100 feet) that are frequently visited by cattle.

The seasonal trend in mean bat detection rates, with peaks during late lactation and early post-lactation periods and declines during late post-lactation and pre-pregnancy periods, aligns with established seasonal patterns for the species in Hawai‘i (Menard 2001, Todd 2012, Gorresen et al. 2013, Thompson and Starcevich 2022, Hoeh et al. 2023). Seasonal fluctuations in mean insect biomass mirrored these patterns, and the significant positive correlation between mean insect biomass and mean bat detection rates across reproductive periods further supports the link between prey availability and bat activity, consistent with findings from diet studies on Hawai‘i Island (Todd 2012) and O‘ahu (Gorresen et al. 2018). The lack of significant interaction effects indicates that the influence of insect biomass on bat activity did not differ across parcels or reproductive periods, suggesting a generally consistent relationship across the mitigation area. Notably, the variation in this relationship, particularly the low bat activity at Parcel 2 despite high insect biomass, and the higher activity at Parcel 3 despite low insect biomass, highlights the importance of habitat quality (i.e., structure) alongside prey availability in shaping bat use of the HMA.

Habitat structure likely influenced these patterns, as Parcel 3 consists primarily of open pasture and forest edge, while Parcel 2 is characterized by closed-canopy *Albizia* (*Falcataria moluccana*) with a shoebutton ardisia (*Ardisia elliptica*) understory and a semi-open interior foraging corridor approximately 50 feet wide. The protection from wind in Parcel 2 may facilitate higher insect biomass, while the limited canopy openings may restrict bat foraging access. Expanding and extending foraging corridors to forest edges could increase accessibility for bats and encourage greater foraging activity in Parcel 2 as mitigation progresses.

Analyses of call types indicated a relatively low proportion of feeding buzzes and almost no social calls, suggesting limited active foraging and low multi-individual use of the site during baseline monitoring. Monitoring also revealed that the first bat calls were typically detected within 30 minutes after sunset, while the last calls occurred approximately one hour before sunrise. Continued monitoring of the timing of nightly activity in future years will help evaluate whether bat activity shifts closer to sunset and sunrise, which may indicate roosting within the vicinity or use of the site as a preferred foraging area immediately upon emergence from roost sites.

Collectively, these baseline findings establish a robust reference point for future assessments of habitat enhancement effectiveness at the HMA. Continued monitoring will be essential to detect changes in bat activity and prey availability as habitat enhancement measures are implemented to ensure that mitigation objectives, including increased bat activity, prey availability, and habitat suitability, are achieved. Additionally, future analyses incorporating habitat structure variables, vegetation changes, and detailed insect diversity metrics may provide a more comprehensive understanding of the mechanisms driving bat use across the HMA.

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## **APPENDIX A: ACOUSTIC MONITORING RESULTS**

**Table 1. Overall Number and Proportion of Detections per Night per Month**

Sampling Month, Year & Reproductive Period	Mitigation Parcel	Sampling location ID	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections	Proportion of Nights with Detections (Mean ± SE)
April 2023 (Pregnancy)	Parcel 1	TT-133	23	0	0.000	0.000 ± 0.000
		TT-134	23	0	0.000	
		TT-135	28	0	0.000	
	Parcel 2	TT-136	24	0	0.000	0.000 ± 0.000
		TT-137	24	0	0.000	
		TT-138	24	0	0.000	
	Parcel 3	TT-139	20	0	0.000	0.000 ± 0.000
		TT-140	30	0	0.000	
		TT-141	24	0	0.000	
	Parcel 4	TT-142	27	1	0.037	0.012 ± 0.015
		TT-143	24	0	0.000	
		TT-144	27	0	0.000	
May 2023 (Pregnancy)	Parcel 1	TT-121	30	0	0.000	0.011 ± 0.014
		TT-122	30	0	0.000	
		TT-123	30	1	0.033	
	Parcel 2	TT-124	31	1	0.032	0.032 ± 0.023
		TT-125	31	0	0.000	
		TT-126	31	2	0.065	
	Parcel 3	TT-127	0	NA	NA	0.032 ± 0.046
		TT-128	31	0	0.000	
		TT-129	31	2	0.065	
	Parcel 4	TT-130	31	0	0.000	0.000 ± 0.000
		TT-131	31	0	0.000	
		TT-132	31	0	0.000	
June 2023 (Pre-pregnancy/Lactation)	Parcel 1	TT-109	0	NA	NA	0.094 ± 0.000
		TT-110	0	NA	NA	
		TT-111	32	3	0.094	
	Parcel 2	TT-112	32	0	0.000	0.042 ± 0.034
		TT-113	32	3	0.094	
		TT-114	32	1	0.031	
	Parcel 3	TT-115	0	NA	NA	0.047 ± 0.066
		TT-116	32	0	0.000	
		TT-117	32	3	0.094	
	Parcel 4	TT-118	32	1	0.031	0.021 ± 0.013
		TT-119	32	1	0.031	
		TT-120	32	0	0.000	
July 2023 (Lactation)	Parcel 1	TT-097	0	NA	NA	0.069 ± 0.000
		TT-098	29	2	0.069	
		TT-099	0	NA	NA	
	Parcel 2	TT-100	30	1	0.033	0.022 ± 0.014
		TT-101	30	1	0.033	
		TT-102	30	0	0.000	
	Parcel 3	TT-103	0	NA	NA	0.069 ± 0.000
		TT-104	0	NA	NA	
		TT-105	29	2	0.069	
	Parcel 4	TT-106	29	3	0.103	0.069 ± 0.042
		TT-107	29	0	0.000	
		TT-108	29	3	0.103	

Sampling Month, Year & Reproductive Period	Mitigation Parcel	Sampling location ID	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections	Proportion of Nights with Detections (Mean ± SE)
August 2023 (Lactation)	Parcel 1	TT-085	29	4	0.138	0.124 ± 0.015
		TT-086	30	3	0.100	
		TT-087	30	4	0.133	
	Parcel 2	TT-088	30	3	0.100	0.089 ± 0.014
		TT-089	30	3	0.100	
		TT-090	30	2	0.067	
	Parcel 3	TT-091	0	NA	NA	0.129 ± 0.137
		TT-092	31	1	0.032	
		TT-093	31	7	0.226	
	Parcel 4	TT-094	31	14	0.452	0.215 ± 0.152
		TT-095	31	5	0.161	
		TT-096	31	1	0.032	
	Control	TT-C01	30	3	0.100	0.167 ± 0.047
		TT-C02	30	7	0.233	
		TT-C03	30	5	0.167	
September 2023 (Post-lactation)	Parcel 1	TT-073	32	0	0.000	0.040 ± 0.049
		TT-074	32	0	0.000	
		TT-075	33	4	0.121	
	Parcel 2	TT-076	31	3	0.097	0.075 ± 0.026
		TT-077	31	1	0.032	
		TT-078	31	3	0.097	
	Parcel 3	TT-079	0	NA	NA	0.258 ± 0.000
		TT-080	0	NA	NA	
		TT-081	31	8	0.258	
	Parcel 4	TT-082	31	4	0.129	0.161 ± 0.046
		TT-083	0	NA	NA	
		TT-084	31	6	0.194	
	Control	TT-C04	32	9	0.281	0.168 ± 0.070
		TT-C05	31	3	0.097	
		TT-C06	32	4	0.125	
October 2023 (Post-lactation)	Parcel 1	TT-061	30	0	0.000	0.022 ± 0.027
		TT-062	30	2	0.067	
		TT-063	30	0	0.000	
	Parcel 2	TT-064	30	4	0.133	0.067 ± 0.047
		TT-065	30	2	0.067	
		TT-066	30	0	0.000	
	Parcel 3	TT-067	0	NA	NA	0.133 ± 0.000
		TT-068	30	4	0.133	
		TT-069	0	NA	NA	
	Parcel 4	TT-070	30	5	0.167	0.233 ± 0.094
		TT-071	0	NA	NA	
		TT-072	30	9	0.300	
	Control	TT-C07	30	1	0.033	0.092 ± 0.051
		TT-C08	29	5	0.172	
			TT-C09	29	2	0.069

