Kawailoa Wind Project Habitat Conservation Plan
FY 2020 Annual Report

Prepared for:
Kawailoa Wind, LLC
61-488 Kamehameha Hwy
Haleiwa, Hawai'i 96712

Prepared by:
Tetra Tech, Inc.
737 Bishop St., Suite 2340
Honolulu, Hawai'i 96813

Submitted August 1, 2020

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

EXECUTIVE SUMMARY

This report summarizes work performed by Kawailoa Wind, LLC (Kawailoa Wind), owner of Kawailoa Wind Project (Project), during the State of Hawaiʻi fiscal year 2020 (FY 2020; July 1, 2019 – June 30, 2020) under the terms of the approved Habitat Conservation Plan (HCP), dated October 27, 2011, and pursuant to the obligations contained in the Project's state Incidental Take License ITL-14 (ITL) and federal Incidental Take Permit TE-59861A-1 (ITP). The Project was constructed in 2011 and 2012, and was commissioned to begin operating on November 2, 2012. Species covered under the 2011 HCP include six state- and federally listed threatened or endangered species, as well as one state-listed endangered species. Kawailoa Wind prepared an HCP Amendment to 1) support a request to increase the amount of take for the Hawaiian hoary bat or ʻopeʻapeʻa (*Lasiurus cinereus semotus*) beyond the take authorized under the current ITP/ITL, and 2) add the endangered Hawaiian petrel or ʻuaʻu (*Pterodroma sandwichensis*) as a Covered Species. The U.S. Fish and Wildlife Service (USFWS) issued an ITP for the HCP Amendment in September 2019. The Hawaiʻi Division of Forestry and Wildlife (DOFAW) has recommended approval of the HCP Amendment to the Board of Land and Natural Resources (BLNR), but the final review and vote by BLNR has been deferred pending the results of a contested case hearing.

Fatality monitoring at the Project continued throughout FY 2020 at all wind turbine generators (WTG) within the 35-meter radius circular search plots. The mean search interval for WTGs and meteorological towers in FY 2020 was 3.5 days and 7.1 days, respectively.

Four 28-day carcass persistence trials were conducted in FY 2020, using 60 bat surrogates and 12 medium-sized bird carcasses. For FY 2020, the probability that a carcass persisted until the next search was 0.83 (95% confidence interval [CI] = [0.76, 0.89]) for all bat surrogate carcasses, and 0.988 (95% CI = [0.95, 1.00]) for medium-sized bird carcasses.

Searcher efficiency trials were conducted over 24 trial days with 80 trial carcasses in FY 2020. The overall searcher efficiencies in FY 2020 for bat surrogate (N = 68) and medium-sized bird (N = 12 carcass trials were 93 percent (95% CI = [0.85, 0.97]) and 100 percent (95% CI = [0.82, 1.00]), respectively.

Kawailoa Wind continued the scavenger control program used to increase the probability that fatalities at the wind facility have the opportunity to be discovered by searchers. Overall, the scavenger control program documented the removal of 78 mongooses and two rats in FY 2020 at the Project.

No Covered Species fatalities or fatalities of other federally or state listed species were observed in FY 2020. The Project's total observed bat take from November 2012 through FY 2020 is 40 bats. The fatality estimate for non-incidental observed bats using the Evidence of Absence estimator (Dalthorp et al. 2017) at the upper 80 percent credibility level is 85 bats and the total indirect take for this estimate is 9 adult bat equivalents. Combining these values, there is an approximately 80 percent chance that actual take of Hawaiian hoary bats at the Project is less than or equal to 94 adult bats.

A total of nine non-listed bird fatalities were found at the Project in FY 2020. This included one species protected by the Migratory Bird Treaty Act: white-tailed tropicbird (*Phaethon lepturus*).

During FY 2020, four permanent ground-based ultrasonic bat detectors were managed at the Project. The four permanent ground-based ultrasonic bat detectors were located at WTGs 1, 10, 21, and 25. Between July 2019 and June 2020, Hawaiian hoary bats were detected on 180 of 1,289 detector-nights (14 percent of detector-nights) at the four permanent locations. In addition to the four permanent detectors, two bat detectors were deployed at WTG 30 to document bat interactions with the ultrasonic acoustic bat deterrent “proof of concept” test and have been maintained through FY 2020.

The ‘Uko‘a Wetland mitigation program for Tier 1 mitigation continued for waterbirds and bats through FY 2020 including invasive vegetation control, predator control and monitoring, fence maintenance, bat lane maintenance, and bat acoustic monitoring. Hawaiian hoary bat research projects conducted by the U.S. Geological Survey and WEST Consultants for Tier 2 and 3 bat mitigation continued in FY 2020. Tier 4 bat mitigation was completed in FY 2019 with the acquisition of the Helemano Wilderness Area. Mitigation for the Hawaiian petrel began in FY 2020. Tier 1 mitigation for Newell’s shearwater or ‘a‘o (*Puffinus newelli*) was completed in FY 2015. Tier 1 pueo or Hawaiian short-eared owl (*Asio flammeus sandwichensis*) mitigation was completed in FY 2017.

Kawailoa Wind and Tetra Tech conducted four meetings with USFWS, DOFAW, or BLNR in FY 2020. In addition, Kawailoa Wind and Tetra Tech met with the Endangered Species Recovery Committee three times during FY 2020.

Table of Contents

List of Tables

List of Figures

List of Appendices

This page intentionally left blank

1.0 Introduction

The Habitat Conservation Plan (HCP) for the Kawailoa Wind Project (Project) was approved by the Hawaiʻi Division of Forestry and Wildlife (DOFAW) in 2012 (SWCA 2011; 2011 HCP). On December 8, 2011, the U.S. Fish and Wildlife Service (USFWS) issued Kawailoa Wind, LLC (Kawailoa Wind) a federal incidental take permit (ITP) for the Project, and DOFAW issued a state incidental take license (ITL) on January 6, 2012. The original ITP and ITL cover the incidental take of six state- and federally listed threatened or endangered species, as well as one state-listed endangered species (referred to as the Covered Species) over a 20-year permit term. The Covered Species in the 2011 HCP include the Hawaiian stilt or aeʻo (*Himantopus mexicanus knudseni*), Hawaiian coot or ʻalae keʻokeʻo (*Fulica alai*), Hawaiian duck or koloa maoli (*Anas wyvilliana*), Hawaiian gallinule or ʻalae ʻula (*Gallinula chloropus sandvicensis*), Newell's shearwater or ʻaʻo (*Puffinus newelli*), Hawaiian hoary bat or ʻopeʻapeʻa (*Lasiurus cinereus semotus*), and the state-listed Hawaiian short-eared owl or pueo (*Asio flammeus sandwichensis*).

Project construction occurred in 2011 and 2012, and was commissioned to begin operating on November 2, 2012. It is owned and operated by Kawailoa Wind, a wholly-owned subsidiary of DESRI IV, LLC, which is an investment fund managed by D.E. Shaw Renewable Investments, LLC.

In September 2019, Kawailoa Wind submitted a final HCP Amendment to USFWS and DOFAW for approval. The purpose of the HCP Amendment is to 1) support a request to increase the amount of take for the Hawaiian hoary bat beyond the take authorized under the current ITP/ITL, and 2) add the endangered Hawaiian petrel or ʻuaʻu (*Pterodroma sandwichensis*) as a Covered Species. Kawailoa Wind received an amended ITP from USFWS on September 4, 2019. The Endangered Species Recovery Committee (ESRC) and Hawaiʻi DOFAW has recommended approval of the HCP Amendment to the Board of Land and Natural Resources (BLNR), but the final review and vote by BLNR has been delayed pending the results of a contested case hearing.

This report summarizes work performed for the Project during the State of Hawaiʻi 2020 fiscal year (FY 2020; July 1, 2019–June 30, 2020) pursuant to the terms and obligations of the 2011 HCP, ITL, and amended ITP.

2.0 Fatality Monitoring

In FY 2020, all 30 wind turbine generators (WTGs) were searched for fatalities twice per week, and the two meteorological (met) towers were searched once per week. Search plots consisted of a 35-meter radius circular plot centered on each WTG, and 50-meter radius plot centered on the two unguyed met towers. The FY 2020 mean search interval for WTGs was 3.5 days (standard deviation [SD] = 0.6 days), and the mean search interval for met towers was 7.1 days (SD = 2 days).

In FY 2020, the search plots were searched by trained dogs accompanied by their handlers. In previous years when conditions limited the use of dogs (e.g., weather, injury, availability of canine search team, etc.), search plots were visually surveyed by Project staff; however, canine teams conducted 100 percent of the WTG searches in FY 2020. Vegetation within the search plots was managed (e.g., mowed) to maximize searcher efficiency (Sections 4.0 and 5.0).

3.0 Bias Correction

3.1 Carcass Persistence Trials

Four 28-day carcass persistence trials were conducted in FY 2020 using bat surrogates (black rat; *Rattus rattus*) and wedge-tailed shearwater (*Puffinus pacificus*) carcasses. Wedge-tailed shearwaters are medium-sized birds that are suitable surrogates for the listed bird species covered in the 2011 HCP and HCP Amendment (see above). For FY 2020, the probability that a carcass persisted until the next search was 0.83 (95% CI = [0.76, 0.89]) for all bat surrogate carcasses (N=60), and was 0.988 (95% CI = [0.95, 1.00]) for medium-sized bird carcasses (N=12).

3.2 Searcher Efficiency Trials

Tetra Tech personnel (non-searchers) administered 80 searcher efficiency trials on 23 trial days during FY 2020. Similar to the carcass persistence trials, wedge-tailed shearwaters were used as surrogates for listed bird species, and black rats were used as surrogates for bats. Searcher efficiency trials occurred throughout the year, and 100 percent were conducted on canine search teams in FY 2020.

Vegetation category (short vs. medium) of the search plot was documented at the time the carcasses were placed and when they were found. The overall searcher efficiency for canine searchers (i.e., combined vegetation classes) in FY 2020 was 93 percent (95% CI = [0.85, 0.97]) for bat surrogates (N = 68) and 100 percent (95% CI = [0.82, 1.00]) for medium-sized bird (N = 12) carcasses.

The mean searcher efficiencies in FY 2020 for canine searchers for bat surrogate (N = 53) and medium-sized bird (N = 11) carcass trials in short vegetation were 90.6 percent (95% CI = [0.81, 0.96]) and 100.0 percent (95% CI = [0.8, 1.00]), respectively. The mean searcher efficiencies in FY 2020 for canine searchers for bat surrogate (N= 15) and medium-sized bird (N= 1) carcass trials in medium vegetation were 100 percent (95% CI = [0.848, 1.00]) and 100 percent (95% CI = [0.15, 1.00]), respectively.

4.0 Vegetation Management

Vegetation in the search plots consists mainly of Guinea grass (*Megathyrsus maximus*), Bermuda grass (*Cynodon dactylon*), and sensitive plant (*Mimosa pudica*). All search plots around the WTGs and met towers were mowed regularly to increase visibility during fatality searches. All plots were mowed to a height of 3 to 4 inches, depending on the type of mower used, and were cut roughly every 3 to 4 weeks. There were no unsearchable areas or rock-lined swales within the 35-meter radius search plots.

5.0 Scavenger Trapping

Active trap locations in FY 2020 covered the same general area where traps were deployed in FY 2019. Traps deployed at the Project in FY 2020 include 22 Doc-250 and 21 GoodNature A24 traps; the same number and types of traps were deployed in FY 2019. The scavenger control program documented the removal of 78 mongooses and two rats in FY 2020. No cats were trapped in FY 2020. In January 2020, the frequency of predator control was reduced; however, carcass persistence times are monitored and trapping is responsive to Project needs.

6.0 Documented Fatalities and Take Estimates

No Hawaiian hoary bat fatalities, Hawaiian petrel fatalities, or other listed species fatalities were found in FY 2020. All non-listed fatalities observed at the Project during FY 2020 are listed in Appendix 1. All observed, downed wildlife were handled and reported in accordance with the Downed Wildlife Protocol provided by USFWS and DOFAW. No injured (live) downed wildlife were observed at the Project in FY 2020.

6.1 Hawaiian Hoary Bat

As stated above, no Hawaiian hoary bat fatalities were documented during FY 2020 (Table 1, Appendix 1). The total take estimate for the Hawaiian hoary bat is based on fatality monitoring data and bias correction data from the start of operation November 2012 through June 2020. An upper credible limit (UCL) of take is estimated from three components: (1) observed direct take (ODT) during protocol (standardized) surveys, (2) unobserved direct take (UDT), and (3) indirect take. The Evidence of Absence software program (EoA; Dalthorp et al. 2017), the agency-approved analysis tool for analyzing direct take, uses results from bias correction trials and ODT to generate UCL of direct take (i.e., ODT + UDT). The USFWS and DOFAW have requested that these calculations be reported at the 80 percent UCL. Values from this analysis can be interpreted as there is an 80 percent probability that actual direct take at the Project over the analysis period was less than or equal to the 80 percent UCL. Associated indirect take is estimated based on observations of the temporal distribution of Covered Species fatalities at the Project and agency guidance regarding life history characteristics of the associated Covered Species.

A total of 40 Hawaiian hoary bat fatalities have been observed at the Project since operations began on November 2, 2012. FY 2020 is the first year since the initiation of commercial operations that a bat fatality has not been observed (Table 1). The highest number of bat fatalities was observed in FY 2014 and 2015. Two of these 40 bats were found outside of fatality search plots and classified as incidental observations. Table 1 also presents the cumulative take estimate (direct take + indirect take) by FY since operations began. Direct take is estimated using the EoA estimator at the 80 percent UCL (Dalthorp et al. 2017). Indirect take is calculated using USFWS (2016) guidance.

Table 1. Hawaiian Hoary Bat Fatalities Observed Since Operations Began and Cumulative Take Estimates.

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

1. Does not include bat fatalities found outside of the search areas (i.e., 2 incidental observations).

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

3. The installation of acoustic deterrents represents an inflection point in the bat fatality rate, reducing the risk to bats, and requires the re-evaluation of 2020 data with the application of an appropriate rho value. Changes in the rho value require discussions with USFWS and DOFAW on the appropriate statistical approach to account for the change in risk.

The estimated direct take (ODT + UDT) for the 40 Hawaiian hoary bat fatalities found between the start of operation (November 2, 2012) and end of FY 2020 is less than or equal to 85 bats (80 percent UCL; Appendix 2). Because 2 of the 40 observed bat fatalities were found outside of the search areas (i.e., were incidental observations), 38 fatalities were used in the direct take analysis, and the 2 incidental observations are accounted for in the estimated value of UDT. The two incidental observations were not found during FY 2020.

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

- The average number of pups attributed to a female that survive to weaning is assumed to be 1.8.
- The sex ratio of bats taken through UDT is assumed to be 45 percent female based on the 40 bats assessed by USGS from the Project.
- The assessment of indirect take to a modeled UDT accounts for the fact that it is not known when the unobserved fatality may have occurred. The period of time from pregnancy to end of pup dependency for any individual bat is estimated to be 3 months. Thus, the probability of taking a female bat that is pregnant or has dependent young is 25 percent.
- The conversion of juveniles to adults is one juvenile to 0.3 adults.

Based on the USFWS methodology (2016), the estimate of cumulative indirect take in FY 2020 is calculated as:

- **Total juvenile take calculated from observed female take (April 1 – September 15)**
  - 10 (observed females) * 1.8 (pups per female) = 18 juveniles
- **Total juvenile take calculated from observed unknown sex take (April 1 – September 15)**
  - 0 (observed unknown sex) * 0.45 (sex ratio observed at Kawailoa Wind)* 1.8 (pups per female) = 0 juveniles
- **Total juvenile take calculated from unobserved take**
  - 45 (unobserved direct take) * 0.45 (sex ratio observed at Kawailoa Wind) * 0.25 (proportion of calendar year females could be pregnant or have dependent pups) * 1.8 (pups per female) = 9.1 juveniles
- **Total Calculated Juvenile Indirect Take** = 27.1 (18 + 0 + 9.1)
- **Total Adult Equivalent Indirect Take =** 0.3 (juvenile to adult conversion factor) * 27.1 = 8.1

Therefore, the estimated indirect take based on the UCL of Hawaiian hoary bat direct take at the Project is nine adult bats (rounded up from 8.1).