Sampling Month, Year & Reproductive Period	Mitigation Parcel	Sampling location ID	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections	Proportion of Nights with Detections (Mean ± SE)
November 2023 (Post-lactation)	Parcel 1	TT-049	27	0	0.000	0.033 ± 0.023
		TT-050	28	1	0.036	
		TT-051	31	2	0.065	
	Parcel 2	TT-052	33	0	0.000	0.000 ± 0.000
		TT-053	28	0	0.000	
		TT-054	32	0	0.000	
	Parcel 3	TT-055	33	3	0.091	0.061 ± 0.043
		TT-056	0	NA	NA	
		TT-057	33	1	0.030	
	Parcel 4	TT-058	33	6	0.182	0.123 ± 0.041
		TT-059	30	2	0.067	
		TT-060	33	4	0.121	
	Control	TT-C10	33	0	0.000	0.011 ± 0.014
		TT-C11	30	1	0.033	
		TT-C12	33	0	0.000	
December 2023 (Post-lactation/Pre-pregnancy)	Parcel 1	TT-037	28	0	0.000	0.023 ± 0.028
		TT-038	29	2	0.069	
		TT-039	30	0	0.000	
	Parcel 2	TT-040	28	0	0.000	0.000 ± 0.000
		TT-041	26	0	0.000	
		TT-042	30	0	0.000	
	Parcel 3	TT-043	29	0	0.000	0.057 ± 0.037
		TT-044	29	3	0.103	
		TT-045	29	2	0.069	
	Parcel 4	TT-046	29	2	0.069	0.124 ± 0.067
		TT-047	30	7	0.233	
		TT-048	29	2	0.069	
	Control	TT-C13	29	0	0.000	0.000 ± 0.000
		TT-C14	29	0	0.000	
		TT-C15	29	0	0.000	
January 2024 (Pre-pregnancy)	Parcel 1	TT-025	27	0	0.000	0.013 ± 0.016
		TT-026	25	0	0.000	
		TT-027	26	1	0.038	
	Parcel 2	TT-028	33	0	0.000	0.000 ± 0.000
		TT-029	27	0	0.000	
		TT-030	29	0	0.000	
	Parcel 3	TT-031	31	1	0.032	0.011 ± 0.013
		TT-032	31	0	0.000	
		TT-033	30	0	0.000	
	Parcel 4	TT-034	33	7	0.212	0.112 ± 0.065
		TT-035	32	1	0.031	
		TT-036	32	3	0.094	
	Control	TT-C16	30	0	0.000	0.000 ± 0.000
		TT-C17	31	0	0.000	
		TT-C18	34	0	0.000	

Sampling Month, Year & Reproductive Period	Mitigation Parcel	Sampling location ID	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections	Proportion of Nights with Detections (Mean ± SE)
February 2024 (Pre-pregnancy)	Parcel 1	TT-013	23	0	0.000	0.000 ± 0.000
		TT-014	23	0	0.000	
		TT-015	23	0	0.000	
	Parcel 2	TT-016	23	0	0.000	0.014 ± 0.018
		TT-017	23	1	0.043	
		TT-018	23	0	0.000	
	Parcel 3	TT-019	23	0	0.000	0.000 ± 0.000
		TT-020	23	0	0.000	
		TT-021	23	0	0.000	
	Parcel 4	TT-022	23	1	0.043	0.029 ± 0.018
		TT-023	23	1	0.043	
		TT-024	23	0	0.000	
	Control	TT-C19	23	0	0.000	0.000 ± 0.000
		TT-C20	23	0	0.000	
		TT-C21	23	0	0.000	
March 2024 (Pre-pregnancy)	Parcel 1	TT-001	29	1	0.034	0.011 ± 0.014
		TT-002	30	0	0.000	
		TT-003	29	0	0.000	
	Parcel 2	TT-004	30	0	0.000	0.000 ± 0.000
		TT-005	29	0	0.000	
		TT-006	30	0	0.000	
	Parcel 3	TT-007	28	0	0.000	0.000 ± 0.000
		TT-008	28	0	0.000	
		TT-009	28	0	0.000	
	Parcel 4	TT-010	31	2	0.065	0.022 ± 0.026
		TT-011	29	0	0.000	
		TT-012	30	0	0.000	
	Control	TT-C22	30	0	0.000	0.000 ± 0.000
		TT-C23	30	0	0.000	
		TT-C24	30	0	0.000	
April 2024 (Pregnancy)	Parcel 1	TT-133	29	1	0.034	0.023 ± 0.014
		TT-134	29	1	0.034	
		TT-135	29	0	0.000	
	Parcel 2	TT-136	29	1	0.034	0.011 ± 0.014
		TT-137	29	0	0.000	
		TT-138	29	0	0.000	
	Parcel 3	TT-139	29	0	0.000	0.011 ± 0.014
		TT-140	29	0	0.000	
		TT-141	29	1	0.034	
	Parcel 4	TT-142	28	0	0.000	0.012 ± 0.015
		TT-143	28	1	0.036	
		TT-144	29	0	0.000	
	Control	TT-C25	29	0	0.000	0.000 ± 0.000
		TT-C26	29	0	0.000	
		TT-C27	29	0	0.000	

Sampling Month, Year & Reproductive Period	Mitigation Parcel	Sampling location ID	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections	Proportion of Nights with Detections (Mean ± SE)
May 2024 (Pregnancy)	Parcel 1	TT-121	28	0	0.000	0.024 ± 0.015
		TT-122	28	1	0.036	
		TT-123	28	1	0.036	
	Parcel 2	TT-124	28	0	0.000	0.000 ± 0.000
		TT-125	28	0	0.000	
		TT-126	28	0	0.000	
	Parcel 3	TT-127	28	2	0.071	0.083 ± 0.015
		TT-128	28	3	0.107	
		TT-129	28	2	0.071	
	Parcel 4	TT-130	28	1	0.036	0.065 ± 0.036
		TT-131	28	1	0.036	
		TT-132	16	2	0.125	
	Control	TT-C28	28	1	0.036	0.024 ± 0.015
		TT-C29	28	1	0.036	
		TT-C30	28	0	0.000	
June 2024 (Pre-pregnancy /Lactation)	Parcel 1	TT-109	31	0	0.000	0.032 ± 0.023
		TT-110	31	2	0.065	
		TT-111	31	1	0.032	
	Parcel 2	TT-112	31	2	0.065	0.086 ± 0.047
		TT-113	31	5	0.161	
		TT-114	31	1	0.032	
	Parcel 3	TT-115	27	0	0.000	0.000 ± 0.000
		TT-116	31	0	0.000	
		TT-117	31	0	0.000	
	Parcel 4	TT-118	31	0	0.000	0.034 ± 0.023
		TT-119	26	1	0.038	
		TT-120	31	2	0.065	
	Control	TT-C31	31	0	0.000	0.032 ± 0.023
		TT-C32	31	1	0.032	
		TT-C33	31	2	0.065	
July 2024 (Lactation)	Parcel 1	TT-097	29	1	0.034	0.056 ± 0.013
		TT-098	30	2	0.067	
		TT-099	30	2	0.067	
	Parcel 2	TT-100	30	1	0.033	0.022 ± 0.014
		TT-101	30	1	0.033	
		TT-102	30	0	0.000	
	Parcel 3	TT-103	30	0	0.000	0.078 ± 0.095
		TT-104	30	0	0.000	
		TT-105	30	7	0.233	
	Parcel 4	TT-106	30	3	0.100	0.044 ± 0.036
		TT-107	30	1	0.033	
		TT-108	30	0	0.000	
	Control	TT-C34	30	1	0.033	0.033 ± 0.000
		TT-C35	30	1	0.033	
		TT-C36	30	1	0.033	

**Table 2. Number and Proportion of Detections per Night per Month at the Proposed Water Tank Location**

Sampling Year	Sampling Month and Year	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
2023	April	30	0	0.000
	May	31	0	0.000
	June	32	1	0.031
	July	30	2	0.067
	August	30	8	0.267
	September	31	8	0.258
	October	30	7	0.233
	November	32	1	0.031
	December	30	7	0.233
2024	January	31	2	0.065
	February	29	2	0.069
	March	31	2	0.065
	April	30	3	0.100
	May	31	5	0.161
	June	7	3	0.429
	July	18	2	0.111

## **APPENDIX B: HAWAIIAN HOARY BAT DIET**

**Table 1. Insect Prey Identified in the Diet of Hawaiian Hoary Bats**

Order	Family	Genus	Species	Citation
Acari	Macrochelidae	unknown	sp.	Todd 2012
Blattodea	Kalotermitidae	Neotermes	connexux	Todd 2012
Blattodea	Kalotermitidae	Neotermes	sp.	Harvey et al. 2019, Pinzari et al. 2019
Blattodea	Zooetermopsidae	Zooetermopsis	sp.	HT Harvey 2019
Coleoptera	Corylophidae	Sericoderus	sp.	Pinzari et al. 2019
Coleoptera	Elateridae	Eopenthes	caerules	Todd 2012
Coleoptera	Nitidulidae	Phenolia	limbatatibialis	Todd 2012
Coleoptera	Nitidulidae	Phenolia	sp.	Pinzari et al. 2019
Coleoptera	Scarabaeidae	Adoretus	sinicus	Todd 2012
Coleoptera	Scarabaeidae	Digitonthophagus	gazella	HT Harvey 2019; Pinzari et al. 2019
Coleoptera	Scarabaeidae	Phanaeus	daphnis	Todd 2012
Coleoptera	Tenebrionidae	Gonocephalum	adpressiforme	Todd 2012
Diptera	Calliphoridae	Calliphora	sp.	HT Harvey 2019
Diptera	Calliphoridae	Chrysomaya	megacephala	Todd 2012
Diptera	Cecidomyiidae	unknown	sp.	Pinzari et al. 2019
Diptera	Culicidae	unknown	sp.	Pinzari et al. 2019
Diptera	Limoniidae	Limoniinae	sp.	HT Harvey 2019
Diptera	Muscidae	Coenosia	sp.	Pinzari et al. 2019
Diptera	Sarcophagidae	Blaesoxipha	plinthopyga	Pinzari et al. 2019
Diptera	Tachinidae	Eucelatoria	armiger	Pinzari et al. 2019
Diptera	Tipulidae	Tipulidae	Limoninae	HT Harvey 2019
Diptera	Tipulidae	Tipulidae	sp.	HT Harvey 2019
Diptera	unknown	unknown	sp.	Pinzari et al. 2019
Ephemeroptera	unknown	unknown	sp.	Pinzari et al. 2019
Hemiptera	Cicadellidae	Gypona	sp.	HT Harvey 2019
Hemiptera	Cicadellidae	unknown	sp.	Pinzari et al. 2019
Hemiptera	Pentatomidae	Nezara	viridula	HT Harvey 2019; Pinzari et al. 2019
Hemiptera	Pentatomidae	Piezodorus	sp.	Pinzari et al. 2019
Hemiptera	Pentatomidae	Thyanta	accerea	Todd 2012
Hemiptera	unknown	unknown	sp.	Pinzari et al. 2019
Lepidoptera	Blastobasidae	Blastobasis	sp.	Pinzari et al. 2019
Lepidoptera	Carposinidae	Carposina	sp.	Pinzari et al. 2019
Lepidoptera	Coleophoridae	Coleophora	sp.	Pinzari et al. 2019
Lepidoptera	Cosmopterigidae	Pyroderces	sp.	Pinzari et al. 2019
Lepidoptera	Crambidae	Herpetogramma	licarsisalis	Pinzari et al. 2019
Lepidoptera	Crambidae	Nomophila	noctuella	Pinzari et al. 2019
Lepidoptera	Crambidae	Nomophila	sp.	Pinzari et al. 2019
Lepidoptera	Crambidae	Omiodes	continuatalis	HT Harvey 2019
Lepidoptera	Crambidae	unkown	sp.	HT Harvey 2019
Lepidoptera	Crambidae	unkown	sp.	Pinzari et al. 2019
Lepidoptera	Erebidae	Hadeninae	sp.	HT Harvey 2019
Lepidoptera	Erebidae	Herpetogramma	licarsisalis	HT Harvey 2019
Lepidoptera	Erebidae	Hypena	sp.	Pinzari et al. 2019
Lepidoptera	Erebidae	Melipotis	indomita	HT Harvey 2019; Pinzari et al. 2019
Lepidoptera	Gelechiidae	Dichomeris	unknown	Pinzari et al. 2019
Lepidoptera	Geometridae	Eupithecia	sp.	Pinzari et al. 2019
Lepidoptera	Geometridae	unkown	sp.	Todd 2012
Lepidoptera	Gracillariidae	unknown	unknown	Pinzari et al. 2019
Lepidoptera	Hesperiidae	unknown	unknown	Pinzari et al. 2019
Lepidoptera	Lycaenidae	unknown	unknown	Pinzari et al. 2019
Lepidoptera	Momphidae	Mompha	sp.	HT Harvey 2019
Lepidoptera	Momphidae (Batrachedridae)	unknown	unknown	Pinzari et al. 2019

Order	Family	Genus	Species	Citation
Lepidoptera	Noctuidae	Athetis	sp.	Pinzari et al. 2019
Lepidoptera	Noctuidae	Athetis	thoracica	HT Harvey 2019
Lepidoptera	Noctuidae	Chrysodeixis	erosoma	HT Harvey 2019
Lepidoptera	Noctuidae	Elaphria	nucicolora	HT Harvey 2019
Lepidoptera	Noctuidae	Feltia	subterranea	Pinzari et al. 2020; Pinzari et al. 2019
Lepidoptera	Noctuidae	Mythimna	sp.	HT Harvey 2019
Lepidoptera	Noctuidae	Mythimna	unipuncta	HT Harvey 2019
Lepidoptera	Noctuidae	Peridroma	saucia	HT Harvey 2019, Pinzari et al. 2019
Lepidoptera	Noctuidae	Pseudaletia	unipuncta	Pinzari et al. 2019
Lepidoptera	Noctuidae	Spoladea	recurvalis	HT Harvey 2019
Lepidoptera	Noctuidae	unkown	sp.	Todd 2012
Lepidoptera	Oecophoridae	Unkown	sp.	Pinzari et al. 2019
Lepidoptera	Pyrilidae	Unkown	sp.	Pinzari et al. 2019
Lepidoptera	Sphingidae	Macroglossum	pyrrhosticum	Todd 2012
Lepidoptera	Sphingidae	Unkown	sp.	Pinzari et al. 2019
Lepidoptera	Tineidae	Opoona	sacchar	HT Harvey 2019
Lepidoptera	Tortricidae	Crociosema	lantana	Pinzari et al. 2019
Lepidoptera	Tortricidae	Cryptophlebia	illepida	HT Harvey 2019
Lepidoptera	Tortricidae	Cryptophlebia	sp.	HT Harvey 2019; Pinzari et al. 2019
Lepidoptera	Xyloryctidae	unknown	unknown	Pinzari et al. 2019
Neuroptera	Hemerobiidae	Hemerobius	sp.	Todd 2012
Orthoptera	Gryllidae	Euconocephalus	sp.	HT Harvey 2019
Orthoptera	Gryllidae	Gryllus	bimaculatus	HT Harvey 2019; Pinzari et al. 2019
Orthoptera	Oedipodinae	unknown	sp.	HT Harvey 2019
Orthoptera	Tettigoniidae	Conocephalus	sp.	Pinzari et al. 2019
Orthoptera	Tettigoniidae	Tettigoniidae	sp.	HT Harvey 2019
Orthoptera	Tettigoniidae	unknown	sp.	HT Harvey 2019
Orthoptera	Trigonidiidae	Trigonidiomorpha	sjostedti	HT Harvey 2019; Pinzari et al. 2019
Orthoptera	unknown	unknown	sp.	HT Harvey 2019

## **APPENDIX C: INSECT MONITORING RESULTS**

**Table 1. Insects Captured at the Mitigation Area. Native Insects Area**

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
Blattodea	Ectobiidae	Blatella	germanica	Roach 1	10-12	light trap, malaise trap			46
	Ectobiidae	Lobopterella	dimidiatipes	Roach 2 (dung)	6-7	dung			
	Kalotermitidae	Neotermes	connexus	Termite 1	8-10	light trap, malaise trap	+		46
	Blattidae	Periplaneta	americana	Roach large	35-40	malaise trap			46
	undetermined	undetermined	undetermined	Roach 3	9-10	malaise trap			
Coleoptera	Anthribidae	Araecerus	undetermined	Col 1	3-4	malaise trap			1
	Anthribidae	Araecerus	fasciculatus	Col 16	3-4	malaise trap			1
	Anthribidae	Araecerus	undetermined	Col 2	3-4	malaise trap			1
	Bostrichidae	Heterobostrychus	aequalis	Bostrichid 1	9-14	light trap			1
	Bostrichidae	Xylothrips	religiosus	Bostrichid fuzzy face	6-7	light trap			1
	Carabidae	Metacolpodes	buchanani	Carabid metallic	12-15	light trap			1
	Cerambycidae	Ceresium	unicolor	Cerambycid 1	12-15	light trap, malaise trap			2
	Cerambycidae	Pacosternus	crinicornis	Cerambycid 4	18-20	malaise trap			2
	Cerambycidae	Sybra	alternans	Cerambycid 2	8-12	malaise trap, light trap			2
	Cerambycidae	Archlagocheirus	funestus	Cerambycid 5	15-18	malaise trap			2
	Cerambycidae	Curtomerus	flavus	Cerambycid 3	6-8	light trap, malaise trap			2
	Cerambycidae	Pterolophia	undetermined	Cerambycid 6	5-6	malaise trap			2
	Tenebrionidae	Diaperis	maculata	Cocc. Red	11-12	light trap	+		3
	Coccinelidae	Bothrocalvia	pupillata	Coccinelid 1	4-5	malaise trap			3
	Curculionidae	Pantomorus	cervinus	Weevil 2	7-8	malaise trap			3
	Curculionidae	nr. Cossininae	undetermined	long weevil	5-6	malaise trap			4
	Curculionidae	Euwallacea	undetermined	Ambrosia 1	4-5	malaise trap			3
	Curculionidae	Xyleborus	undetermined	Ambrosia 2	3-4	malaise trap			3
	Curculionidae	Orchidophilus	undetermined	Weevil 1	3-4	malaise trap			3
	Elateridae	Conoderus	exsul	Elateridae 1	10-12	light trap, malaise trap	+		4
Elateridae	undetermined	undetermined	Elateridae small	5-6	malaise trap	+		4	
Histeridae	Atholus	confinis	COL tick-like	6-12	dung			4	