The UCL for Project take of the Hawaiian hoary bat at the 80 percent credibility level is 94 adult bats (85 estimated direct take + 9 estimated indirect take)[1]. That is, there is an approximately 80 percent probability that actual take at the Project at the end of FY 2020 is less than or equal to 94 bats. This estimate falls within the Tier 4 bat take request detailed in the HCP Amendment, which has a total take request of 115 bats. The HCP Amendment addresses the exceedance of the previously authorized bat take limit (Tiers 1-3) in the 2011 HCP through the identification of additional avoidance and minimization measures, as well as additional compensatory mitigation for the Hawaiian hoary bat (Tetra Tech 2019).

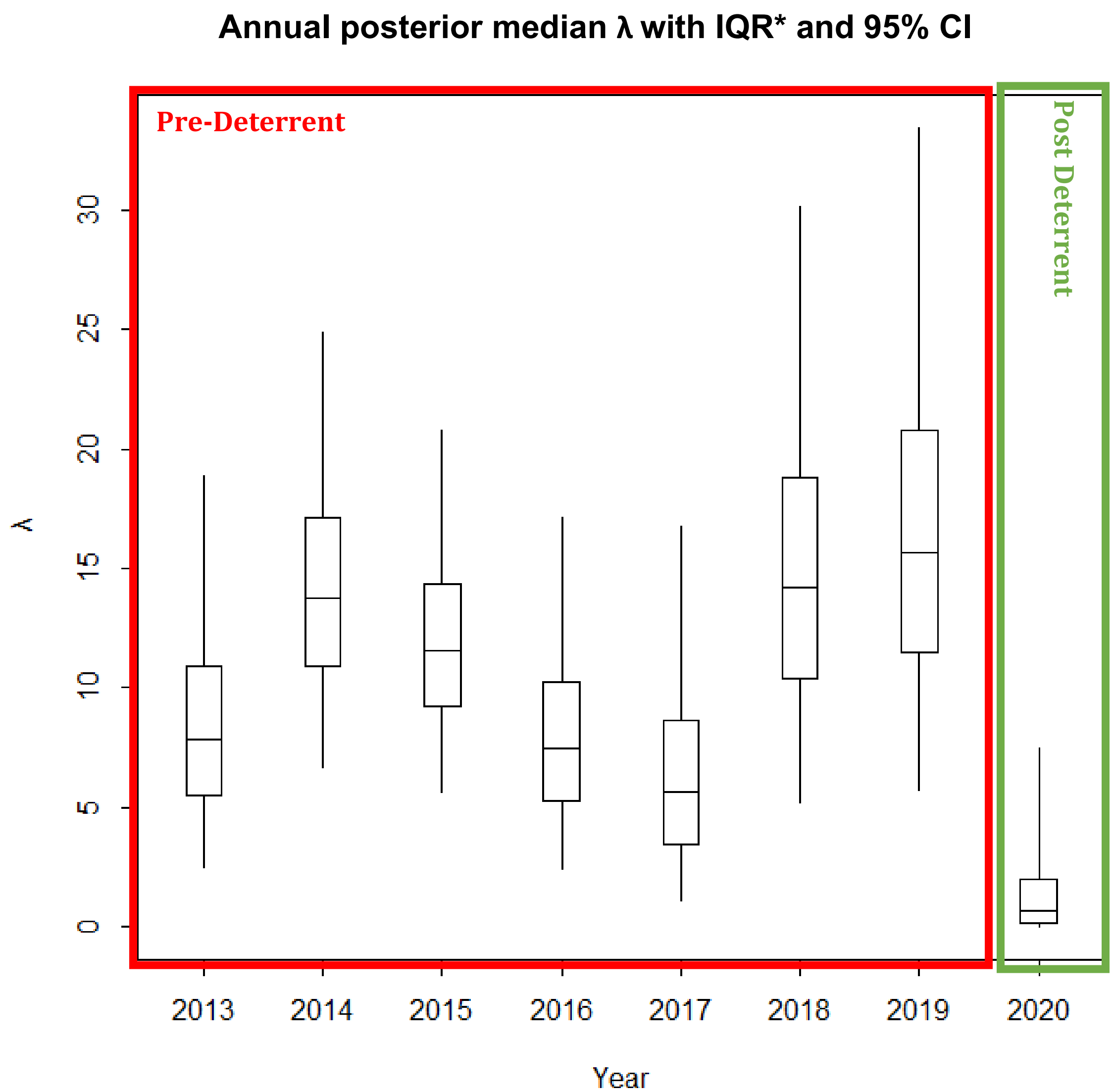
The minimization measures associated with the HCP Amendment demonstrate a statistically significant reduction in the fatality rate. This reduction warrants the application of an appropriate rho value in the EoA model. A comparison of the fatality rates before and after the application of minimization measures associated with the HCP Amendment shows the fatality rate in FY 2020 is reduced from an average of 11.15 bats per year estimated by EoA to 1.48 bats per year (Figure 1). A test for misspecification of rho in EoA demonstrates that the rho value of 1 in 2020 is overestimated (p value = 0.00658). Using a rho value of 0.5, the test for misspecification exceeds the threshold of 0.05 (p value = 0.052). The estimate of a rho of 0.5 is statistically supported by EoA (95 percent certain) and is conservative (assumes lower deterrent effectiveness than suggested by available data) because of the use of 95 percent confidence level and the single year of monitoring data

[1] This total is estimated using a rho value of 1. The assessment of take is subject to change if a rho value less than one is determined to apply.

following the installation of the ultrasonic acoustic deterrent (UAD); the estimated rho value is likely to decrease as additional monitoring data are collected.

Kawailoa Wind proposes methods for determining an appropriate and conservative rho value in Appendix 3. Assessment of rho in the post-UAD installation period will continue to incorporate ongoing fatality monitoring results in the post-UAD period through the approach outlined in Appendix 3. The inclusion of multiple years will provide statistical rigor to accurately assess changes in rho given the observed inter-annual variability. The rho value applied for periods with the current minimization measures will be re-evaluated annually to adjust for additional information until Kawailoa Wind, USFWS, and DOFAW have sufficient evidence for the reduction in fatalities associated with deterrents. The use of a rho value less than 1 to evaluate compliance with authorized take limits is subject to approval from USFWS and DOFAW, as such this approach has not been used in the current analysis of cumulative take estimates. The details of this comparison are provided in Appendix 3.

A take projection can be generated with EoA and with methods outlined in the HCP to estimate the likelihood of staying within the permitted take within the permit term. The take projection is influenced by the rho value as outlined in the preceding paragraphs. Given the use of a rho value of 0.5, the median take projection in the last year of the permit term (2032) is 148 (Interquartile Range [IQR]: 141, 158). This value would be well below the total take authorization of 220 bats. This method of projection is likely to overestimate project impacts because the take rate prior to deterrent installation heavily impacts the projection despite the application of a rho value less than one (10.2 estimated fatality rate from FY 2013 through FY 2020 * 0.5 rho value = approximately 5.1 bats per year estimated future fatality rate). The HCP specifies a comparison of the current take estimate and the current take rate to total authorized take over the permit term to determine if adaptive management is warranted. This method can also be used to evaluate take rates on an ongoing basis. EoA estimated the take rate at the Project in FY 2020 is 1.48 bats per year; extrapolating from the current direct take estimate, and the current take rate the Project estimates a direct take total of 102.8 bats (85 bats estimated by EoA in FY 2020 + 1.48 bats per year * 12 years remaining in the permit term). The Project's current ratio of indirect take to direct take indicates the estimated indirect take is 9.6 percent of the direct take estimate (8.13 adult bat equivalents estimated in FY 2020 / 85 bats estimated from direct take). When an estimate of indirect take of 9.8 adult bat equivalents (9.6 percent * 102.8 bats estimated from direct take) is added to the direct take estimate, the estimated take is 112.6 adult bat equivalents (102.8 bats estimated through direct take + 9.8 bats estimated through indirect take) in year 2032. This indicates the Project may stay below the Tier 4 maximum of 115 bats through the permit term. Both the EoA and HCP methods of generating take projections indicate the Project will stay below the HCP Amendment take estimates through the permit term.



***Interquartile Range**

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

6.2 Non-listed Species

Nine bird fatalities representing six species were documented at WTGs at the Project in FY 2020. No fatalities have been observed at either of the two met towers. One of the species observed in FY 2020 is protected by the Migratory Bird Treaty Act (MBTA): white-tailed tropicbird (one bird; *Phaethon lepturus*). In addition, eight fatalities of non-native introduced birds without MBTA protection were documented: common waxbill (one bird; *Estrilda astrild*), spotted dove (three birds; *Spilopelia chinensis*), ring-necked pheasant (one bird; *Phasianus colchicus*), zebra dove (one bird; *Geopelia striata*), and scaly-breasted munia (two birds; *Lonchura punctulata*). For a complete list of fatalities for FY 2020, see Appendix 1.

7.0 Wildlife Education and Observation Program

Wildlife Education and Observation Program (WEOP) trainings continue to be conducted on an as-needed basis to provide on-site personnel with the information they need to be able to respond appropriately in the event they observe a listed species or encounter a fatality while on site. Tetra Tech biologists conducted nine WEOP trainings in FY 2020.

8.0 Mitigation

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

8.1 Hawaiian Hoary Bats

For the Hawaiian hoary bat, mitigation is required based on where the estimated Project take falls with respect to tiers identified in the 2011 HCP and HCP Amendment. Management activities for Tier 1 mitigation continued at ʻUkoʻa Wetland during FY 2020 (see Section 8.1.2). USFWS and DOFAW approved bat research projects for Tiers 2/3 mitigation published or continued in FY 2020 (see Section 8.1.3). Kawailoa Wind contributed funds toward the purchase and long-term protection of the Helemano Wilderness Area for Tier 4 mitigation under the HCP Amendment, as described in Section 8.1.5 below. Kawailoa Wind is currently in the planning phase for Tier 5 bat mitigation, in coordination with USFWS and DOFAW (see Section 8.1.6).

8.1.1 On-site Acoustic Surveys

Following commitments outlined in the 2011 HCP (SWCA 2011), bat activity was intensively monitored at 42 sites (30 WTGs at ground and nacelle, and 12 gulch detectors) across the Project during the first 3 years of systematic fatality monitoring (beginning in August of 2013, FY 2014). Having identified no significant correlates with acoustic bat activity that could inform curtailment during the required intensive acoustic monitoring period (April 2012 to November 2015), Kawailoa Wind reduced the acoustic monitoring effort at the Project in the second quarter of FY 2017 to four permanent ground-based units located at WTGs 1, 10, 21, and 25 (Figure 2). These locations were randomly chosen after eliminating detectors with high or low detection rates.

The acoustic monitoring equipment has changed over time. Each site has used Wildlife Acoustic (WA; Wildlife Acoustics, Maynard, MA, USA) Song Meter (SM) 2 detectors that included one of up to three microphone types consistent with current technology at the time. Since January 2015, each acoustic monitoring unit consists of a WA SM2BAT+ ultrasonic recorder (SM2), currently equipped with one WA SM3-U1 ultrasonic microphone positioned 6.5 meters above ground level. Prior to January 2015, SM2s were equipped with WA SMX-US ultrasonic microphones. Monitoring of acoustic activity at these sites will continue into FY 2021.

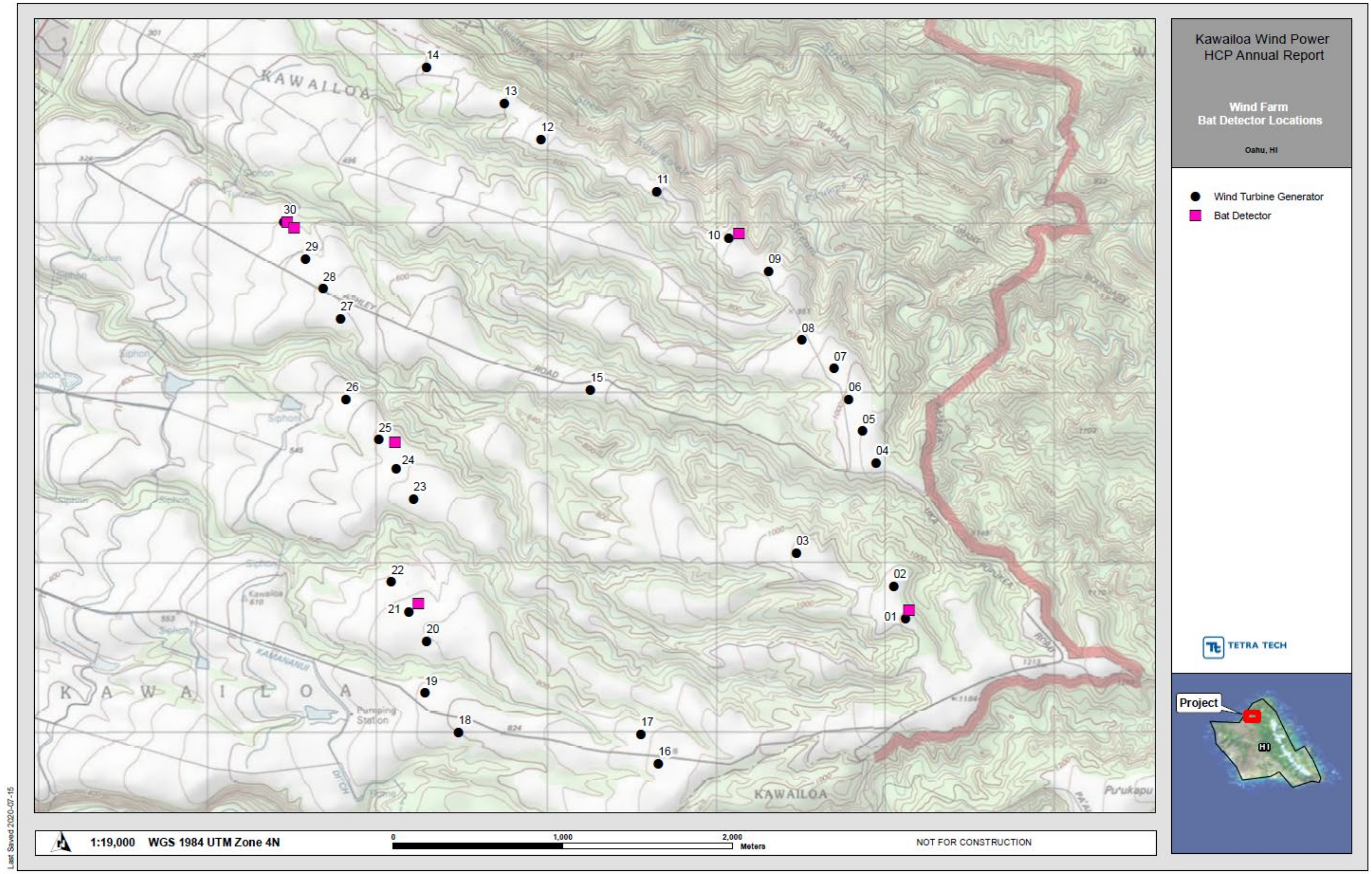


Figure 2. Four Permanent Ground-based Bat Acoustic Detector Locations and Two Bat Acoustic Detector Locations at UAD Installed Turbine 30 at the Project in FY 2020.