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Nitidulidae	Stelidota	geminata	Col 14	6-7	light trap, malaise trap	+		5
	Nitidulidae	undetermined	undetermined	Nit tiny	6-7	malaise trap	+		5
	Nitidulidae	undetermined	undetermined	Nitidulid 3	3-4	malaise trap	+		5
	Oedemeridae	Eobia	bicolor or Thelyphassa apicata	Oedemeridae	9-12	light trap, malaise trap			5
	Ptinidae	undetermined	undetermined	Col 5	3-4	malaise trap			5
	Scarabaeidae	Onthophagus	unknown	Scarab 1	10-12	light trap, malaise trap	+		6
	Scarabaeidae	Aphodiinae	undetermined	Col 12	3-4	light trap, malaise trap	+		6
	Scarabaeidae	Parapsammodius	bidens	Col 13	3-4	light trap, malaise trap	+		6
	Scarabaeidae	Aphodiinae	undetermined	Scarab tiny	5-6	dung	+		6
	Scarabaeidae	Copris	incertus	Scarab 1-horn huge	12-16	light trap, malaise trap, dung	+		6
	Scarabaeidae	Digitonthophagus	gazella	Scarab 2-horn back	8-12	light trap, malaise trap, dung	+		6
	Scarabaeidae	Oniticellus	militaris	Scarab mottled	7-9	dung	+		7
	Scarabaeidae	Onthophagus	incensus	Scarab green	7-10	dung, malaise trap	+		7
	Scarabaeidae	Onthophagus	sagittarius	Scarab 2 (1-horn)	8-10	light trap, malaise trap, dung	+		7
	Scarabaeidae	undetermined	undetermined	Scarab 3	15-16	dung, light trap	+		7
	Silvanidae	Cryptamorpha	desjardinsii	Col 6	4-5	malaise trap			8
	Staphylinidae	undetermined	undetermined	Col 7	3-4	malaise trap			8
	Staphylinidae	undetermined	undetermined	Staphylinid 1	3-4	light trap, malaise trap			8
	Staphylinidae	undetermined	undetermined	Staphylinid 2	5-6	malaise trap			8
	Staphylinidae	undetermined	undetermined	Staphylinid 3	3-4	light trap, malaise trap			8
	Tenebrionidae	undetermined	undetermined	Col 10	6-7	dung, light trap, malaise trap	+		8
	Chrysomelidae	undetermined	undetermined	Bruchinae	4-5	light trap, malaise trap			9
	Curculionidae	Crossotarsus	externedentatus	Col 15	5-6	light trap			9

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
Dermoptera	Chelisochidae	Chelisoches	morio	Derm 1	18-24	light trap, malaise trap			46
	undetermined	undetermined	undetermined	Derm 2	13-15	dung, malaise trap			
Diptera	Calliphoridae	undetermined	undetermined	Dip 30	6-7	malaise trap	+		10
	Calliphoridae	Lucilia	undetermined	Metallic green	9-10	light trap	+		10
	Cecidomyiidae	undetermined	undetermined	Midge 3	3-4	light trap, malaise trap	+		
	Chironomidae	undetermined	undetermined	Midge 2	4-5	malaise trap			
	Dolichopodidae	undetermined	undetermined	Dolichopodid 1	3-4	light trap, malaise trap			
	Lauxaniidae	Homoneura	unguiculata	Dip 12	3-4	light trap, malaise trap			10
	Lauxaniidae	Poecilominettia	sexseriata	Dip 1	3-4	light trap, malaise trap			10
	Muscidae	undetermined	undetermined	Dip 21	7-8	light trap, malaise trap	+		11
	Muscoidea	undetermined	undetermined	Dip 3	4-6	light trap, malaise trap			11
	Neriidae	Telostylinus	lineolatus	Dip 24	6-7	malaise trap			11
	Sepsidae	undetermined	undetermined	Dip 14	3-4	malaise trap			12
	Syrphidae	Allograpta	obliqua	Syrphid 2	8-9	malaise trap			12
	Syrphidae	Copestylum	apicale	Dip 17	7-8	malaise trap			12
	Syrphidae	undetermined	undetermined	Syrphid 1	5-6	malaise trap			12
	Tachinidae	undetermined	undetermined	Dip 29	5-6	malaise trap	+		11
	Tephritidae	Tetreuaresta	undetermined	Dip 8	3-4	light trap, malaise trap			12
	Tipulidae	undetermined	undetermined	Tipulidae 1	5-6	light trap, malaise trap	+		13
	Tipulidae	undetermined	undetermined	Tipulidae 1-spot	5-6	malaise trap	+		13
	Tipulidae	undetermined	undetermined	Tipulidae 2	9-10	malaise trap	+		13
	Tipulidae	undetermined	undetermined	Tipulidae 5	4-5	malaise trap	+		13
Tipulidae	undetermined	undetermined	Tipulidae pale	4-5	malaise trap	+		13	
undetermined	undetermined	undetermined	Dip 10	5-6	light trap, malaise trap			14	
undetermined	undetermined	undetermined	Dip 11	4-5	light trap, malaise trap			14	

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	undetermined	undetermined	undetermined	Dip 13	3-4	malaise trap			14
	undetermined	undetermined	undetermined	Dip 15	4-5	light trap, malaise trap			14
	undetermined	undetermined	undetermined	Dip 16	3-4	malaise trap			15
	undetermined	undetermined	undetermined	Dip 18	4-5	malaise trap			15
	Chloropidae	undetermined	undetermined	Dip 19	3-4	malaise trap			15
	undetermined	undetermined	undetermined	Dip 2	3-4	malaise trap			14
	undetermined	undetermined	undetermined	Dip 20	3-4	light trap, malaise trap			15
	undetermined	undetermined	undetermined	Dip 22	4-5	light trap, malaise trap			15
	undetermined	undetermined	undetermined	Dip 25	3-4	malaise trap			15
	undetermined	undetermined	undetermined	Dip 26	4-5	malaise trap			16
	Sepsidae	undetermined	undetermined	Dip 27	4-5	malaise trap			16
	undetermined	undetermined	undetermined	Dip 28	3-4	malaise trap			16
	undetermined	undetermined	undetermined	Dip 31	5-6	malaise trap			16
	undetermined	undetermined	undetermined	Dip 32	3-4	malaise trap			16
	undetermined	undetermined	undetermined	Dip 33	3-4	malaise trap			16
	undetermined	undetermined	undetermined	Dip 34	4-5	malaise trap			17
	undetermined	undetermined	undetermined	Dip 35	4-5	malaise trap			17
	undetermined	undetermined	undetermined	Dip 36	3-4	malaise trap			17
	undetermined	undetermined	undetermined	Dip 9	9-10	malaise trap			14
	undetermined	undetermined	undetermined	Giant dark wing	15-17	malaise trap			17
Hemiptera	Cicadellidae	Sophonia	orientalis	2-spot leafhopper	3-4	light trap	+		18
	Cicadellidae	undetermined	undetermined	Cicadellid green	6-7	light trap	+		18
	Cicadellidae	undetermined	undetermined	Cicadellid 3	8-10	light trap	+		18
	Cydnidae	Geotomus	pygmaeus	Geotomus	4-5	light trap, malaise trap			18
	Derbidae	Lamenia	caliginea	Derbidae	3-4	malaise trap			18
	Flatidae	Melormenis	basalis	Flatid brown	4-5	light trap, malaise trap			19
	Flatidae	Siphanta	acuta	Flatid green	4-5	light trap, malaise trap			19
	Rhyparochromidae	Horridipamera	inconspicua	Lygeid 1	5-6	light trap			19

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Miridae	Hyalopeplus	pellucidus	Hyalopeplus	5-6	light trap, malaise trap			20
	Miridae	undetermined	undetermined	Hem 2	3-4	malaise trap			19
	Miridae	Dagbertus	undetermined	Mirid spotted legs	3-4	light trap, malaise trap			19
	Miridae	undetermined	undetermined	Miridae 1	3-4	malaise trap			20
	Miridae	undetermined	undetermined	Miridae 2	3-4	malaise trap			20
	Miridae	undetermined	undetermined	Miridae 3	3-4	malaise trap			20
	Miridae	Deraeocoris	orientalis	Miridae 4	3-4	malaise trap			20
	Nabidae	Nabis	capsiformis?	Nabidae clear legs	10-12	malaise trap			21
	Nabidae	Nabis	undetermined	Nabidae spotted legs	10-12	malaise trap			21
	Nabidae	undetermined	undetermined	Nabid large	13-14	light trap			21
	Pentatomidae	Plautia	stali	Scute green	10-12	light trap	+		21
	Reduviidae	unknown	unkown	Nabidae point rostrum	10-12	malaise trap	+		21
	Reduviidae	Polididus	armatissimus	spiney	10-12	light trap			21
	Tropiduchidae	Kallitaxila	granulata	Hom 1	4-5	light trap, malaise trap			22
	Ampulicidae	Ampulex	compressa	metallic green	21-22	malaise trap			23
	Apidae	Apis	mellifera	honey bee	12-15	light trap, malaise trap			23
	Braconidae	undetermined	undetermined	Braconid 1	3-4	malaise trap			23
	Braconidae	undetermined	undetermined	Hym 1	3-4	malaise trap			24
	Braconidae	undetermined	undetermined	Hym 10	3-4	light trap, malaise trap			24
	Braconidae	undetermined	undetermined	Hym 14	3-4	malaise trap			24
	Braconidae	undetermined	undetermined	Ichneumonid 10	4-5	malaise trap			23
	Braconidae	undetermined	undetermined	Ichneumonid 11	4-5	malaise trap			24
	Braconidae	undetermined	undetermined	Ichneumonid 12	5-6	malaise trap			24
	Braconidae	undetermined	undetermined	Ichneumonid 14	4-5	malaise trap			31
	Braconidae	undetermined	undetermined	Ichneumonid 15	4-5	malaise trap			24
	Braconidae	undetermined	undetermined	Ichneumonid 8	3-4	malaise trap			23
	Braconidae	undetermined	undetermined	Ichneumonid 9	3-4	malaise trap			23
	Chalcidoidea	undetermined	undetermined	Hym 11	3-4	malaise trap			25
Hymenoptera									

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Chalcidoidea	undetermined	undetermined	Hym 12	3-4	malaise trap			25
	Chalcidoidea	undetermined	undetermined	Hym 16 feather anten	3-4	malaise trap			25
	Chalcidoidea	undetermined	undetermined	Hym 18	3-4	malaise trap			25
	Chalcidoidea	undetermined	undetermined	Hym 19	3-4	malaise trap			25
	Chalcidoidea	undetermined	undetermined	Hym 6	3-4	light trap, malaise trap			25
	Chrysoidea	undetermined	undetermined	Hym 13	4-5	malaise trap			26
	Chrysoidea	undetermined	undetermined	Hym 15	3-4	malaise trap			26
	Chrysoidea	undetermined	undetermined	Hym 16	3-4	malaise trap			26
	Chrysoidea	undetermined	undetermined	Hym 7	4-5	malaise trap			26
	Chrysoidea	undetermined	undetermined	Hym 8	3-4	light trap, malaise trap			26
	Chrysoidea	undetermined	undetermined	Hym 9	4-5	light trap, malaise trap			26
	Crabronidae	undetermined	undetermined	Hym 2	7-8	malaise trap			27
	Eupelmidae	undetermined	undetermined	Hym 5	4-5	malaise trap			27
	Formicidae	undetermined	undetermined	Ant 1, Ant 3	5-6	malaise trap			28
	Formicidae	undetermined	undetermined	Ant 10	5-6	malaise trap			29
	Formicidae	undetermined	undetermined	Ant 2	3-4	malaise trap			28
	Formicidae	undetermined	undetermined	Ant 4	3-4	malaise trap			28
	Formicidae	undetermined	undetermined	Ant 5 no node	6-7	malaise trap, light trap			28
	Formicidae	undetermined	undetermined	Ant 6	3-4	malaise trap			28
	Formicidae	undetermined	undetermined	Ant 7 single node	3-4	malaise trap			28
	Formicidae	undetermined	undetermined	Ant 8	3-4	malaise trap			29
	Formicidae	undetermined	undetermined	Ant 9	4-5	malaise trap			29
	Formicidae	undetermined	undetermined	ant 1 (propod spines)	4-5	dung			29
	Ichneumonidae	Pimpla	punicipes	Ichneumonid 13	7-9	malaise trap			31
	Ichneumonidae	undetermined	undetermined	Ichneumonid 1	4-8	malaise trap			30
	Ichneumonidae	undetermined	undetermined	Ichneumonid 2	7-8	malaise trap			30
	Ichneumonidae	undetermined	undetermined	Ichneumonid 3	6-7	malaise trap			30
	Ichneumonidae	undetermined	undetermined	Ichneumonid 4	6-7	malaise trap			30
	Ichneumonidae	undetermined	undetermined	Ichneumonid 5	7-8	malaise trap			30
	Ichneumonidae	undetermined	undetermined	Ichneumonid 6	5-6	malaise trap			30

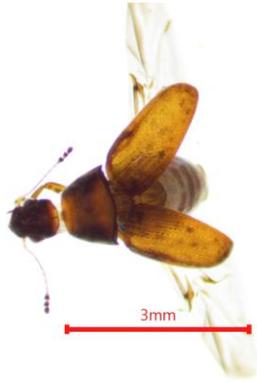
Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Ichneumonidae	undetermined	undetermined	Ichneumonid 7	4-5	malaise trap			31
	Vespidae	Vespula	pensylvanica	Vespula	12-15	malaise trap			31
	undetermined	undetermined	undetermined	Hym 17	3-4	malaise trap			32
	undetermined	undetermined	undetermined	Hym 3	5-6	malaise trap			32
	undetermined	undetermined	undetermined	Hym 4	3-4	malaise trap			32
Lepidoptera	Autostichidae	Stoeberhinus	testaceus	Stoeberhinus	5-6	light trap, malaise trap		+	33
	Carposinidae	Carposina	undetermined	Carposina sp (white)	4-5	light trap	+	+	33
	Cosmopterigidae	Hyposmocoma	undetermined	Gelechiid mottled 1	5-6	light trap	+	+	
	Crambidae	Eudonia	undetermined	Eudonia 1	5-6	light trap	+	+	33
	Crambidae	Eudonia	undetermined	Eudonia B&W	5-6	light trap	+	+	34
	Crambidae	Eudonia	undetermined	Eudonia mottled	5-6	light trap	+	+	33
	Crambidae	Mestalobes	undetermined	Lep 1	5-6	light trap, malaise trap	+	+	34
	Crambidae	Mestalobes	undetermined	Lep 4	6-8	light trap	+	+	34
	Crambidae	Mestalobes	undetermined	Lep 5	8-10	light trap, malaise trap	+	+	34
	Crambidae	Mestalobes	undetermined	White wing stripe	5-6	light trap	+	+	34
	Crambidae	Spoladea	recurvalis	Lep 25	10-12	light trap	+	+	33
	Erebidae	Ascalapha	odorata	Black witch	25-30	light trap	+	+	
	Erebidae	Bocana	manifestalis	Black plumose	17-18	light trap	+	+	35
	Erebidae	Eublemma	accedens	bicolor	5-6	light trap	+	+	35
	Erebidae	Hypena	laceratalis	Long beak dark	9-10	light trap	+	+	35
	Euteliidae	Penicillaria	jocosatrix	White hind wing	14-15	light trap		+	35
	Gelechoidea	possibly Hyposmocoma	undetermined	Lep 3	4-6	light trap, malaise trap			37
	Gelechoidea	undetermined	undetermined	Gelechiid 1	3-4	light trap, malaise trap			36
	Gelechoidea	undetermined	undetermined	Gelechiid mottled 2	4-5	light trap			36
	Gelechoidea	undetermined	undetermined	Gelechiid silver	4-5	light trap			36
Gelechoidea	undetermined	undetermined	Gelechiid white	3-4	light trap			36	
Gelechoidea	undetermined	undetermined	Gelechiid white, spotted	3-4	light trap			36	