The objective of monitoring is to understand better the annual and seasonal variations in bat activity at the project. Analysis of variance (ANOVA) and Tukey's honest significance difference (Tukey's HSD) were used to test for differences in detection rates between FY 2014 and FY 2020. A linear model (LM) was used to test for a change in detection rates across all monitoring years. Data were normalized using a square root transformation. The distribution of residuals from the LM indicated the data did not violate assumptions of the model. All tests were 2-tailed, employed an alpha value of 0.05, and were conducted in the R statistical software (R Core Team 2017). These same methods are used for analyzing bat acoustic monitoring for 'Uko'a Wetland (Section 8.1.3), with the exception of the linear model, which was not performed for 'Uko'a.

In July 2018, site WTG-30 was fitted with an NRG ultrasonic UAD as a "proof of concept" test (see Tetra Tech 2019), and in May and June 2019 all WTGs at Kawailoa Wind were fitted with similar UADs. Two SM2 units were deployed at WTG-30 in September 2018 to monitor bat activity. One SM2 unit (WTG-30H) was deployed approximately 75 meters east-southeast of site WTG-30 at the historical location, monitored in FYs 2014 to 2016. The second SM2 unit (WTG-30N) was deployed approximately 27 meters east of site WTG-30.Hawaiian hoary bats were detected on 180 of 1,289 (14.0 percent) detector-nights sampled throughout FY 2020 (July 2019 – June 2020). The annual detection rate in FY 2020 was lower than the annual detection rate in FY 2019 (25.6 percent; Tetra Tech 2019), although not significant (Tukey's HSD: $P > 0.273$). Annual detection rates varied between all monitoring years (Table 2); however, only differences between FY 2014 and FY 2018, and FY 2014 and FY 2019 were significantly different (ANOVA: $F_{6,83} = 2.99$, $P < 0.012$; Tukey's HSD: FY 2014 - FY 2018 $P < 0.040$, FY 2014 – FY 2019 $P < 0.005$). Across all monitoring years (FY 2014 to FY 2020), there is significant increasing trend in the annual detection rates (LM: $R^2 = 6.36\%$; $F_{2,83} = 6.57$, $P < 0.013$; Figure 3). If FY 2014 is removed, there is still an increasing trend in the annual detection rates, although not significant (LM: $R^2 = 1.21\%$; $F_{2,83} = 0.85$, $P > 0.359$). The low r-squared value of this trend suggests that little of the variation is explained by the linear model, this could be an indication of inherent inter-annual variation or the importance of variables not included in the model, residuals did not suggest model misspecification.

Table 2. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections at Four Permanent Ground-based Detectors Sampled from FY 2014 through FY 2020.

Sampling Period	Number of Nights Sampled	Number of Nights with Detections	Proportion of Nights with Detections
FY 2014 (July 2013 – June 2014)	1,271	91	0.072
FY 2015 (July 2014 – June 2015)	1,021	155	0.152
FY 2016 (July 2015 – June 2016)	1,298	208	0.160
FY 2017 (July 2016 – June 2017)	1,378	173	0.126
FY 2018 (July 2017 – June 2018)	1,421	275	0.194
FY 2019 (July 2018 – June 2019)	1,262	323	0.256
FY 2020 (July 2019 – June 2020)	1,289	180	0.140

Note: FY 2013 not included due to minimal number of detector-nights compared to other years.

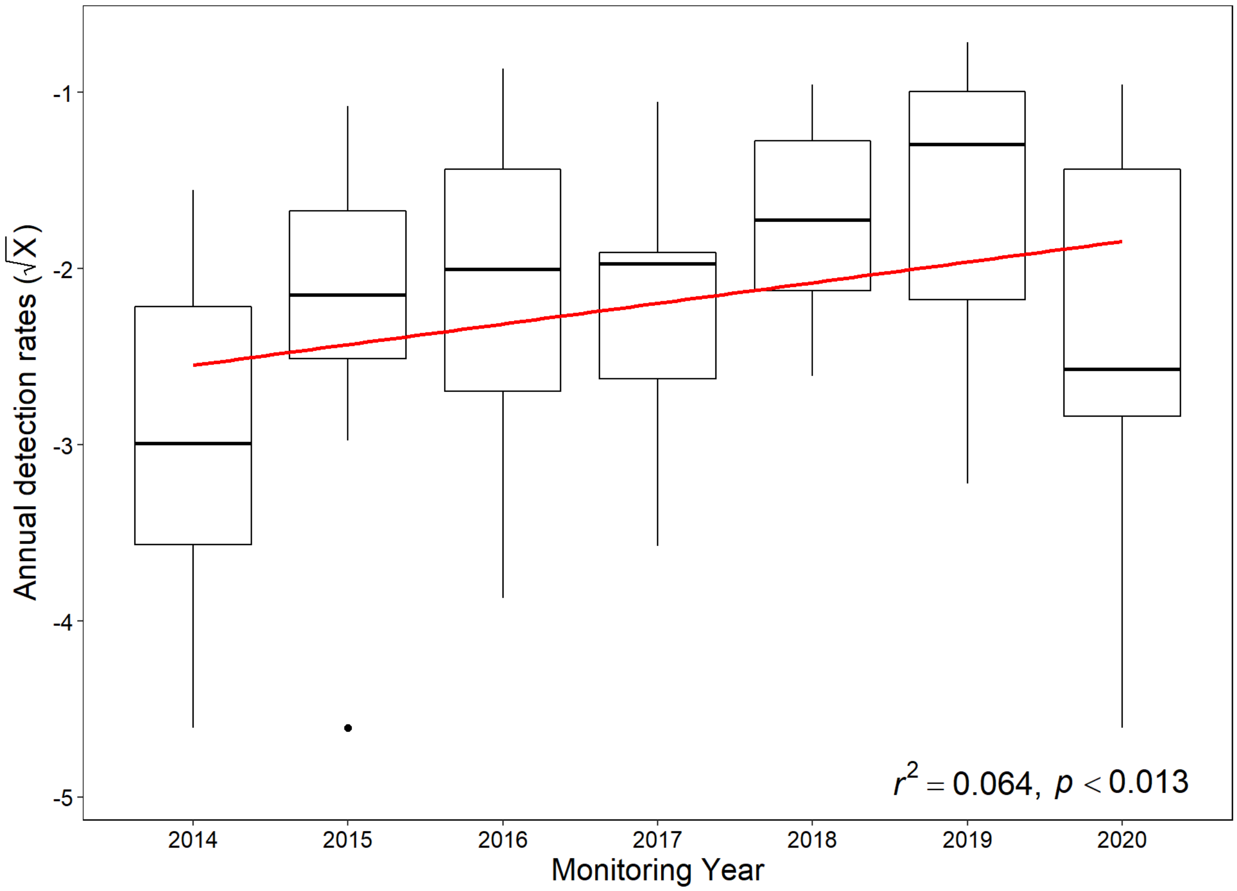


Figure 3. Linear Regression Showing the Increasing Trend in the Annual Detection Rates at the Project between FY 2014 and FY 2020. Box and whiskers represent the 25th, 50th, and 75th quartiles with 95% confidence intervals.

In FY 2020, elevated detection rates were observed during the lactation period (July and August) and early, post-lactation (September) period, with increased rates again in May and June during the pregnancy reproductive period[2]. A decline in the detection rates occurred shortly after the transition to the post-lactation (September to December) reproductive period. Lower detection rates were observed from October of the post-lactation to April of the pregnancy reproductive periods (Figure 4).

[2] Reproductive periods correspond approximately with reproductive periods as defined by Gorresen et al. (2013).

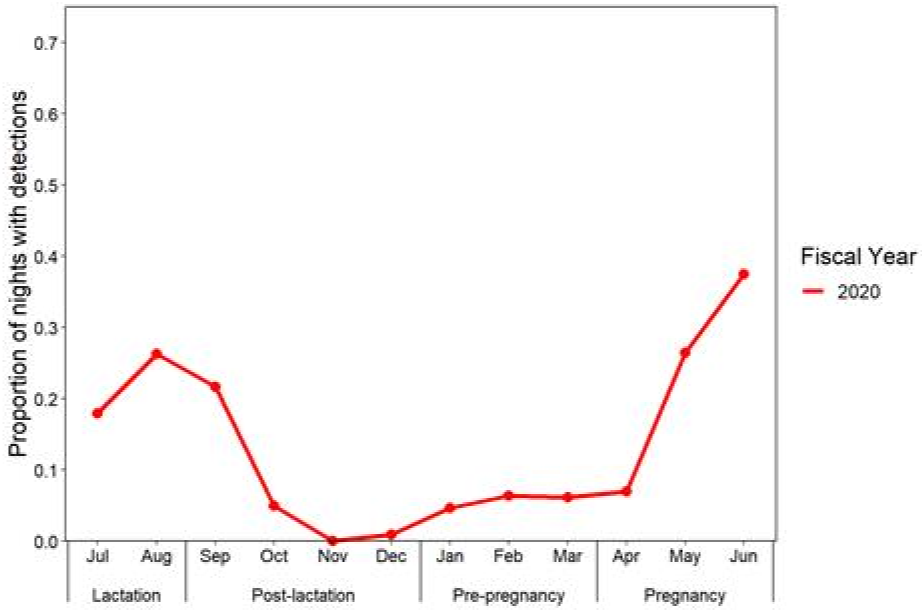


Figure 4. Monthly Detection Rates at Kawailoa in FY 2020 with Corresponding Reproductive Periods.

The temporal patterns in the detection rates for the FY 2020 sampling period were relatively similar to the detections rates observed in previous sampling years (Figure 5). The general temporal pattern in the detection rates observed at the Project has also been reported in Hawaiian hoary bats monitored at other low elevation sites on O'ahu (Starcevich et al. 2020) and Hawai'i Island (Todd 2012).

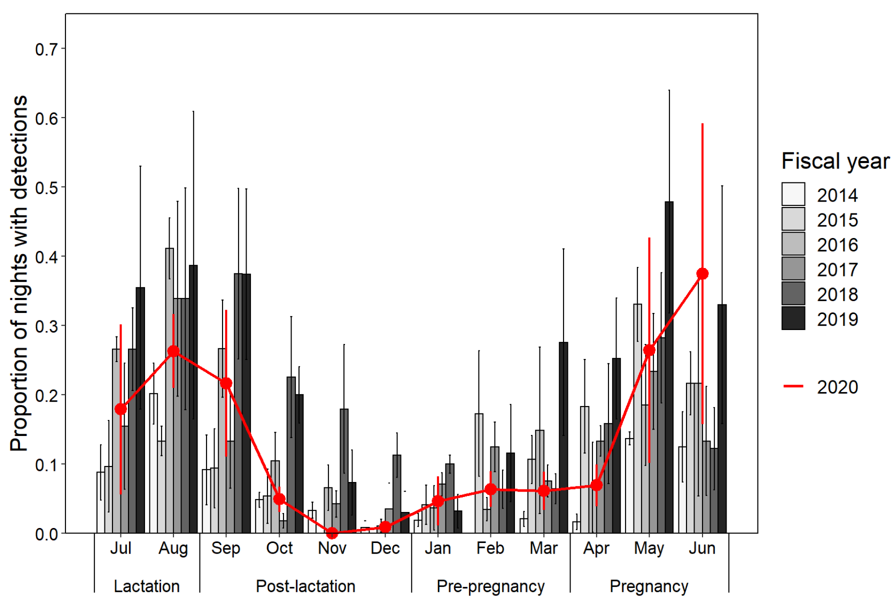


Figure 5. Monthly Bat Detection Rates at Kawailoa for FY 2014 to FY 2020 with Corresponding Reproductive Periods.

Detection rates varied among the four sampling locations. During the lactation (July and August) and early post-lactation (September) reproductive periods, detections rates were highest at sites WTG-1 and WTG-25 (Figure 6). Throughout the remainder of the post-lactation (October to December) reproductive period, detection rates declined at all sites, with periodic detections occurring at site WTG-10 (Figure 6). During the pre-pregnancy (January through March) reproductive period, there was a slight increase in the detection rates at sites WTG-10 and WTG-21, with no detection nights at site WTG-1 and only a single detection night in the months of February and March at site WTG-25. In the pregnancy reproductive period (April through June) detection rates remained relatively consistent at site WTG-21, while increases in detection rates were observed at sites WTG-1, WTG-10, and WTG-25. The highest detection rates were observed at site WTG-25 during May and June of the pregnancy reproductive period.

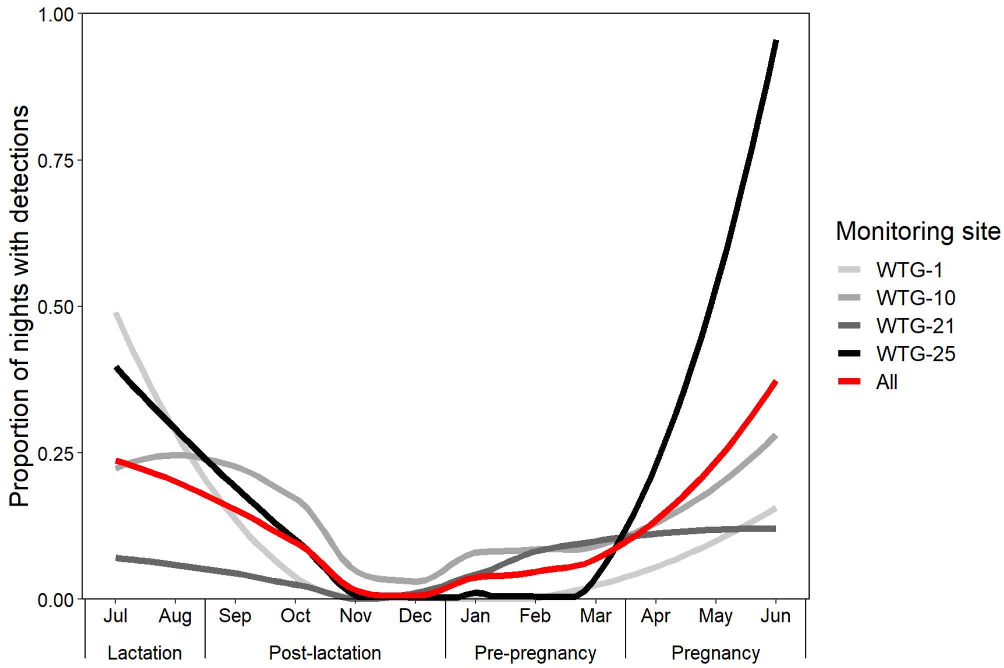


Figure 6. Site-Specific Variation in Detection Rates for Each Month of FY 2020 with Corresponding Reproductive Periods. Trend Lines are fitted with Loess smoothing curve.

8.1.2 Acoustic Monitoring at UAD Installed Turbine

At site WTG-30N, Hawaiian hoary bats were detected on 32 nights out of 340 (9.4 percent) detector-nights sampled in FY 2020, which was similar to the annual detection rate (8.9 percent) observed in FY 2019 (September 2018 to June 2019). At WTG-30H, Hawaiian hoary bats were detected on 56 nights out of 364 (15.4 percent) detector-nights sampled in FY2020, which was a slight increase compared to the annual detection rate (9.5 percent) observed in FY2019, although not significant ($t_{2,22}$ = 0.15, P > 0.885) and within range of the variation (4.3 to 14.1 percent) observed in previous sampling years.

8.1.3 ‘Uko‘a Wetland (Tier 1)

Mitigation for bats and waterbirds continued at ‘Uko‘a Wetland during FY 2020. In FY 2016 (March 2016), USFWS and DOFAW provided written confirmation permitting adaptive management for the original bat and waterbird mitigation proposed at ‘Uko‘a Wetland. This included the following:

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

In FY 2020, activities associated with Tier 1 bat mitigation included invasive vegetation removal, predator control, monitoring predator presence, fence monitoring and maintenance, bat lane maintenance, and bat acoustic monitoring. Additional details for each are provided below. Based on the approved ‘Uko‘a Wetland Hawaiian Hoary Bat Mitigation Management Plan (H. T. Harvey and SWCA 2014), bat acoustic monitoring will continue for 3 to 5 years post-restoration. Based on the approved ‘Uko'a Wetland Management Plan for Waterbirds 2012–2032 (SWCA 2012), vegetation management, predator and ungulate control, and fence maintenance will continue for the permit term (20 years).