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Gelechoidea	undetermined	undetermined	Gelechiid white, tiny	3-4	light trap			36
	Gelechoidea	undetermined	undetermined	Lep 3.6	3-4	malaise trap			37
	Geometridae	Psamatodes	abydata	Yellow	10-12	light trap	+	+	38
	Geometridae	Scotorythra	arboricolens/corticea	Scoto yellow	12-15	light trap	+	+	38
	Geometridae	Thyrinteina	arnobia	Geo mottled	13-20	light trap	+		38
	Immidae	Imma	mylias	Lep 24	8-10	light trap		+	38
	Limacodidae	Darna	pallivitta	Plumose	12-15	malaise trap		+	38
	Noctuidae	Amyna	natalis	Indented shoulder	8-9	light trap	+	+	39
	Noctuidae	Antiblemma	acclinalis	moth 1	10-12	light trap	+		39
	Noctuidae	Athetis	thoracica	Athetis	15-18	light trap	+	+	39
	Noctuidae	Callopietria	floridensis	Moth 5	16-18	light trap	+	+	39
	Noctuidae	Elaphria	nucicolora	Lep 22	10-12	light trap	+	+	39
	Noctuidae	Feltia	subterranea	Agrotis	20-25	light trap	+	+	40
	Noctuidae	Gonitis	vulpicolor	Noctuid yellow	18-20	light trap	+		40
	Noctuidae	Mythimna	unipuncta	Noctuid pale	18-20	light trap	+	+	40
	Noctuidae	Ophiusa	disjungens	Lep yellow large	27-34	light trap, malaise trap	+		40
	Noctuidae	Spodoptera	auritia	Lep 20	5-6	light trap	+	+	40
	Pyalidae	Herpetogramma	licarsisalis	Pyalid 1	10-12	light trap, malaise trap	+		41
	Pyalidae	undetermined	undetermined	Pyalid mottled	10-12	light trap	+		41
	Sphingidae	Agrius	cingulata	Pink hawk moth	34-35	light trap	+	+	
	Sphingidae	Hyles	calida	Sphingid 1	28-29	light trap	+	+	41
	Sphingidae	undetermined	undetermined	large hawk moth	48-49	light trap	+		
	Tineidae	Erechthias	pelotrichia	White with long palps	5-6	light trap	+	+	42
	Tineidae	Erechthias	simulans	Gelechiid B&W	6-8	light trap	+	+	42
	Tineidae	Opogona	omoscopa	Tineid gold	8-10	light trap	+	+	42
	Tineidae	undetermined	undetermined	Lep 2	8-10	malaise trap	+		42
	Tineidae	undetermined	undetermined	Lep 3.5	5-6	malaise trap	+		42
	Tineidae	undetermined	undetermined	Tineid 1	5-6	malaise trap	+		42
	Tortricidae	Amorbia	emigratella	Tortricidae 2	6-8	light trap	+	+	43
	Tortricidae	Crociosema	lantana	poiny wing	5-6	light trap	+	+	43

Order	Family	Genus	Species	Morphospecies Name	Size (mm)	Sampling Method	Identified Hawaiian Hoary Bat Prey	Native	Appendix Pg. #
	Tortricidae	Cryptophlebia	illepida	Tortricid red	6-10	light trap, malaise trap	+	+	43
	Tortricidae	Platynota	undetermined	Lep 7	7-8	light trap, malaise trap	+	+	43
	undetermined	undetermined	undetermined	"Thyrocopa"	8-10	light trap			
	undetermined	undetermined	undetermined	Lep 11	8-9	malaise trap			44
	undetermined	undetermined	undetermined	Lep 17	5-6	malaise trap			44
	undetermined	undetermined	undetermined	Lep 18	5-6	light trap, malaise trap			44
	undetermined	undetermined	undetermined	Lep 19-1	3-4	malaise trap			44
	undetermined	undetermined	undetermined	Lep 19-2	9-10	light trap			44
	undetermined	undetermined	undetermined	Lep 20	5-6	malaise trap			45
	undetermined	undetermined	undetermined	Lep 5	8-10	malaise trap			44
	undetermined	undetermined	undetermined	Lep 8	6-7	light trap			44
Neuroptera	Chrysopidae	undetermined	undetermined	Chrysopidae	8-10	light trap, malaise trap			46
	Hemerobiidae	undetermined	undetermined	Hemerobiidae	5-6	light trap, Malaise trap	+		46
Orthoptera	Gryllidae	undetermined	undetermined	Cricket 1	6-8	malaise trap	+		47
	Gryllidae	undetermined	undetermined	Cricket huge dark	22-23	malaise trap	+		48
	Gryllidae	Nanixipha	nahoa	Cricket striped legs	6-8	light trap, malaise trap	+		47
	Gryllidae	undetermined	undetermined	dark	6-8	malaise trap	+		47
	Tettigoniidae	Conocephalus	saltator	Cricket 2	12-15	light trap, malaise trap	+		47
	Tettigoniidae	nr. Elimaea	punctifera	Cricket huge 2	22-25	malaise trap	+		47
	Tettigoniidae	nr. Phaneroptera	furcifera	Cricket huge	22-25	malaise trap	+		47
Psocodea	Tettigoniidae	undetermined	undetermined	Katydid (27 mm)	27-28	light trap	+		
	Psocidae	undetermined	undetermined	Psocid 2	3-4	malaise trap			48
	undetermined	undetermined	undetermined	psocid 1	3-4	malaise trap			48
Trichoptera	Hydropsychidae	Cheumatopsyche	analis	Trichoptera 1	4-5	light trap			48

# Anthribidae, Bostrichidae, Carabidae

Anthribidae



*Araecerus* sp.

Anthribidae



*Araecerus* sp.



*Araecerus fasciculatus*

Bostrichidae



*Heterobostrychus aequalis*

Bostrichidae



*Xylothrips religiosus*

Carabidae



*Metacolpodes buchanani*

# Cerambycidae

Cerambycidae



nr. *Archlagocheirus funestus*

Cerambycidae



*Ceresium unicolor*

Cerambycidae



*Pacosternus crinicornis*

Cerambycidae



*Sybra alternans*

Cerambycidae



nr. *Curtomerus flavus*

Cerambycidae



*Pterolophia*

# Coccinelidae, Curculionidae

Coccinelidae



*Bothrocalvia pupillata*

Tenebrionidae



*Diaperis nr. maculata*

Curculionidae



*Orchidophilus*

Curculionidae



*Pantomorus cervinus*

Curculionidae



*Euwallacea*

Curculionidae



*Xyleborus*

# Cuculionidae, Elateridae, Histeridae

Curculionidae



Nr. Cossiniinae (long weevil)

Elateridae



Conoderus exsul

Elateridae



Elateridae small

Histeridae



Atholus confinis

# Nitidulidae, Oedemeridae, Ptinidae

Nitidulidae



*Stelidota geminata*

Nitidulidae



nr. *Carophilus* (Nit 3)

Nitidulidae



Nitidulid tiny

Oedemeridae



*Eobia bicolor*

Oedemeridae



nr. *Thelyphassa apicata*

Ptinidae



Col 5

# Scarabaeidae

Scarabaeidae



Aphodiinae tiny

Scarabaeidae



Aphodiinae Col 12

Scarabaeidae



Parapsammoidius bidens

Scarabaeidae



Onthophagus

Scarabaeidae



Copris incertus

Scarabaeidae



Digitonthophagus gazella

# Scarabaeidae

Scarabaeidae



*Oniticellus militaris*

Scarabaeidae



*Onthophagus incensus*

Scarabaeidae



*Onthophagus sagitarius*

Scarabaeidae



*Scarab 3*

# Silvanidae, Staphylinidae, Tenebrionidae

Silvanidae



*Cryptomorpha desjardinsii*

Staphylinidae



Staphylinidae 1

Staphylinidae



Staphylinidae 2

Staphylinidae



Staphylinidae 3 (bottom)

Staphylinidae



Staphylinidae Col 7

Tenebrionidae



Tenebrionidae Col 10

# Undetermined



Chrysomelidae



Bruchinae

Curculionidae

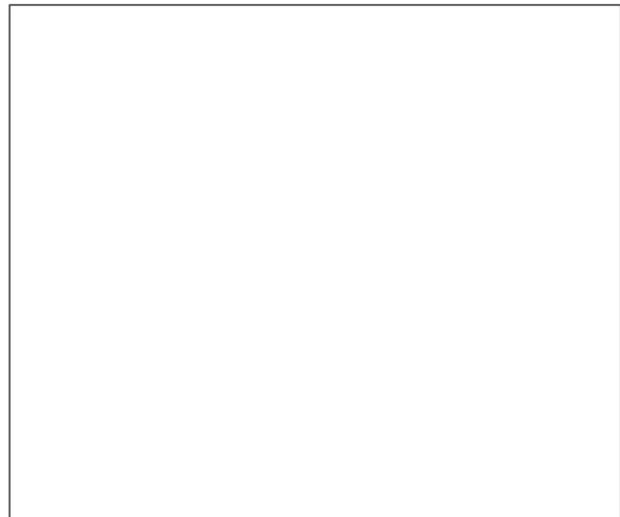
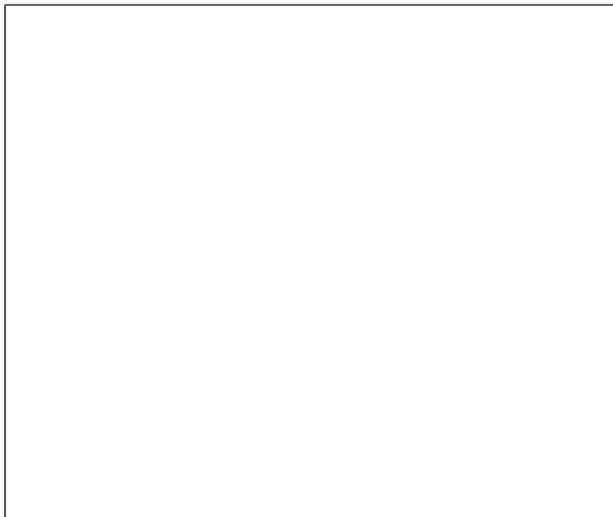


*Crossotarsus externedentatus*

Anthribidae



*Araecerus fasciculatus*



# Calliphoridae, Lauxaniidae

Calliphoridae



Dip 30

Calliphoridae



Lucilia

Lauxaniidae



Poecilominettia sexseriata

Lauxaniidae



Homoneura unguiculata

# Muscoidea (Muscidae, Tachinidae); Neriidae

Muscoidea



Dip 3

Muscidae



Dip 21

Tachinidae



Dip 29

Neriidae



*Telostylus lineolatus*

# Sepsidae, Syrphidae, Tephritidae

Sepsidae



Dip 14

Syrphidae



Syrphid 1

Syrphidae



*Allograpta obliqua*

Syrphidae



*Copestylum apicale*

Tephritidae



*Tetreuaresta*

# Tipulidae

Tipulidae



Tipulid 1

Tipulidae



Tipulid 2

Tipulidae



Tipulid 5

Tipulidae



Tipulid pale

Tipulidae



Tipulid 1-spot

# Undetermined

Undetermined



Dip 2

Undetermined



Dip 9

Undetermined



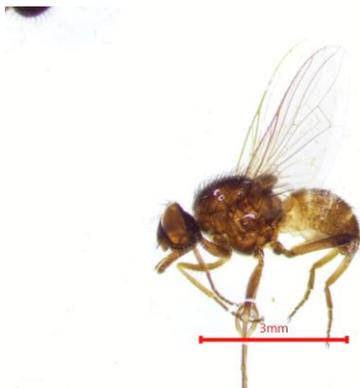
Dip 10

Undetermined



Dip 11

Undetermined



Dip 13

Undetermined



Dip 15

# Undetermined

Undetermined



Dip 16

Undetermined



Dip 18

Chloropidae



Dip 19

Undetermined



Dip 20

Undetermined



Dip 22

Undetermined



Dip 25

# Undetermined

Undetermined



Dip 26

Sepsidae



Dip 27

Undetermined



Dip 28

Undetermined



Dip 31

Undetermined



Dip 32

Undetermined



Dip 33

# Undetermined

Undetermined



Dip 34

Undetermined



Dip 35

Undetermined



Dip 36

Undetermined



Giant dark wing

# Cicadellidae, Cydnidae, Derbidae

Cicadellidae



*Sophonia orientalis*

Cicadellidae



Cicadellid 3

Cicadellidae



Cicadellid green

Cydnidae



*Geotomus pygmaeus*

Derbidae



*Lamenia caliginea*

# Flatidae, Rhyparochromidae, Miridae

Flatidae



*Melormenis basalis*

Flatidae



*Siphanta acuta*

Rhyparochromidae



*Horridipamera inconspicua*

Anthocoridae



Hem 2

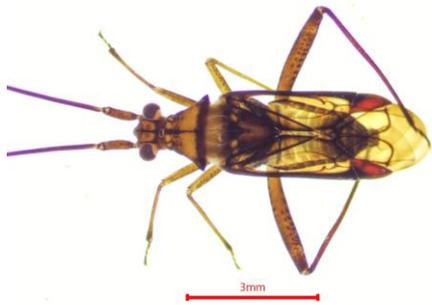
Miridae



*Dagbertus*

# Miridae

Miridae



*Hyalopeplus pellucidus*

Miridae



Mirid 1

Miridae



Mirid 2

Miridae



Mirid 3

Miridae



*Deraeocoris orientalis*

# Nabidae, Pentatomidae, Reduviidae

Nabidae



*Nabis nr. capsiformis* (clear legs)

Nabidae



*Nabis sp.* (spotted legs)

Nabidae



Nabid large

Pentatomidae



*Plautia stali*

Reduviidae



unknown

Reduviidae



*Polididus armatissimus*

# Tropiduchidae

Tropiduchidae



*Kallitaxila granulata*

# Ampulicidae, Apidae, Braconidae

Ampulicidae



Ampulex compressa

Apidae



Apis mellifera

Braconidae



Braconidae 1 & 2

Braconidae



Ich 8

Braconidae



Hym 9

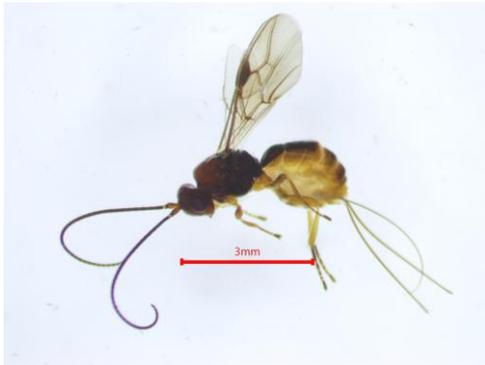
Braconidae



Ich 10

# Braconidae

Braconidae



Ich 11

Braconidae



Ich 12

Braconidae



Hym 14

Braconidae



Ich 15

Braconidae



Hym 1

Braconidae



Hym 10

# Chalcidoidea

Chalcidoidea



Hym 6

Chalcidoidea



Hym 11

Chalcidoidea



Hym 12

Chalcidoidea



Hym 18

Chalcidoidea



Hym 19

Chalcidoidea



Hym 6 feather antennae

# Chrysoidea

Chrysoidea



Hym 7

Chrysoidea



Hym 8

Chrysoidea



Hym 9

Chrysoidea



Hym 13

Chrysoidea



Hym 15

Chrysoidea



Hym 16

# Crabronidae, Eupelmidae

Crabronidae



Hym 2

Eupelmidae



Hym 5

# Formicidae

Formicidae



Ant 1, ant 3

Formicidae



Ant 2

Formicidae



Ant 4

Formicidae



Ant 5

Formicidae



Ant 6

Formicidae



Ant 7

# Formicidae

Formicidae



Ant 8

Formicidae



Ant 9

Formicidae



Ant 10

Formicidae



Ant 1 (dung)

# Ichneumonidae

Ichneumonidae



Ichneumonidae 1

Ichneumonidae



Ichneumonidae 2

Ichneumonidae



Ichneumonidae 3

Ichneumonidae



Ichneumonidae 4

Ichneumonidae



Ichneumonidae 5

Ichneumonidae



Ichneumonidae 6

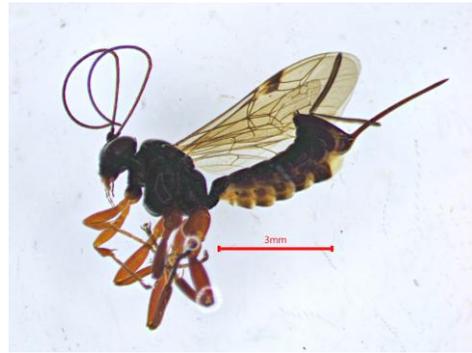
# Ichneumonidae, Vespidae

Ichneumonidae



Ichneumonidae 7

Ichneumonidae



Pimpla punicipes

Ichneumonidae



Ichneumonidae 14

Vespidae



Vespula pensylvanica

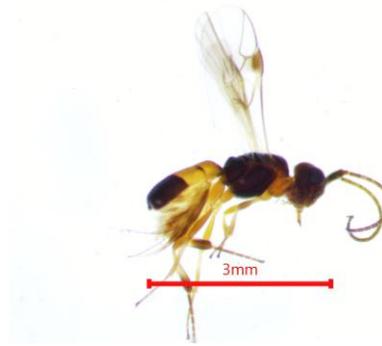
# Undetermined

Undetermined



Hym 3

Undetermined



Hym 4

Undetermined



Hym 17

# Austostichidae, Carposinidae, Crambidae

Austostichidae



*Stoeberhinus testaceus*

Carposinidae



*Carposina* sp. (white)

Crambidae



*Spolodea recurvalis*

Crambidae



*Eudonia* 1

Crambidae



*Eudonia* mottled

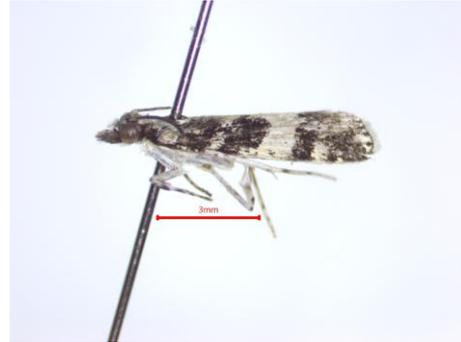
# Crambidae

Crambidae



Eudonia spp.

Crambidae



Eudonia sp.

Crambidae



Mestalobes sp.(white wing stripe)

Crambidae



Mestalobes sp. (Lep 4)

Crambidae



Mestalobes sp. (Lep 5)

Crambidae



Mestalobes (Lep 1)

# Erebidae, Euteliidae

Erebidae



*Bocana manifestalis*

Erebidae



*Eublemma accedens*

Erebidae



*Hypena laceratalis*

Euteliidae



*Penicillaria jocosatrix*

# Gelechoidea

Gelechoidea



Gelechoidea spp.