8.1.3.1 Invasive Vegetation Removal

In FY 2020, Hapa Landscaping conducted quarterly maintenance visits to remove any areas of water hyacinth (*Eichhornia crassipes*) or other invasive vegetation that regenerated in the previously cleared open water area including water lettuce (*Pistia stratiotes*) and California grass (*Urochloa mutica*). Scheduled visits were modified as needed to accommodate staff schedules and avoid disturbing Hawaiian common gallinule nests and chicks in the area. Figure 7 shows a representative photograph of this ongoing maintenance.

Figure 7. Open Water Resulting from Ongoing Removal of Invasive Vegetation at ʻUkoʻa Wetland in FY 2020. Photo Taken in June 2020.

8.1.3.2 Predator Control and Monitoring Predator Presence

The Project contracted Grey Boar Wildlife Services, LLC (Grey Boar) to conduct predator and ungulate removal at ʻUkoʻa Wetland, as well as to monitor and repair the fence. Predator control first began at ʻUkoʻa Wetland in June 2014 (FY 2014). The following trap types are used throughout at ʻUkoʻa Wetland in FY 2020: four pig corral and two pig box traps, 100 GoodNature A24s, 12 live cages, and 50 Doc-250s. In FY 2020, a total of 203 predators were removed from ʻUkoʻa Wetland including 7 pigs, 168 mongoose, 3 cats, and 25 rats (Grey Boar 2019a, 2019b, 2020a, 2020b).

Tracking tunnels were set on four dates during FY 2020 to assess the presence of rodents, mongoose, and cats within the wetland. A total of 27 tracking tunnels were used to detect predator presence. The cards were baited with fish paste and collected one day after setting. Tracks were then counted and recorded. Percent activity (number of cards with tracks divided by total number of cards set out) is shown in Table 3.

Rat activity varied between 7.0 percent and 11.1 percent, mongoose activity varied between zero and 7.0 percent, mice activity varied between zero and 18.0 percent and cat activity varied from zero to 4.0 percent. Overall, tracking tunnel data since 2014 shows a general reduction in predator presence, specifically mongoose and rats, since the predator program was initiated.

Table 3. Percent Predator Activity Based on Tracking Tunnels at ‘Uko‘a Wetland during FY 2020.

Date	Rats	Mongoose	Mice	Cats
September 6, 2019	11.1%	0.0%	3.7%	0.0%
December 7, 2019	7.4%	3.7%	0.0%	0.0%
April 24, 2020	15.0%	7.0%	18.0%	0.0%
June 26, 2020	7.0%	7.0%	29.1%	4.0%

8.1.3.3 Fence Monitoring and Maintenance

Fence inspections were conducted by Grey Boar while checking predator control traps. The fence was visually inspected for any signs of ungulate disturbance, damage, or vandalism. During FY 2020, several sections of fence were repaired. In February 2020, a large Kiawe tree (*Prosopis pallida*) was cleared that had fallen and crushed a portion of the fence. The main cause of fence damage continues to be trespassers.

8.1.3.4 Bat Lanes

Oahu Tree Works, LLC finished bat lane construction in December 2017 (FY 2018). In total, there are 16 bat lanes within 10 zones throughout ‘Uko‘a Wetland (Figure 8). Bat lane maintenance occurred in Q4 of FY 2020. Lane maintenance in FY 2020 consisted of cutting branches and vegetation that regrew within the 5-meter-wide bat lanes. Figure 9 shows one of the bat lanes shortly after lane maintenance in June 2020.

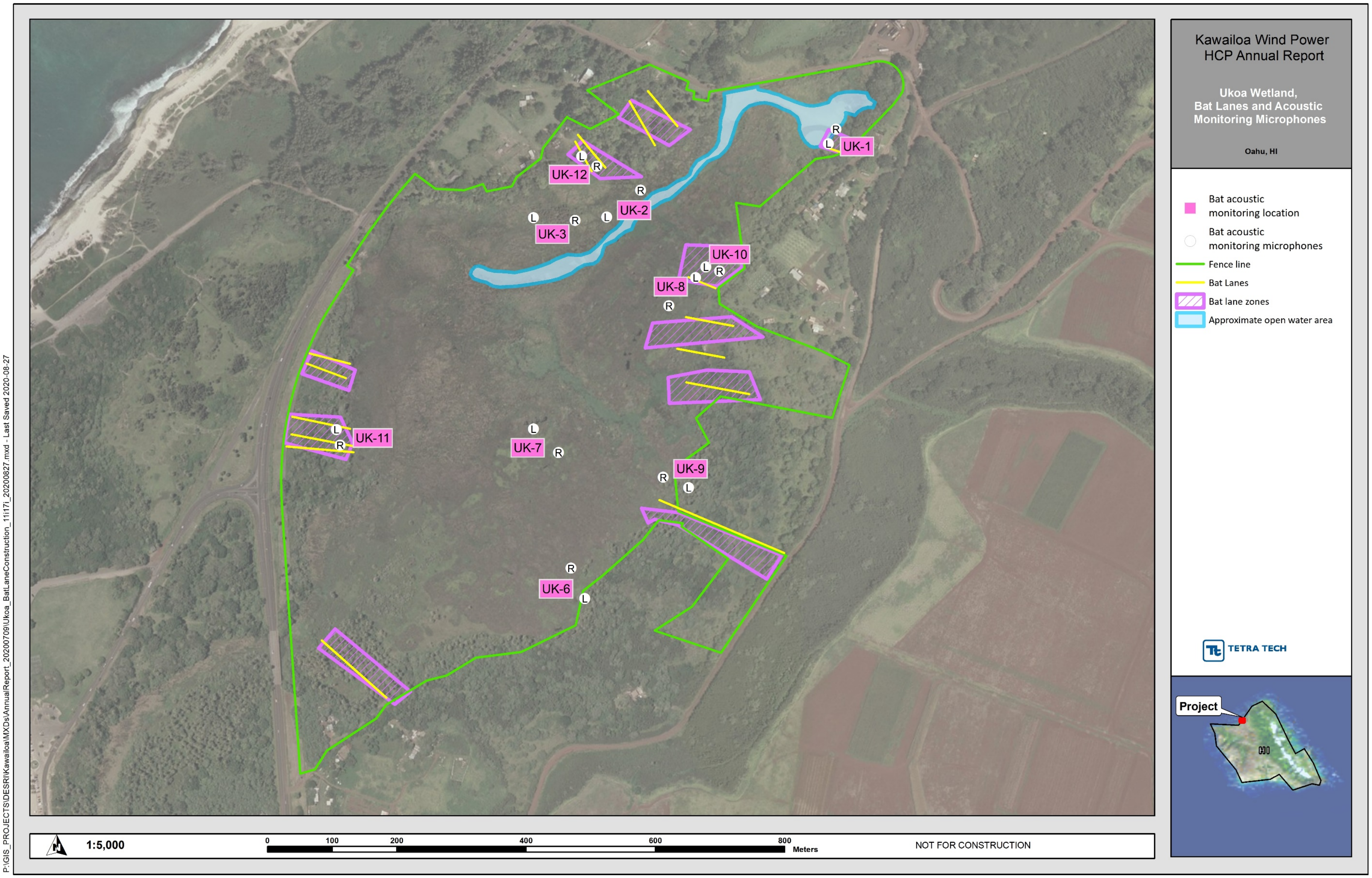


Figure 8. Bat Lanes and Bat Acoustic Detector Microphones at ‘Uko‘a Wetland.

Figure 9. Bat Lane at ʻUkoʻa Wetland. Photo Taken in June 2020.

8.1.3.5 Bat Acoustic Surveys at ʻUko'a

In June 2017 (FY 2017), following the removal of invasive vegetation at the ʻUko'a Wetland area and during the construction of bat lanes, 10 WA SM2 units were deployed at locations previously monitored between FY 2012 and FY 2015 (see Figure 8). To maintain consistency in monitoring methods across all sampling years of the study, the acoustic monitoring equipment deployed in FY 2017 was similar to the equipment used in previous sampling years. Each site consisted of a single WA SM2 unit equipped with two WA SMX-U1 ultrasonic microphones, one each on the left and right channel ports. Microphones were placed approximately 30 meters apart (Figure 8) and positioned between 3 and 6.5 meters above ground level. The proportion of detector-nights containing a single bat pass (any call file containing two or more bat echolocation pulses; Gannon et al. 2003) was used as a measure to quantify bat activity. Acoustic detections for each site were pooled across both microphone channels. To avoid double counting, only a single detection was counted when both microphones recorded a call at the same time.

The methods used to analyze bat acoustic data at ‘Uko’a are the same as those used in the analysis of bat acoustic data at the Project (Section 8.1.1).

In FY 2020 (July 2019 – June 2020), Hawaiian hoary bats were detected on 680 nights out of 3,344 (20.3 percent) detector-nights sampled. The annual detection rate in FY 2020 was higher than the annual detection rate (13.8 percent) in FY 2019 (Tetra Tech 2019), although not significant (Tukey’s HSD: $P > 0.421$). Between FY 2012 and FY 2020, annual detection rates varied among sampling years (Table 4), with significant differences (ANOVA: $F_{8,78} = 4.81$, $P < 0.001$) between FY 2014 and 2016 (Tukey’s HSD: $P < 0.006$), 2014 and 2018 (Tukey’s HSD: $P < 0.010$), 2014 and 2020 (Tukey’s HSD: $P < 0.001$), and 2015 and 2020 (Tukey’s HSD: $P < 0.025$). Despite this variation, there is a significant increase in the annual detection rates across all years (LM: $R^2 = 17.84\%$; $F_{2,76} = 17.72$, $P < 0.001$). There are some inconsistencies in sampling periods for some of the monitoring years. Sampling in FY 2012, FY 2016, and FY 2017 only occurred during the pregnancy and lactation reproductive periods, which have higher rates of detections.

Table 4. Number of Nights Sampled, Number of Nights with Detections, and Proportion of Nights with Bat Detections for FY 2012 through FY 2020.

Dates	Before or After Vegetation Removal	No. of Nights Sampled	No. of Nights with Detections	Proportion of Nights with Detections
FY 2012 (April – June 2012)	Before	256	25	0.098
FY 2013 (July 2012 –June 2013)	Before	2,135	192	0.090
FY 2014 (July 2013 – June 2014)	Before	2,777	100	0.036
FY 2015 (July 2014 – June 2015)	Before	2,541	187	0.074
FY 2016 (July – October 2015)	Before	926	198	0.214
FY 2017 (June 2017)	After	163	9	0.055
FY 2018 (July 2017 – June 2018)	After	3,381	498	0.147
FY 2019 (July 2018 – June 2019)	After	3,373	466	0.138
FY 2020 (July 2019 – June 2020)	After	3,334	680	0.204

Detection rates in FY 2020 peaked during the lactation reproductive period (July to August) followed by a decline in the detection rate at the onset of the post-lactation (September to December) reproductive period (Figure 10). Detection rates fluctuated throughout the post-lactation, pre-pregnancy (January to March), and early pregnancy (April to June) reproductive periods. A second peak in detection rates occurred in May, followed by a slight decline in June during the pregnancy reproductive period. The temporal patterns in the detection rates for the FY

2020 sampling period are similar to the detections rates observed at ʻUkoʻa Wetland in previous sampling years (Figure 11).

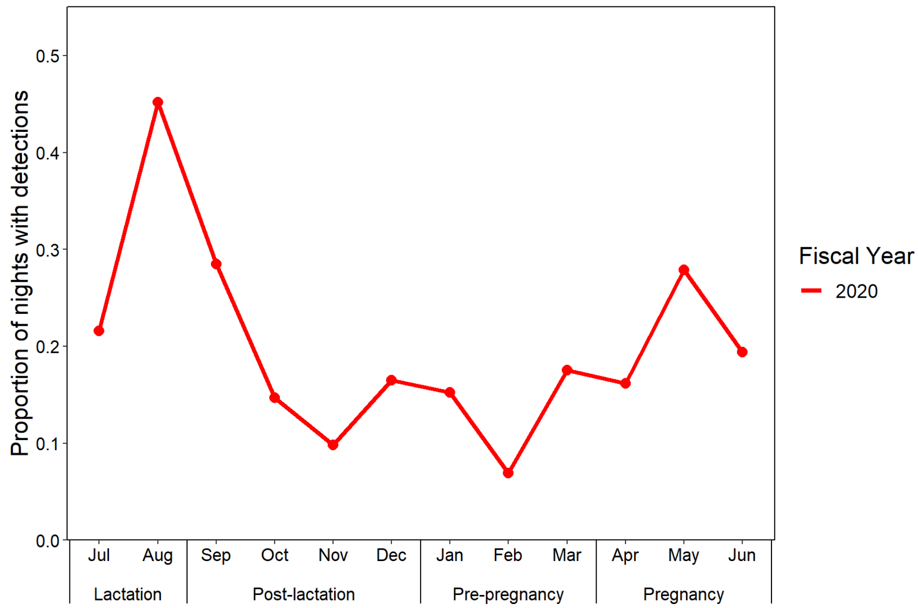


Figure 10. Monthly Detection Rates at ʻUkoʻa Wetland in FY 2020 with Corresponding Reproductive Periods.

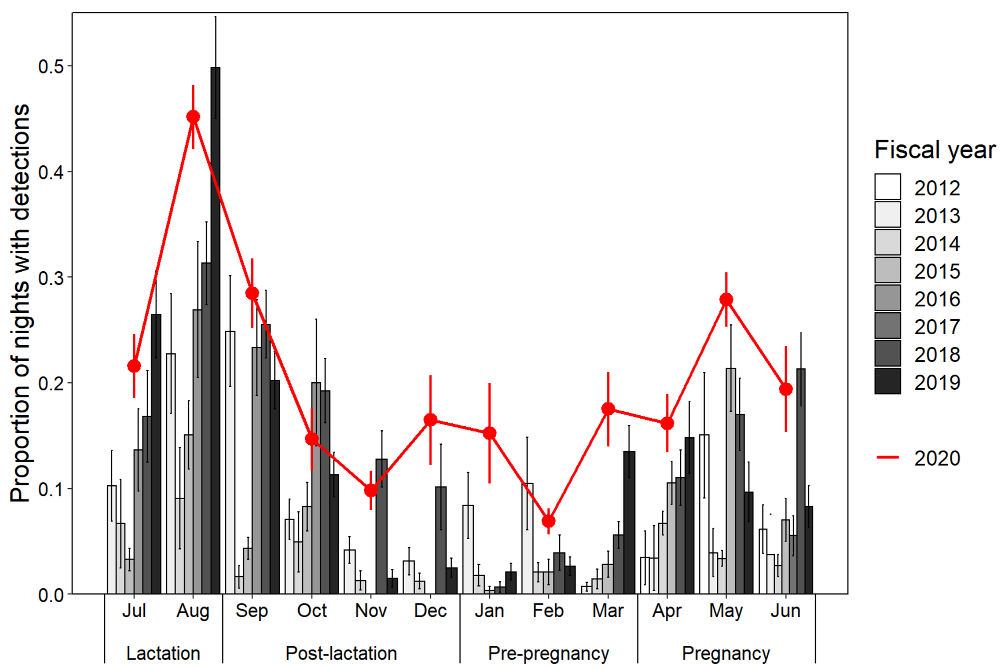


Figure 11. Monthly Bat Detection Rates at ʻUkoʻa Wetland for FY 2014 to FY 2020 With Corresponding Reproductive Periods.

Comparison of detection rates for each month before (FY 2012 to FY 2016) and after (FY 2017 to 2018) mitigation measures were implemented at 'Uko'a Wetland indicate an increase in the detection rates for several of the months and reproductive periods throughout the year (Figure 12). In addition to observed increases in monthly detection rates, there was also an observed increase in the mean proportion of nights with feeding buzzes recorded at several of the monitoring sites after mitigation measures were implemented (Figure 13). A feeding buzz is classified as a burst of pulses at a very high rate with less than 11 milliseconds between pulses (Griffin et al. 1960) and are indicative of foraging behaviors. Monitoring sites UK-1, UK-2, UK-6, UK-11, and UK-12 had the greatest observed increase subsequent to mitigation implementation (Figure 13). The observed increases in the detection rates and feeding buzzes are a positive indication for the effects of management but may correlate with factors other than the invasive species removal or bat lane installation.

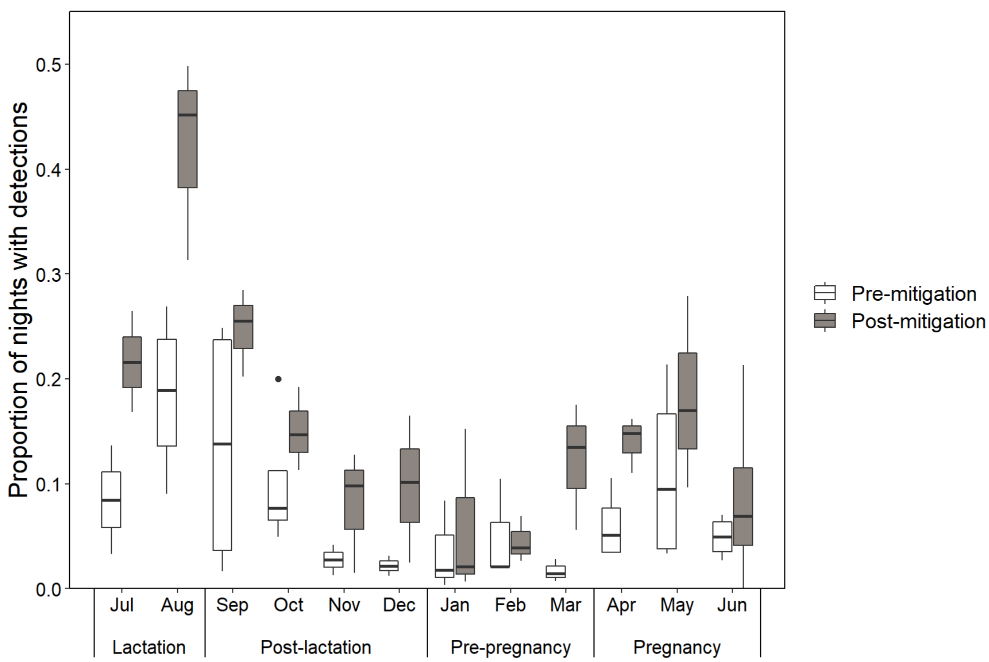


Figure 12. Monthly Bat Detection rates with at 'Uko'a Wetland Before (FY 2012 – 2016) and After (FY 2017– 2019) Invasive Vegetation Removal and Bat Lane Construction.

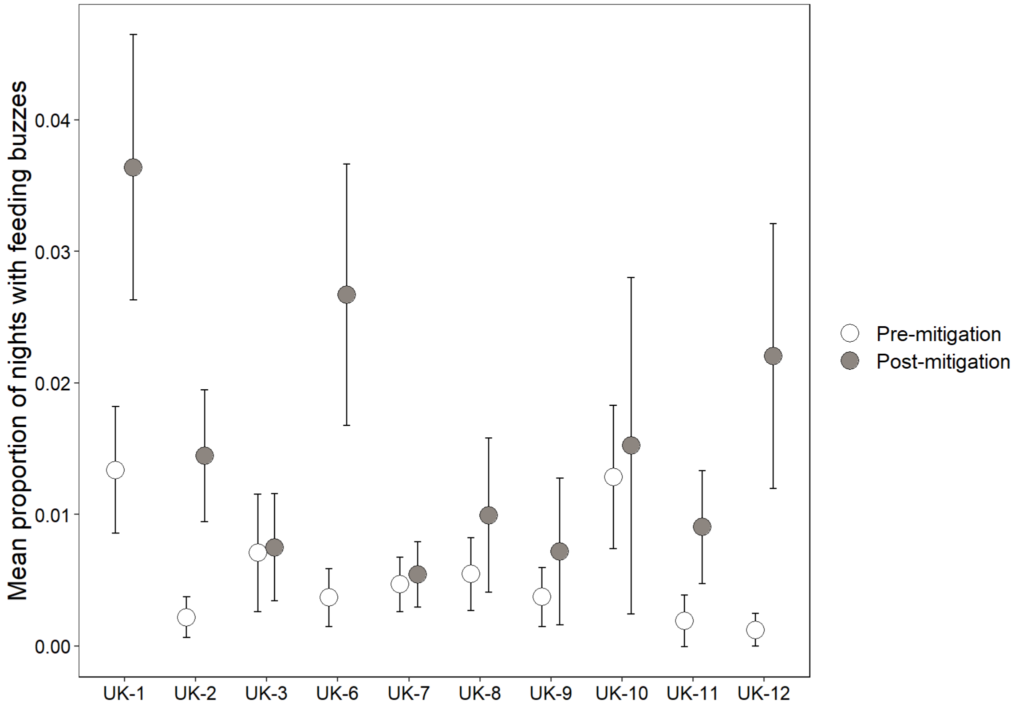


Figure 13. Mean Proportion of Feeding Buzzes and Standard Errors for Each Monitoring Site at 'Uko'a Wetland Before (FY 2012-2016) and After (FY 2017-2019) Invasive Vegetation Removal and Bat Lane Construction.

8.1.4 Studies (Tier 2/3)

Kawailoa Wind finalized contracts with WEST Consultants (WEST) and the U.S. Geological Survey (USGS) in FY 2017 to conduct three multi-year studies as Tier 2/3 Hawaiian hoary bat mitigation. These studies were recommended to Kawailoa Wind by USFWS and DOFAW. The total funding for the three projects is over $1.6 million.

One of the USGS research projects (Modeling Foraging Habitat Suitability) was completed in FY 2019 and the research was published in *PLOS ONE* (Gorresen et al. 2018). During FY 2020, Kawailoa Wind continued to fund the WEST project and the second USGS genetics study. A summary of the work completed for these studies during FY 2020 is provided below.

The objectives of USGS' *Hawaiian Hoary Bat Conservation Genetics* study are to improve the understanding of the genetic diversity of the Hawaiian hoary bat, identify bat prey items, and identify the sex of bat carcasses and any sex-specific food habits. Data on these topics will help inform conservation planning and improve host-plant selection for future habitat restoration efforts. A technical report was published for this study in November 2018 (Pinzari and Bonaccorso 2018a). In FY 2020, USGS released additional data from this study on April 13, 2020 (Pinzari and Bonaccorso 2018b). During FY 2020, this research determined the sex of five Hawaiian hoary bat tissue samples using genotyping, which allows for more reliable evaluation of the ratio of males to females affected by collisions with WTGs. The results indicate that 53 percent of observed fatalities at wind farms are male. As part of the research, DNA will continue to be extracted from any new tissue samples from bats (as acquired), and sex determination of additional bat carcasses will continue.

The goal of WEST's multi-year *Hawaiian Hoary Bat Acoustic Surveys* study was to examine the distribution and seasonal occupancy of the Hawaiian hoary bat on O'ahu. Occupancy is the modeling of the proportion of an area occupied by a species or fraction of landscape units where the species is present (MacKenzie et al. 2019). The island-wide, randomized block, multi-season monitoring study design of *Hawaiian Hoary Bat Acoustic Surveys* can be used to estimate island-wide trends in occupancy. The Year 2 Status Report for the study (June 8, 2017 to October 7, 2019) was submitted to ESRC in February 2020 (Starcevich et al. 2020; Appendix 4). The preliminary study results were presented to ESRC in March 2020. Throughout FY 2020, WEST continued data downloads and processing from the detectors deployed throughout O'ahu. As approved by ESRC in March 2019, the study also tested drone/thermal sampling to assess ability to count bats. Preliminary results of this monitoring indicate stable occupancy rate on O'ahu over the monitoring period (Figure 14).

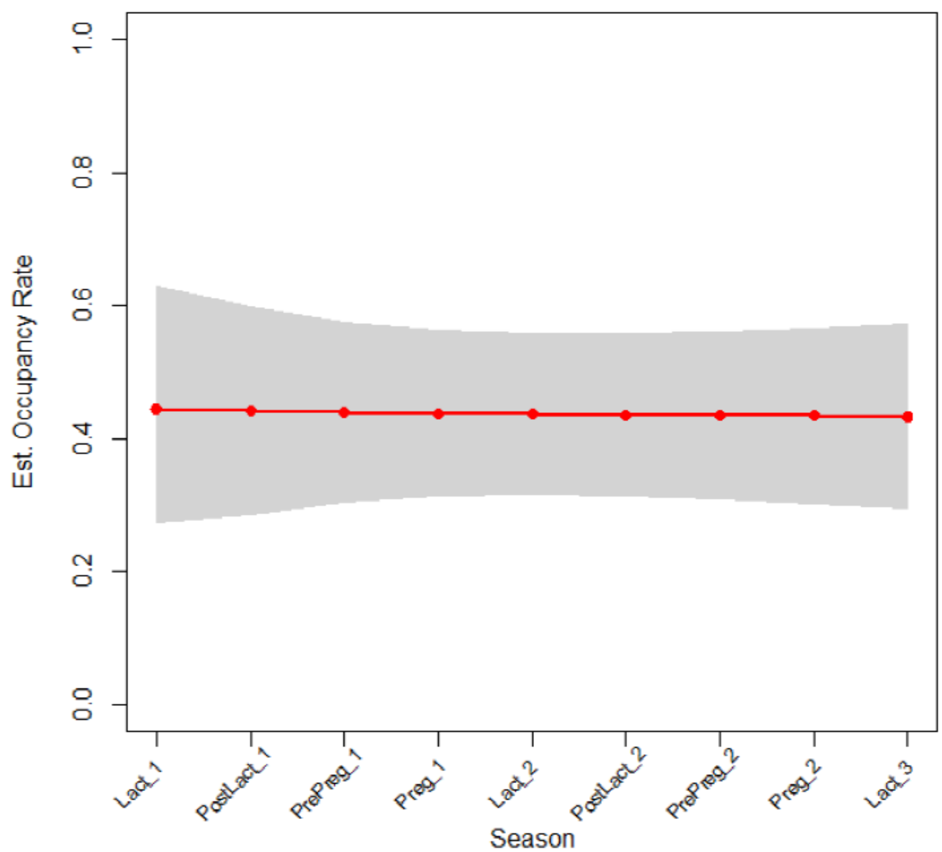


Figure 14. Seasonal Occupancy Estimates from Acoustic Monitoring on O'ahu (Starcevich et al. 2020)

8.1.5 Waimea Native Forest (Tier 3)

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

8.1.6 Helemano Wilderness Area Mitigation (Tier 4)

To satisfy Tier 4 mitigation, Kawailoa Wind completed additional bat mitigation per the HCP Amendment in coordination with the USFWS and DOFAW. The HCP Amendment identifies Tier 4 Hawaiian hoary bat mitigation as contributing $2,750,000 to TPL toward the purchase and long-term protection of the nearly 2,900-acre Helemano Wilderness Area (HWA). Kawailoa Wind proactively provided funds to TPL in October 2018, to ensure mitigation continues to occur ahead of bat take. Further details of this bat mitigation are provided in the HCP Amendment (Tetra Tech 2019).

8.1.7 Tier 5

As outlined in the HCP Amendment, Tier 5 bat mitigation consists of implementation of one or a combination of the following: 1) contributing funding to acquire property that will protect bat roosting and foraging habitat in perpetuity, and/or 2) conduct bat habitat management/restoration to improve bat foraging and/or roosting habitat at the Central Koʻolau area, HWA, Waimea Native Forest, or similar site. In accordance with the mitigation planning requirements under the HCP Amendment, planning for Tier 5 bat mitigation has begun. In March 2020, Kawailoa and Tetra Tech had a semi-annual HCP meeting with USFWS and DOFAW in which Tier 5 bat mitigation was discussed. A Site-Specific Mitigation Implementation Plan for Tier 5 mitigation was submitted to USFWS and DOFAW on May 1, 2020. Kawailoa Wind is continuing planning for this mitigation despite no bat take being observed in FY 2020.

8.2 Waterbirds

As stated above, USFWS and DOFAW provided written confirmation permitting adaptive management for the original bat and waterbird mitigation. Some activities completed for waterbird mitigation at ʻUkoʻa Wetland overlap with bat mitigation requirements and are summarized in Section 9.1.2 above. Tetra Tech conducts waterbird surveys as part of the waterbird mitigation, as described below.

Prior to each vegetation maintenance event, a biologist conducts waterbird surveys to identify if nests or chicks were present in the vicinity of the planned work area. These surveys are required as a Best Management Practice when contractors are working at the site to minimize impacts to endangered Hawaiian waterbirds.

Comprehensive weekly waterbird surveys began at ʻUkoʻa Wetland in January 2017, and continued throughout FY 2020 (Table 5). Surveys were conducted weekly from December 2019 through June 2020 in FY 2020. A qualified biologist conducted surveys at eight point count (PC) stations set up in the vicinity of the open water and in areas with previous waterbird sightings. In May 2020, an additional PC station (PC station 9) was added in an area where gallinule were observed that were not observed in the previous FYs (Figure 15). In addition to the PC stations, independent waterbird observations are recorded while walking between stations. The detailed protocols for these surveys were provided in the FY 2017 Annual Report (Tetra Tech 2017). The individuals at ʻUkoʻa are not banded; therefore, assessments of changes on an individual basis is not possible.

Table 5. Average Number of Hawaiian Common Gallinule Detected per Survey by Fiscal Year.