Gelechoidea



Gelechoidea tiny white

Gelechoidea



Gelechoidea white

Gelechoidea



Gelechoidea mottled

Gelechoidea



Gelechoidea silver (bottom), white (top)

Gelechoidea



Gelechoidea large spot

# Gelechoidea

Gelechoidea



Poss. Hyposmocoma (Lep 3)

Gelechoidea



Lep 3.6

# Geometridae, Immidae, Limacodidae

Geometridae



*Thyrinteina arnobia*

Geometridae



*Psamotodes abydata*

Geometridae



*Scotorythra arboricolens/corticea*

Immidae



*Imma mylias*

Limacodidae



*Darna pallivitta*

# Noctuidae

Noctuidae



*Amyna natalis* (female)

Noctuidae



*Amyna natalis* (male)

Noctuidae



*Antiblemma acclinalis*

Noctuidae



*Athetis thoracica*

Noctuidae



*Callopietria floridensis*

Noctuidae



*Elaphria nucicolora*

# Noctuidae

Noctuidae



*Feltia subterranea*

Noctuidae



*Gonitis vulpicolor*

Noctuidae



*Mythimna unipuncta*

Noctuidae



*Ophiusa disjungens*

Noctuidae



*Spodoptera Mauritia* (female)

Noctuidae



*Spodoptera Mauritia* (male)

# Pyralidae, Sphingidae

Pyralidae



*Herpetogramma licarsisalis*

Pyralidae



Pyralidae mottled

Sphingidae



*Hyles calida*

# Tineidae

Tineidae



*Erechthias simulans*

Tineidae



*Erechthias pelotricha*

Tineidae



*Opogona omoscopa*

Tineidae



Lep 2

Tineidae



Lep 3.5

Tineidae



Tineidae 1

# Tortricidae

Tortricidae



*Amorbia emigratella*

Tortricidae



*Crocidosema lantana*

Tortricidae



*Cryptophlebia illepida*

Tortricidae



*Cryptophlebia illepida*

Tortricidae



*Platynota rostrana*

Tortricidae



*Platynota* sp. (Lep 7)

# Undetermined

Undetermined



Lep 5

Undetermined



Lep 8

Undetermined



Lep 11

Undetermined



Lep 17

Undetermined



Lep 18

Undetermined



Lep 19

# Undetermined

Undetermined



Lep 20

# Blattodea, Dermaptera, Neuroptera

Ectobiidae



*Blatella germanica*

Blattidae



*Periplaneta americana*

Kalotermitidae



*Neotermes connexus*

Chelisochoidea



*Chelisoches morio*

Chrysopidae



Chrysopidae 1

Hemerobiidae



Hemerobiidae 1

# Orthoptera

Gryllidae



Cricket 1

Tettigoniidae



Conocephalus saltator

Tettigoniidae



nr. *Phaneroptera furcifera*

Tettigoniidae



nr. *Elimaea punctifera*

Gryllidae



Cricket dark

Gryllidae



*Nanixipha naho*

# Orthoptera, Psocoptera, Trichoptera

Gryllidae



Cricket huge dark

Psocoptera



Psocid 1

Psocoptera



Psocidae

Trichoptera



Cheumatopsyche analis

**Table 2. Pairwise Comparison of Insect Biomass for Mitigation Parcels During the Four Reproductive Periods with Ratios of Means**

Reproductive Period	Contrast	Log Estimate	SE	Z-ratio	P-value	Ratio of Means
Lactation	Control - Parcel 1	-0.23	0.18	-1.25	0.720	0.79
	Control - Parcel 2	-0.99	0.18	-5.39	0.000	0.37
	Control - Parcel 3	0.64	0.18	3.51	0.004	1.90
	Control - Parcel 4	-0.64	0.18	-3.46	0.005	0.53
	Parcel 1 - Parcel 2	-0.76	0.18	-4.12	0.000	0.47
	Parcel 1 - Parcel 3	0.87	0.19	4.70	0.000	2.40
	Parcel 1 - Parcel 4	-0.41	0.18	-2.23	0.170	0.67
	Parcel 2 - Parcel 3	1.63	0.18	8.87	0.000	5.11
	Parcel 2 - Parcel 4	0.35	0.18	1.89	0.321	1.42
	Parcel 3 - Parcel 4	-1.28	0.19	-6.87	0.000	0.28
Post-Lactation	Control - Parcel 1	0.09	0.18	0.50	0.988	1.10
	Control - Parcel 2	-0.99	0.18	-5.39	0.000	0.37
	Control - Parcel 3	1.58	0.18	8.56	0.000	4.83
	Control - Parcel 4	-0.92	0.18	-5.01	0.000	0.40
	Parcel 1 - Parcel 2	-1.09	0.18	-5.87	0.000	0.34
	Parcel 1 - Parcel 3	1.48	0.18	8.06	0.000	4.41
	Parcel 1 - Parcel 4	-1.01	0.18	-5.50	0.000	0.37
	Parcel 2 - Parcel 3	2.57	0.19	13.70	0.000	13.07
	Parcel 2 - Parcel 4	0.08	0.18	0.43	0.993	1.08
	Parcel 3 - Parcel 4	-2.49	0.19	-13.44	0.000	0.08
Pre-Pregnancy	Control - Parcel 1	-0.01	0.18	-0.04	1.000	0.99
	Control - Parcel 2	0.21	0.18	1.15	0.781	1.23
	Control - Parcel 3	-0.14	0.18	-0.74	0.947	0.87
	Control - Parcel 4	-0.56	0.18	-3.06	0.019	0.57
	Parcel 1 - Parcel 2	0.22	0.18	1.19	0.758	1.24
	Parcel 1 - Parcel 3	-0.13	0.18	-0.70	0.956	0.88
	Parcel 1 - Parcel 4	-0.56	0.18	-3.03	0.020	0.57
	Parcel 2 - Parcel 3	-0.35	0.18	-1.89	0.323	0.71
	Parcel 2 - Parcel 4	-0.77	0.18	-4.21	0.000	0.46
	Parcel 3 - Parcel 4	-0.43	0.18	-2.32	0.139	0.65

Reproductive Period	Contrast	Log Estimate	SE	Z-ratio	P-value	Ratio of Means
Pregnancy	Control - Parcel 1	0.01	0.18	0.05	1.000	1.01
	Control - Parcel 2	-1.20	0.18	-6.48	0.000	0.30
	Control - Parcel 3	0.50	0.18	2.70	0.054	1.64
	Control - Parcel 4	0.29	0.18	1.56	0.524	1.33
	Parcel 1 - Parcel 2	-1.21	0.19	-6.50	0.000	0.30
	Parcel 1 - Parcel 3	0.49	0.18	2.65	0.061	1.63
	Parcel 1 - Parcel 4	0.28	0.18	1.50	0.565	1.32
	Parcel 2 - Parcel 3	1.69	0.18	9.20	0.000	5.43
	Parcel 2 - Parcel 4	1.48	0.18	8.04	0.000	4.40
	Parcel 3 - Parcel 4	-0.21	0.18	-1.15	0.782	0.81

**Table 3. Aikake Information Criterion (AICc), Delta Scores, Weights and Regression Coefficients of the Explanatory Variables for Bat Detection Rates at the Helemano Mitigation Area. Categorical Fixed Effects Get a + When They Are Included in the Model**

Intercept	Insect Biomass	Parcel	Reproductive Period	Insect Biomass : Parcel	Insect Biomass : Reproductive Period	Parcel : Reproductive Period	Insect Biomass : Parcel : Reproductive Period	df	AICc	ΔAICc	weight
0.03	0.02	+	+					10	-233.94	0.00	0.66
0.06		+	+					9	-231.18	2.76	0.16
0.03	0.03	+	+	+				14	-230.39	3.55	0.11
0.01	0.04	+	+		+			13	-228.30	5.64	0.04
0.00	0.04	+						7	-224.92	9.02	0.01
0.00	0.04	+	+	+	+			17	-224.78	9.16	0.01
0.04	0.02		+					6	-223.79	10.15	0.00
0.10	-0.02	+	+	+		+		26	-223.22	10.72	0.00
0.06			+					5	-223.05	10.89	0.00
-0.02	0.07	+		+				11	-222.83	11.11	0.00
0.02	0.03		+		+			9	-222.44	11.50	0.00
0.05	0.02	+	+			+		22	-221.00	12.94	0.00
0.00	0.06	+	+		+	+		25	-218.24	15.70	0.00
0.08		+	+			+		21	-217.45	16.49	0.00
0.01	0.03							3	-214.80	19.14	0.00
0.07	0.01	+	+	+	+	+		29	-212.32	21.62	0.00
0.04		+						6	-201.89	32.05	0.00
0.04								2	-200.56	33.38	0.00
0.06	0.01	+	+	+	+	+	+	41	-85.55	148.39	0.00