Sampling Period	No. of Surveys	Average No. of Adults Detected per Survey	Average No. of Chicks Detected per Survey	Average No. of Fledglings Detected per Survey
FY 2017 (January 2017–June 2017)	25	5.7	0.8	1.0
FY 2018 (July 2017–June 2018)	38	4.1	0.4	0.0
FY 2019 (July 2018–June 2019)	41	3.0	0.4	0.0
FY 2020 (July 2019–June 2020)	40	1.9	0.1	0.0

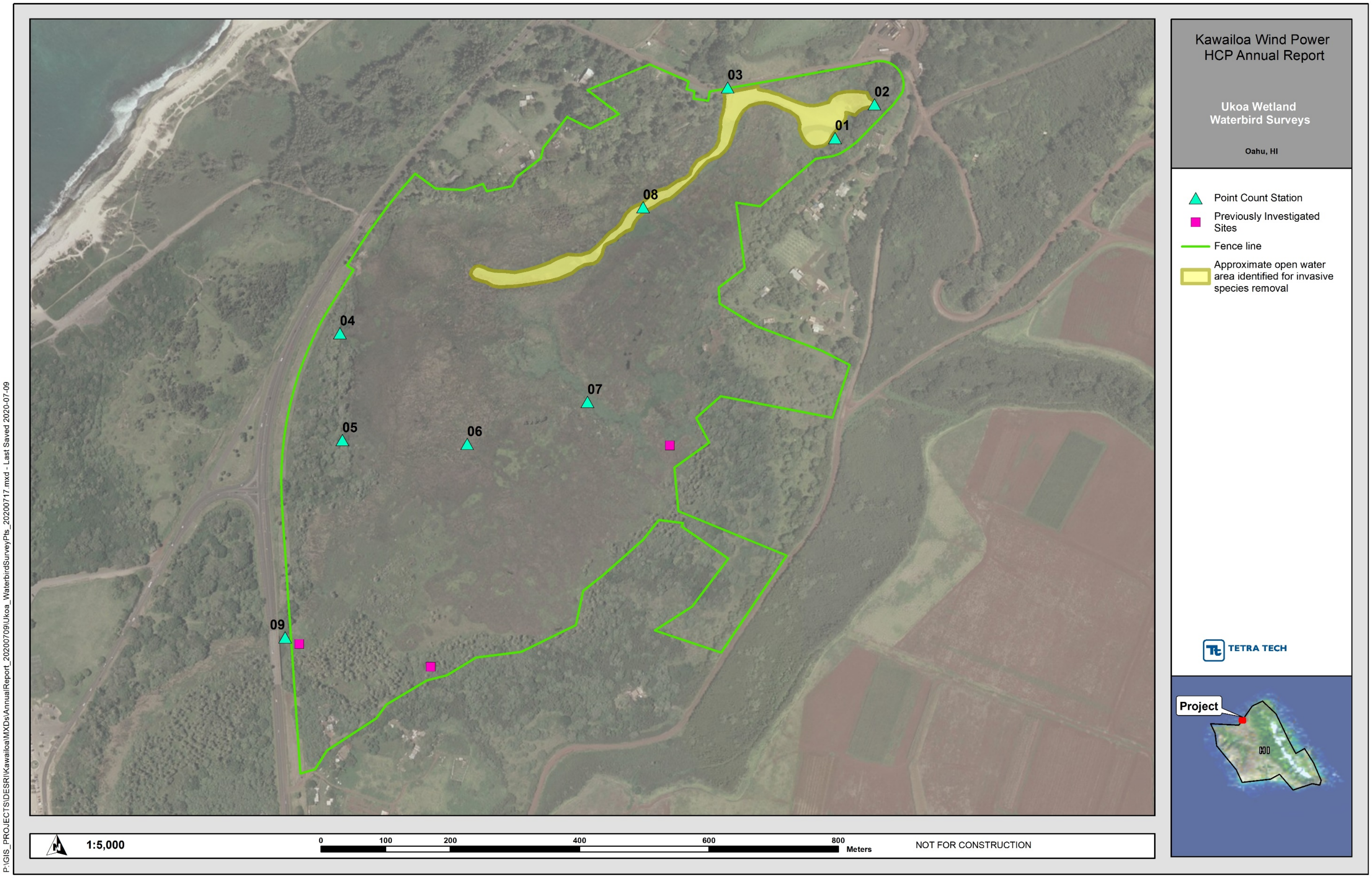


Figure 15. Waterbird Point Count Station Locations at ʻUkoʻa Wetland.

A total of 40 waterbird surveys were completed in FY 2020. The Hawaiian common gallinule was the most frequently detected listed waterbird during weekly surveys. In FY 2020, gallinule were recorded at all PC stations except PC 2 (Figure 16). Gallinule (either adults or chicks) were observed on 37 out of 40 survey dates. Average monthly gallinule detections for FY 2020 are shown in Figure 17.

Gallinule breeding activity (e.g., nests or chicks) was observed at PC stations 1 and 3 between December 2019 and June 2020 (Figure 16). This consisted of three separate events. It is believed that no gallinule chicks successfully fledged from these breeding events observed at ʻUkoʻa Wetland in FY 2020; the cause of reproductive failure is not known. In FY 2020, one cracked egg was observed, and one nest contained two unattended, unhatched eggs. No fledglings or immature gallinule have been observed at ʻUkoʻa Wetland since February 2017.

Table 5 summarizes gallinule detections since comprehensive waterbird surveys began in January 2017. Gallinule detections have declined each fiscal year. The removal of water hyacinth in the open water area has altered habitat available to gallinule, and the birds may be using areas of the wetland that are not currently surveyed.

Effort was made in FY 2020 to find other areas where gallinule may be foraging and breeding. Additionally, a single aerial drone survey was conducted in June 2020 to assess the current vegetation communities at ʻUkoʻa Wetland to help identify additional PC locations that are currently not being surveyed. The results of the drone survey showed several areas within ʻUkoʻa Wetland that could possibly harbor waterbirds that are currently not being surveyed. These areas will be investigated further and additional PC stations may be added in Q1 of FY 2021.

Five adult Hawaiian stilt detections were made on three separate survey dates in FY 2020. Stilts were observed flying overhead at PC stations 6 and 8 and were observed foraging off Kamehameha Highway. No Hawaiian coot were detected in FY 2020.

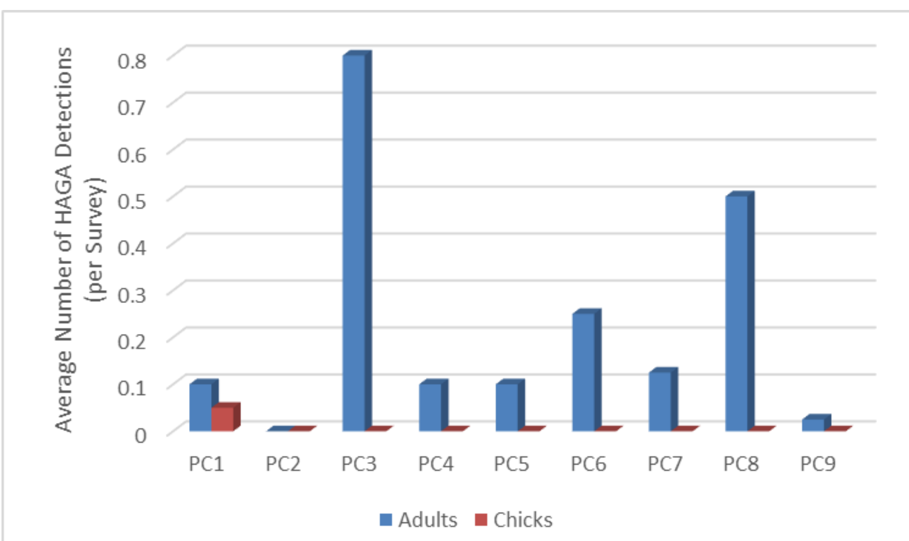


Figure 16. Average Number of Hawaiian Common Gallinule (HAGA) Detections per Survey at Point Count Stations in FY 2020.

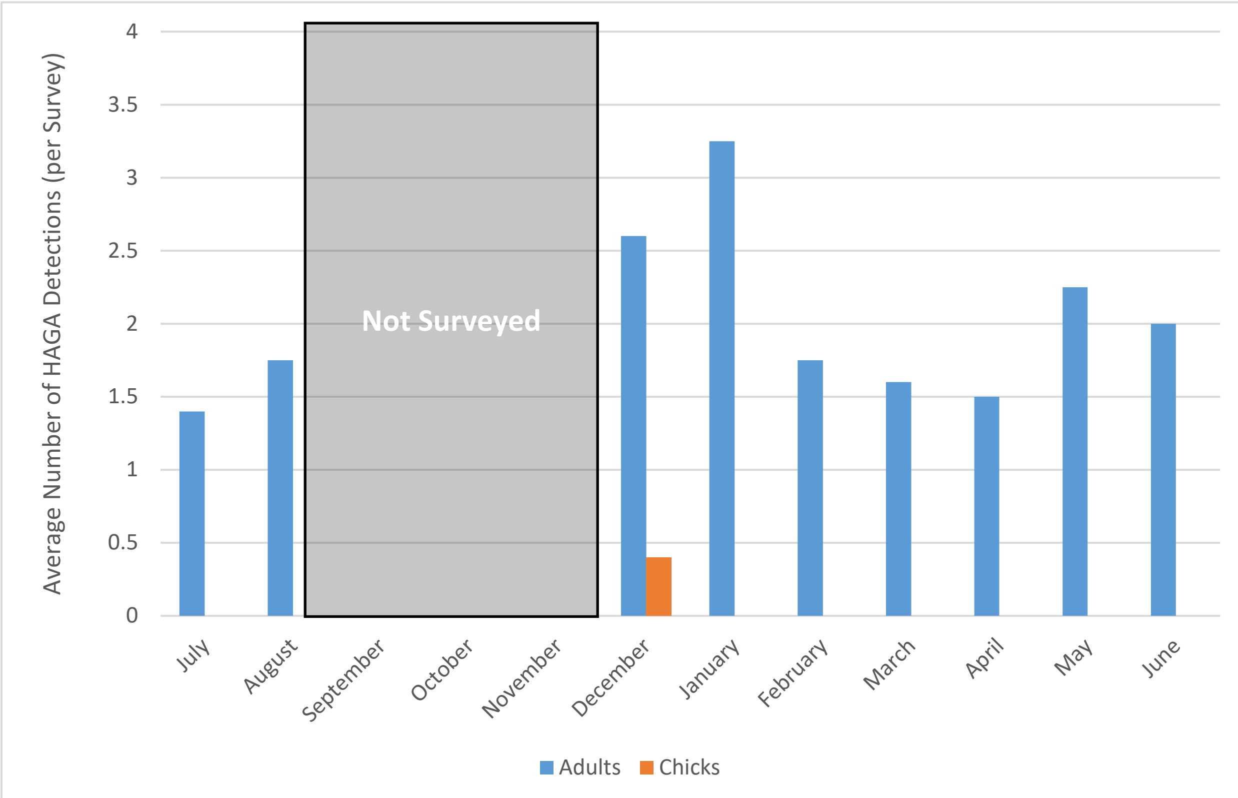


Figure 17. Average Number of Hawaiian Common Gallinule (HAGA) Detections by Month (per Survey) at Point Count Stations in FY 2020.

8.3 Seabirds

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

Details on the mitigation for the Hawaiian petrel is described in the HCP Amendment (Tetra Tech 2019). Kawailoa Wind has finalized contracts with Hallux Ecosystem Restoration LLC and the Kauaʻi Endangered Seabird Recovery Project to conduct predator control and burrow monitoring at the Hanakāpīʻai and Hanakoa seabird colonies within the Hono O Nā Pali Natural Area Reserve on Kauaʻi in 2020. The work is currently underway, and details will be reported in the FY 2021 annual report.

8.4 Hawaiian Short-eared Owls or Pueo

Mitigation for the Hawaiian short-eared owl was completed in FY 2017.

9.0 Adaptive Management

Kawailoa Wind is committed to the ongoing implementation of operational avoidance and minimization measures described in the 2011 HCP and has been evaluating other options to further reduce the risk to bats since Project operations began in 2012. Kawailoa Wind implemented multiple adaptive management steps to understand and reduce the risk to the Hawaiian hoary bat in previous fiscal years including modifying the low wind speed curtailment (LWSC) regime, implementing innovative approaches to post-construction mortality monitoring, and supporting development of the latest technologies that could reduce WTG collision risk to bats. Details on the Project's adaptive management are provided in the FY 2018 Annual Report (Tetra Tech 2018), HCP Amendment (Tetra Tech 2019), and FY 2019 Annual Report (Tetra Tech 2020).

In the beginning of FY 2019 (July 25, 2018), Kawailoa Wind extended the rolling average time from 10 to 20 minutes to reduce the number of start and stop events. The 20-minute averaging resulted in unanticipated WTG behavior and LWSC averaging was returned to 10 minutes on December 5, 2019. Kawailoa Wind is working with Siemens to determine if a solution can be implemented. Until a solution is found, Kawailoa Wind is operating with an LWSC based on the 10-minute average wind speed to ensure that WTGs are not operating when bats are likely to be present. When an appropriate implementation is found, Kawailoa Wind will return to LWSC based on the 20-minute average.

Kawailoa Wind also installed acoustic deterrents at all 30 Project WTGs in May and June 2019. To date, no bat fatalities have been observed at WTGs with operational bat deterrent systems. Deterrent functionality is monitored remotely to ensure the systems are functioning properly. After 1 year of deterrent operation, single unit failures have been detected on five WTGs. Each WTG is installed with five units, each having some overlap in coverage in the deterred airspace. The result of a single unit failure is less than one-fifth of the rotor swept area. If one unit is deficient, a WTG has adequate coverage across the rotor swept area due to redundancy provided by the other four units. Kawailoa Wind and NRG have worked together to install replacements as quickly as feasible. Of the five deterrent unit failures two have been replaced. The remaining three deterrent unit failures were detected in June, and replacement parts have been delivered to the Project. Despite single deterrent unit failures, no bat fatalities have been detected.

10.0 Collection Permits

Annual reports for the Project's federal and state collection permits were submitted in Q2 of FY 2020. The State's Protected Wildlife Permit (Permit No. WL19-33) was issued on March 25, 2019 and expires March 25, 2021. The USFWS special purpose utility permit (MB22099C-0) was issued on April 5, 2019 and expires March 31, 2022.

11.0 Agency Meetings, Consultations, and Visits

Kawailoa Wind and Tetra Tech conducted or participated in three meetings with USFWS and DOFAW staff in FY 2019, as well as three ESRC meetings and one BLNR meeting. The purpose of these meetings varied and included required semi-annual meetings, as well as discussions regarding the HCP Amendment and Hawaiian hoary bat mitigation.

Meetings took place on:

- July 25, 2019 – ESRC approval of HCP Amendment;
- September 27, 2019 – BLNR Approval of the EIS and DOFAW request for approval of the HCP Amendment;
- November 5, 2018 – USFWS and DOFAW semi-annual meeting;
- December 18, 2019 – USFWS and DOFAW discussion of Tier 5 bat mitigation;
- January 15, 2020 – ESRC annual report review;
- March 5-6, 2020 – ESRC bat workshop; and
- March 30, 2020 – USFWS and DOFAW semi-annual meeting.

12.0 Expenditures

Total HCP-related expenditures for the Project in FY 2020 were approximately $864,000 (Table 6).

Table 6. Estimated HCP-Related Expenditures at the Project in FY 2020.

Category	Amount
Permit Compliance	$101,000
Facility Vegetation Management	$150,000
Fatality Monitoring	$101,000
‘Uko‘a Wetland Mitigation Compliance	$98,000
Hawaiian Petrel Mitigation	$103,000
Tier 2/3 Bat Research Projects	$294,000
Tier 5 Bat Mitigation Preparation	$17,000
Total Cost for FY 2020	**$864,000**

13.0 Literature Cited

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

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

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

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

Grey Boar (Grey Boar Wildlife Services LLC). 2019a. Ukoa Predator Control Program. 3rd Quarter Report 2018. Prepared for Kawailoa Wind LLC.

Grey Boar. 2019b. Ukoa Predator Control Program. 4th Quarter Report 2018. Prepared for Kawailoa Wind LLC.

Grey Boar. 2020a. Ukoa Predator Control Program. 1st Quarter Report 2019. Prepared for Kawailoa Wind LLC.

Grey Boar. 2020b. Ukoa Predator Control Program. 2nd Quarter Report 2019. Prepared for Kawailoa Wind LLC.

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

H. T. Harvey and SWCA (H. T. Harvey and Associates and SWCA Environmental Consultants). 2014. 'Uko'a Wetland Hawaiian Hoary Bat Mitigation Management Plan. Prepared for First Wind. Approved by USFWS and DOFAW 2014.

MacKenzie D.I, Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L., Hines, J.E. 2019. Occupancy Estimation and Modeling (Second Edition), Academic Press, https://doi.org/10.1016/B978-0-12-407197-1.00002-8.

Pinzari, C.A. and F.J. Bonaccorso. 2018a. A Test of Sex Specific Genetic Markers in the Hawaiian Hoary Bat and Relevance to Population Studies. Hawaii Cooperative Studies Unit Technical Report HCSU-085.

Pinzari, C.A. and F.J. Bonaccorso. 2018b. Hawaiian Islands Hawaiian Hoary Bat Genetic Sexing 2009-2018 (ver. 4.0, April 2020): U.S. Geological Survey data release. Available at: https://doi.org/10.5066/P9R7L1NS. Accessed March 2020.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.R-project.org/

Starcevich, L.A., J. Thompson, T. Rintz, E. Adamczyk, M. Martin, and D. Solick. 2020. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study. Project Update and Second Year Analysis. Dated February 13, 2020. Prepared for: Hawaii Endangered Species Research Committee.

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

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

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

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

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

Tetra Tech. 2020. Kawailoa Wind Power Habitat Conservation Plan, FY 2019 Annual Report. Revised January 2020.

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

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

APPENDIX 1

DOCUMENTED FATALITIES AT THE PROJECT DURING FY 2020

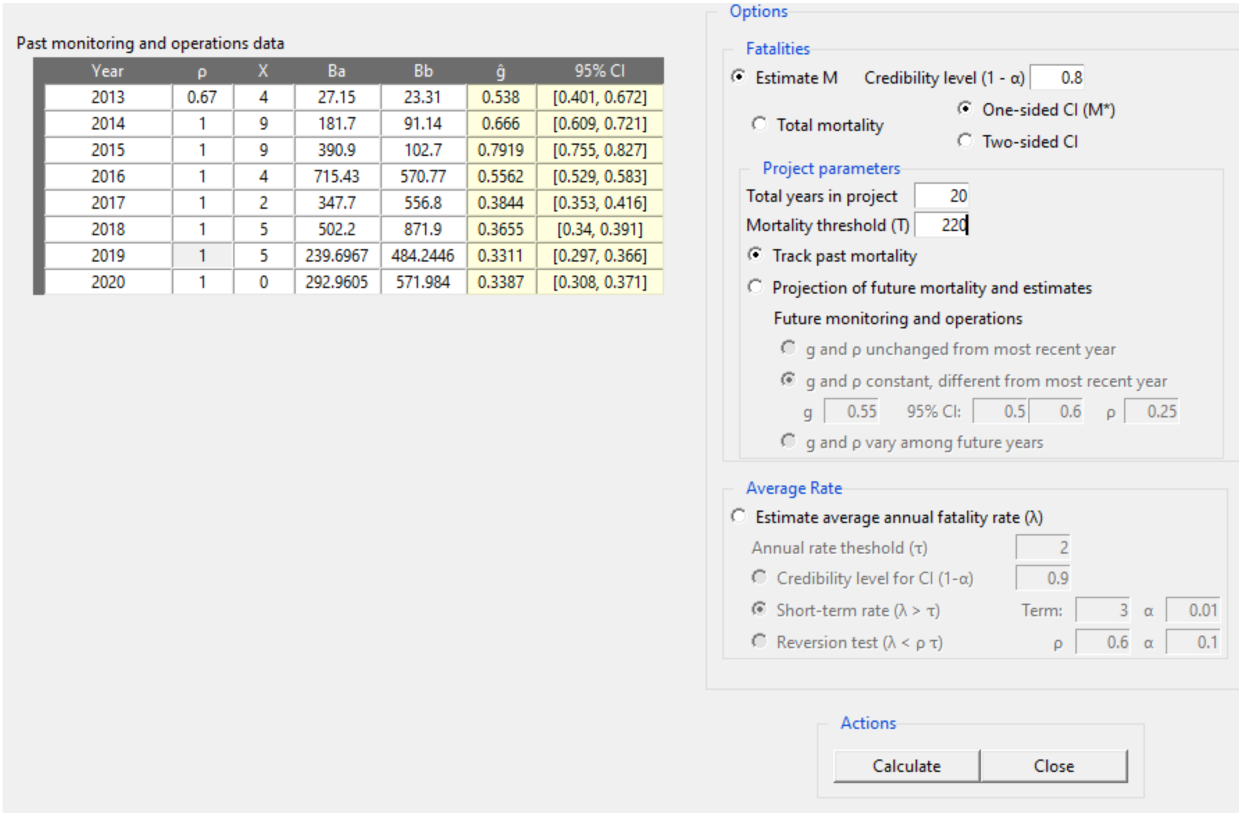
Species[1]	Date Documented	WTG	Distance to WTG (meters)	Bearing from WTG (degrees)
Spilopelia chinensis (spotted dove)	2/6/2020	05	2	9
Phasianus colchicus (ring-necked pheasant)	4/7/2020	18	1	79
Spilopelia chinensis (spotted dove)	4/20/2020	27	2	230
Spilopelia chinensis (spotted dove)	4/30/2020	01	1	226
Phaethon lepturus (white-tailed tropicbird)	5/5/2020	25	49	250
Estrilda astrild (common waxbill)	5/26/2020	05	22	96
Geopelia striata (zebra dove)	6/29/20	30	3	300
Lonchura punctulata (nutmeg mannikin)	6/30/20	28	5	286
Lonchura punctulata (nutmeg mannikin)	6/30/20	28	28	220
1. Species protected by the Migratory Bird Treaty Act are highlighted in gray.				

This page intentionally left blank

APPENDIX 2

DALTHORP ET AL. (2017) FATALITY ESTIMATION FOR HAWAIIAN HOARY BATS AT PROJECT THROUGH FY 2020

Figure 1. Dalthorp et al. (2017) Fatality Estimation for Hawaiian hoary bats at Project through FY 2020.[3]

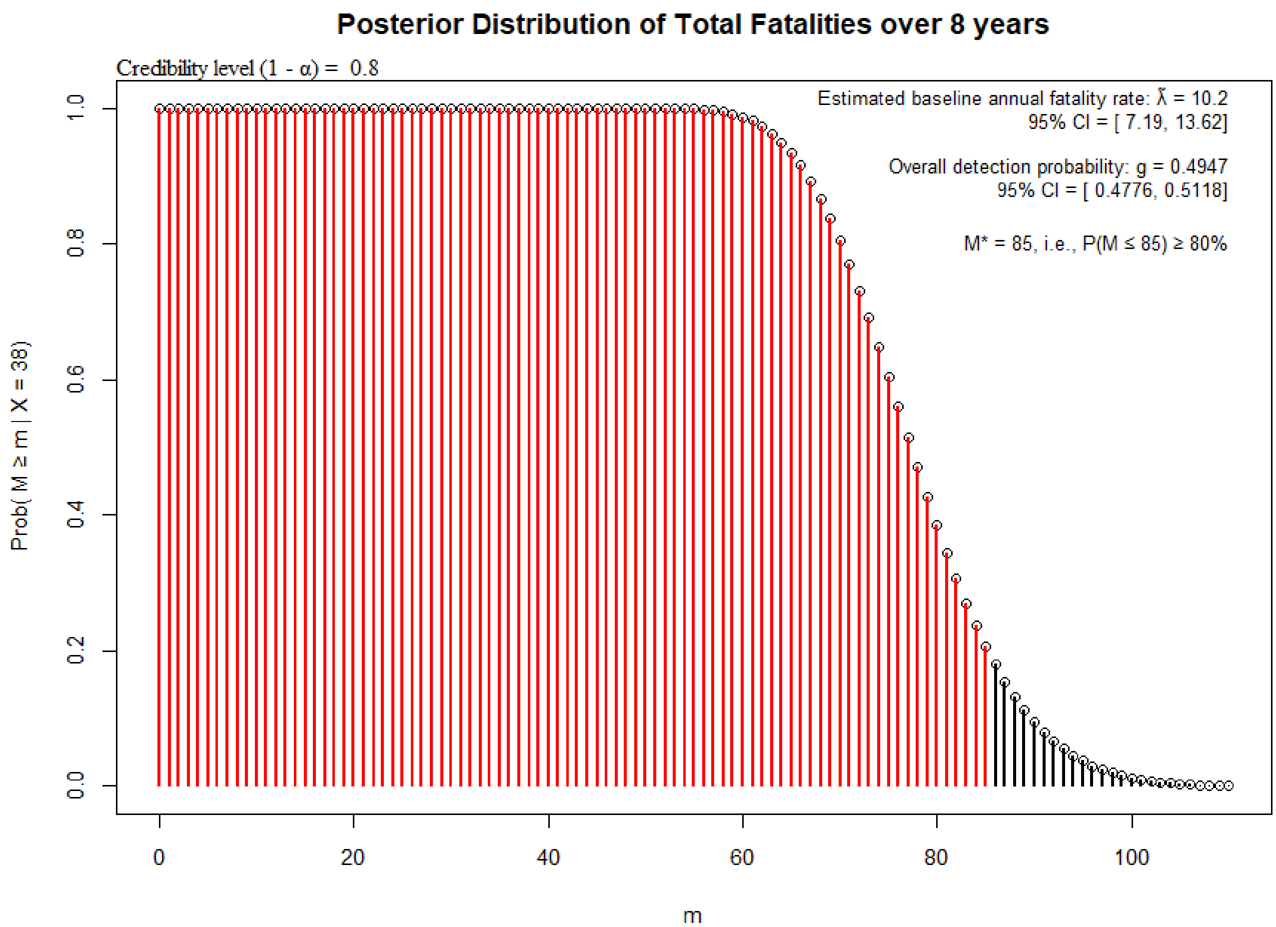


Past monitoring and operations data

Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	0.67	4	27.15	23.31	0.538	[0.401, 0.672]
2014	1	9	181.7	91.14	0.666	[0.609, 0.721]
2015	1	9	390.9	102.7	0.7919	[0.755, 0.827]
2016	1	4	715.43	570.77	0.5562	[0.529, 0.583]
2017	1	2	347.7	556.8	0.3844	[0.353, 0.416]
2018	1	5	502.2	871.9	0.3655	[0.34, 0.391]
2019	1	5	239.6967	484.2446	0.3311	[0.297, 0.366]
2020	1	0	292.9605	571.984	0.3387	[0.308, 0.371]

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

Figure 2. Posterior Distribution: Dalthorp et al. (2017) Fatality Estimation for Hawaiian hoary bats at Project for FY 2020



APPENDIX 3

METHODOLOGY FOR DETERMINING AN APPROPRIATE RHO VALUE

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

The effectiveness of UADs on the Hawaiian hoary bat is not known, but evidence from monitoring at the Project suggests the Hawaiian hoary bat fatality rate is reduced at the Project after installation of UADs. The effectiveness of UADs for mainland hoary bats at Los Vientos Wind Farm in Texas was found to be 78.3 percent (95% confidence interval [CI]: 61.5–95.1%) reduced relative to WTGs without UADs active. Differences in site conditions and the species-specific responses led to uncertainty if this reduction will be replicated at the Project. Additionally, the Project has implemented low wind speed curtailment at 5 meters per second (m/s) with a 0.2 m/s hysteresis, further reducing the risk to bats relative to the study at Los Vientos.

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

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

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

To test if the rho value is appropriately specified before and after installation of UADs, each period was grouped as a single period in the multi-years module of EoA and tested for misspecification of rho using the multi-year module of EoA. The total time period November 2012-June 2019, which correlates with FY 2013-FY 2019, represents the pre-UAD period, and July 2019-June 2020, which correlates with FY 2020, represents the post-UAD installation period. The cumulative detection probability for each period was calculated using EoA to group the years (FY 2013-2019, and FY

2020) and provide a cumulative detection probability. For each period, the observed fatalities were summed to calculate the total observed fatalities for the period. The pre-deterrent period therefore represents the pooled data from FY 2013 to FY 2019 including: rho which represents the years of monitoring from November 2012-June 2019 or 6.67 years, the sum of observed bat fatalities (38 bats), and the cumulative detection probability from November 2012 to June 2019 (0.518). The inputs are provided in Table 2.

Comparing the fatality monitoring data before and after UADs demonstrates that fatality rates are overestimated after installation of UADs if the same rho is used for both periods. At a rho value of 1, the test for misspecification returns a significant result when testing for a p value less than 0.05 (p value =0.00657); the EoA outputs for this trial are shown in Figure 2. The rho value was decreased incrementally by 0.05 until the p value for the test of misspecification of rho exceeded a p value of 0.05. The first rho value with a test of misspecification p value greater than 0.05 (p value= 0.0515) was found when rho = 0.5 or a 50 percent reduction in fatality rate after installation of UADs; the EoA outputs for this trial are shown in Figure 3. Therefore, Project data suggest 95 percent confidence that Hawaiian hoary bat risk at the Project is reduced by at least 50 percent through the use of UADs.

Similar to the pre-UAD grouping discussed above, post-UAD installation will be grouped to test for misspecification of rho. The rho for the post-UAD period will begin with rho=1 for all years (i.e., after 4 years, rho=4). For multiple years, the rho value for the post-UAD period is represented by the equation: rho * years of monitoring. In practice this would be assumed to be the same for all years. For example, if after year four, the cumulative rho value of 0.5 for the post-UAD period (2020-2024) is indicated by the EoA test for misspecification of rho, the annual rho value would be 0.5/4 years, or 0.125. Similarly, if a rho value of 4 is indicted by the EoA test for misspecification of rho for the same period (2020-2024), the rho value would be 1 for all years (4 rho/4 years = 1 rho/year).

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

> "All projects start off with using ρ = 1. If an additional minimization such as raising the cut in speed (see Appendix D) or deterrents are implemented, the rho-value is still kept at 1 until tests on assumed weights indicate that there may be a difference in fatality rates. This may require several years of deploying the minimization action before any difference can be supported by the test on the rho-value. If the tests do confirm a change in the fatality rates between periods beyond a reasonable doubt, a rho-value can be put in place, retroactively, for the periods in which the minimization action was deployed, if approved by the Service. The tests can be rerun to determine if the rho value continues to be reasonable. Note, however, that the actual rho-value is not calculated by the model and may never be known.

> The best that can be done is to maintain testing of the rho value being used to see if it is reasonable".

An appropriate rho value needs to be incorporated in the Project EoA assessment to account for the reduced risk to bats from the installation of UADs at the Project. An appropriate rho value will have sufficient years of supporting data for both pre- and post-minimization effectiveness to statistically account for inter-annual variability in the observed take rate. Once a final rho value is determined, the final rho will be applied to all years in which UADs are active.

Table 1. Fatality Rates for Each Year of Project Operation.

Year	Observed Fatalities	Detection Probability	Fatality Estimate at the 80% Credible Level	Median Fatality Estimate	Fatality Estimate 95% CI	Lambda	Lambda 95% CI
2013	4	0.538	10	7	[4,14]	8.588	[2.4860,18.8300]
2014	9	0.666	16	13	[10,20]	14.3	[6.6690,24.8700]
2015	9	0.792	13	11	[9,15]	12.01	[5.6190,20.7900]
2016	4	0.556	10	7	[4,12]	8.097	[2.4270,17.1400]
2017	2	0.384	8	5	[2,12]	6.52	[1.0810,16.7800]
2018	5	0.365	19	14	[7,26]	15.08	[5.2150,30.1300]
2019	5	0.331	21	15	[7,28]	16.68	[5.7490,33.4400]
2020	0	0.339	2	0	[0,4]	1.481	[0.0014,7.4490]

Table 2. Inputs for the Test of Misspecification of Rho.

Year	P (rho)	X (Observed Fatalities)	Ba (Shape)	Bb (Scale)	$\hat{g}$ (Detection Probability)	95% CI
2013-2019	6.67	38	1356	1262	0.518	[0.499, 0.537]
2020	1 or 0.5	0	278.2	507	0.3543	[0.321, 0.388]

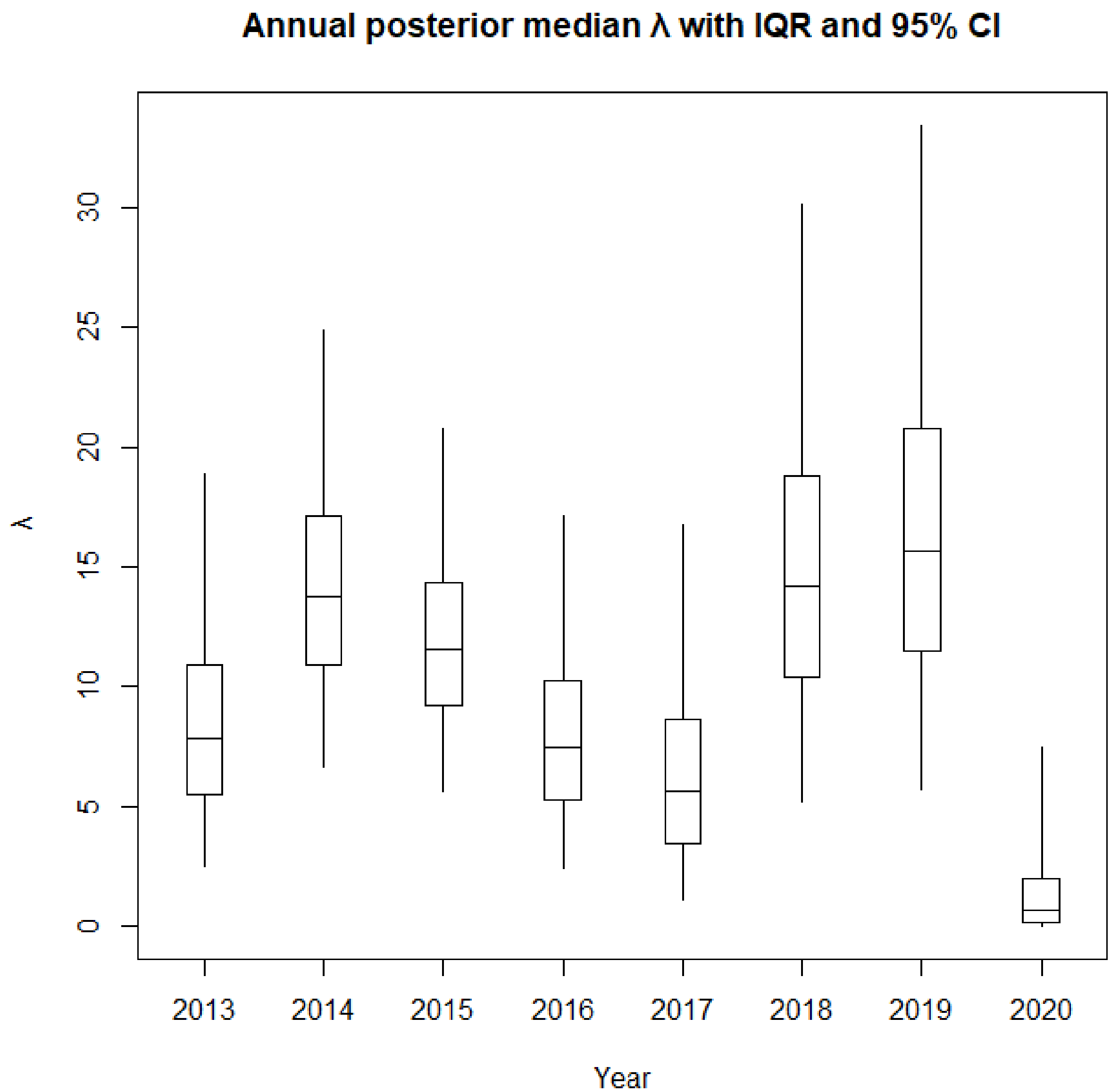


Figure 1. Annual Hawaiian Hoary Bat Fatality Rates Estimated by EoA for the Project at the 80 Percent Credible Level.

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

M* = 84 for 1 - a = 0.8, i.e., P(M <= 84) >= 80%
Estimated overall detection probability: g = 0.497, 95% CI = [0.479, 0.514]
   Ba = 1611, Bb = 1632.9
Estimated baseline fatality rate (for rho = 1): lambda = 10.11, 95% CI = [7.16, 13.6]

Cumulative Mortality Estimates
                                              mean
Year          X    g     M*  median  95% CI  lambda       95% CI
2013-2019    38 0.518   81    73     [59, 91]  74.37   [52.64, 99.84]
2020         38 0.497   84    77     [61, 95]  77.56   [54.92, 104.1]


Annual Mortality Estimates
                                              mean
Year          X    g     M*  median  95% CI  lambda       95% CI
2013-2019    38 0.518   81    73     [59, 91] 74.3700   [52.6400, 99.8400]
2020          0 0.354    1     0     [0, 4] 1.4160   [0.0014, 7.1220]


Test of assumed relative weights (rho) and potential bias
              Fitted rho
Assumed rho     95% CI
   6.67     [7.036, 7.669]
      1     [0.001, 0.627]

p = 0.00657 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.034

================================================================================
Input
Year (or period)  rho    X    Ba     Bb   ghat    95% CI
2013-2019        6.670  38   1356   1262 0.518 [0.499, 0.537]
2020             1.000   0  278.2    507 0.354 [0.321, 0.388]
```

Figure 2. Testing for Misspecification of Rho with a Rho Value of 1.

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

M* = 83 for 1 - a = 0.8, i.e., P(M <= 83) >= 80%
Estimated overall detection probability: g = 0.507, 95% CI = [0.489, 0.524]
   Ba = 1508.3, Bb = 1469.4
Estimated baseline fatality rate (for rho = 1): lambda = 10.61, 95% CI = [7.51, 14.2]

Cumulative Mortality Estimates
                                             mean
Year          X    g     M*  median  95% CI  lambda       95% CI
2013-2019    38 0.518   81    73     [59, 91]  74.37   [52.64, 99.84]
2020         38 0.507   83    75     [60, 93]  76.04   [53.84, 102.1]


Annual Mortality Estimates
                                             mean
Year          X    g     M*  median  95% CI  lambda       95% CI
2013-2019    38 0.518   81    73     [59, 91] 74.3700   [52.6400, 99.8400]
2020          0 0.354    1     0     [0, 4] 1.4160   [0.0014, 7.1220]


Test of assumed relative weights (rho) and potential bias
              Fitted rho
Assumed rho     95% CI
   6.67     [6.468, 7.169]
    0.5     [0.001, 0.691]

p = 0.05152 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.014

================================================================================
Input
Year (or period)  rho    X    Ba     Bb   ghat    95% CI
2013-2019        6.670  38   1356   1262 0.518 [0.499, 0.537]
2020             0.500   0  278.2    507 0.354 [0.321, 0.388]
```

Figure 3. Testing for Misspecification of Rho with a Rho Value of 0.5.

Literature Cited:

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

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

Weaver, S., and I. Castro-Arellano. 2019. Studying Behavior and Testing Strategies to Reduce Impact of Wind Energy on Bats in Texas. Final Performance Report. Prepared for the State Wildlife Grant Program, Texas.

This page intentionally left blank.

APPENDIX 4

OAHU HAWAIIAN HOARY BAT OCCUPANCY AND DISTRIBUTION STUDY PROJECT UPDATE AND SECOND YEAR ANALYSIS, DATED FEBRUARY2020 (STARCEVICH ET AL. 2020)

OAHU HAWAIIAN HOARY BAT

OCCUPANCY AND DISTRIBUTION STUDY

Project Update and Second Year Analysis

Prepared for:

Hawaii Endangered Species Research Committee

Prepared by:

**Leigh Ann Starcevich, Joel Thompson, Troy Rintz,
Erica Adamczyk, Mysti Martin, and Donald Solick**

Western EcoSystems Technology, Inc.
2725 NW Walnut Boulevard
Corvallis, Oregon 97330

February 13, 2020

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

In response to a request for proposals issued in 2016 by Hawaii's Endangered Species Recovery Committee (ESRC), Western EcoSystems Technology, Inc. (WEST) developed a 5-year study proposal to investigate the distribution and seasonal occupancy of Hawaiian hoary bat (HAHOBA; *Lasiurus cinereus semotus*) on the island of Oahu. The initial study proposal, submitted in fall 2016, was modified as a result of two meetings and discussions with the ESRC Bat subcommittee, which occurred in January and February, 2017. Based on discussions with the ESRC and Bat subcommittee, it was decided the initial goals of the study should be to examine the distribution and seasonal occupancy of HAHOBA, with study plans for subsequent years to be based on the results of the initial year(s) of data.

A final study plan developed in early 2017 that focused on HAHOBA distribution and occupancy was considered to be consistent with the recommendations and priorities of the ESRC bat subcommittee. The objectives of the study were to 1) provide information on bat occupancy, distribution, and detection probabilities for the island of Oahu, 2) examine seasonal changes in distribution by estimating seasonal changes in occupancy, and 3) collect data that could be used later to assess HAHOBA habitat use relationships.

While field studies are ongoing, the second year of data collection for the HAHOBA Occupancy and Distribution Study (Occupancy Study) has been completed. This preliminary report has been developed to update the ESRC and other cooperating entities on the status of the Occupancy Study and initial analysis results.

In this report, we describe the sampling design and methods used to collect and analyze the data. We then summarize the results of the second year of field studies and occupancy analysis, and conclude with recommendations for ongoing studies and future analysis. This report is an interim update based on the data available to date (as of October 2019); therefore, readers should recognize that this interim report addresses only the first approximately two years of data from a multi-year project and revised analyses that may affect interpretation of results will be forthcoming as the study progresses.

METHODS

In this section, we describe the sampling design, field data collection methods, and occupancy modeling techniques used to address HAHOBA distribution on Oahu.

Sampling Design

The sampling design was developed to form the basis for island-wide inference. A sampling frame of 787 grid cells was obtained by overlaying a grid of 0.8 square miles (2.3 square kilometers) cells across the island of Oahu. To allow for island-wide inference, no areas on Oahu were omitted from the sampling frame except for small nearshore islands. From the grid of 787 cells, an equiprobable generalized random tessellation stratified sample (Stevens and Olsen 2003, 2004) of 100 grid cells was selected for placement of acoustic bat detectors (Figure 1). An oversample of 150 grid cells was also selected to provide an extra set of spatially balanced sites to use if the main sample of 100 grid cells could not be completely surveyed. Reasons a grid cell might not be surveyed every year include inaccessibility due to safety issues, landowner denial of access, and possible relocation of detectors to new grid cells if the sampling design is amended.

Field Data Collection

Wildlife Acoustics Song Meter SM4Bat (SM4) full spectrum bat detectors fitted with model SMM-U1 ultrasonic microphones (Wildlife Acoustics, Inc., Concord, Massachusetts) were initially deployed for all data collection conducted by WEST; however, SMM-U1 microphones started to malfunction in April 2019 and Wildlife Acoustics recommended updating to SMM-U2 ultrasonic microphones (Wildlife Acoustics, Inc., Concord, Massachusetts). New SMM-U2 microphones were deployed throughout summer and fall 2019 when a maintenance check was required. Microphone type was recorded so that microphone effects could be examined as a covariate in detection probability models. Data from cooperating entities sometimes was collected using older Wildlife Acoustics full spectrum bat detectors (e.g., SM3Bat) outfitted with SMM-U1 microphones. The SM4 detectors are small, measuring roughly eight inches (in) tall x five in wide x three in deep (20 centimeters [cm] tall x 13 cm wide x eight cm deep) and are fully self-contained (Figure 2). Some of the detectors located in easily accessible areas with relatively high risk of theft or vandalism were operated on internal batteries to minimize their detectability by people, while most detectors utilized a small external battery and accompanying solar panel as a power source (Figure 2).

Detectors were attached to existing structures (e.g., fence posts, light poles) or newly installed t-posts, via attachment of a 10-foot (ft; 3-meter) length of 0.75 in (1.9 cm) diameter metal conduit used to extend the microphone to approximately three m above ground (Figure 2). In some cases, the 10-ft pole was supported by small guy wires. The detector, and external battery and solar panels (when used), were mounted low on the pole with the microphone mounted at the top of the pole (Figure 2). In some developed areas, units were contained in a small (about 15 in [38 cm]) toolbox and placed on top of an appropriately sized outbuilding (approximately 10 ft above ground).

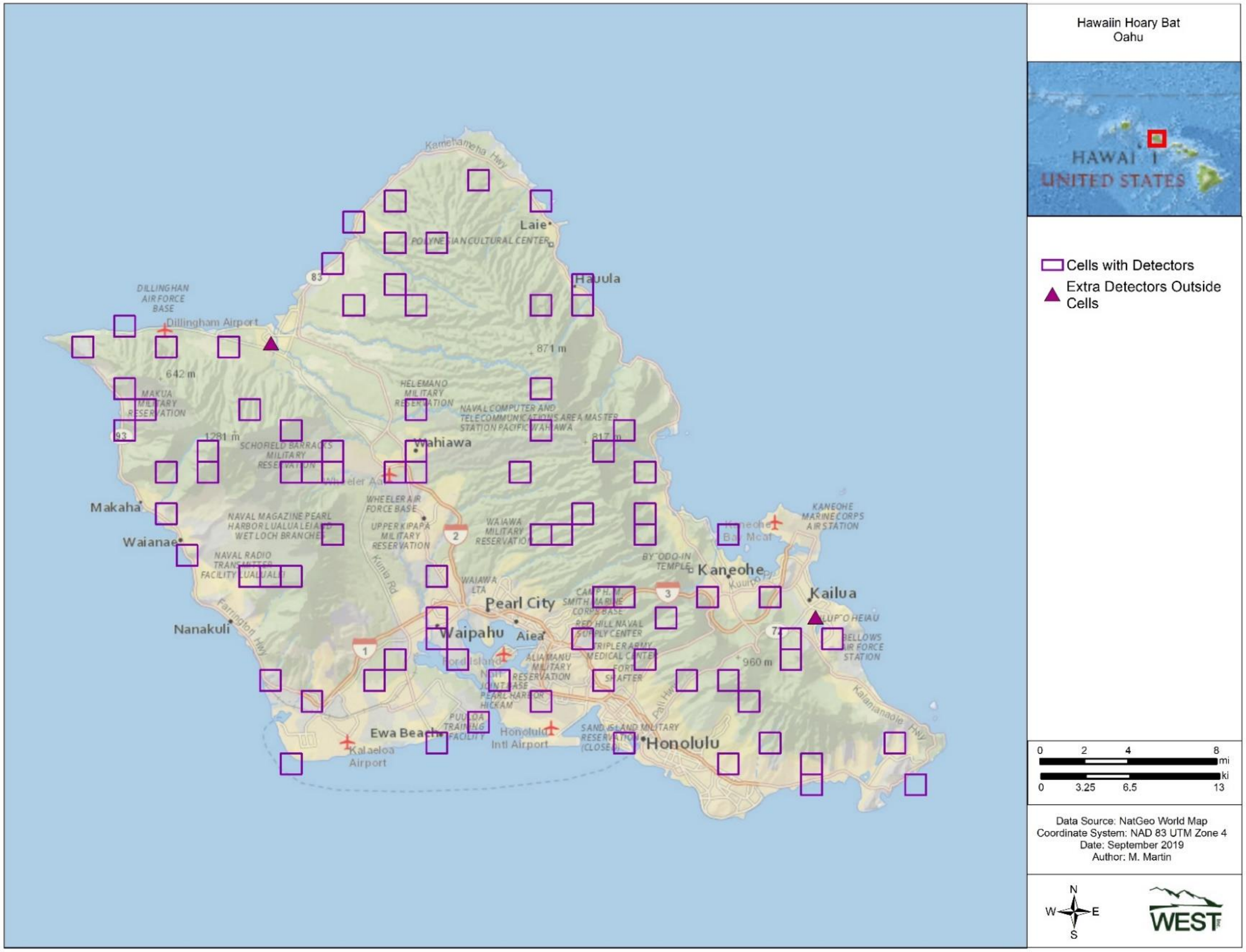


Figure 1: Equiprobable generalized random tessellation stratified sample of 100 grid cells used for initial study design of the island-wide occupancy study of Hawaiian hoary bats on Oahu.

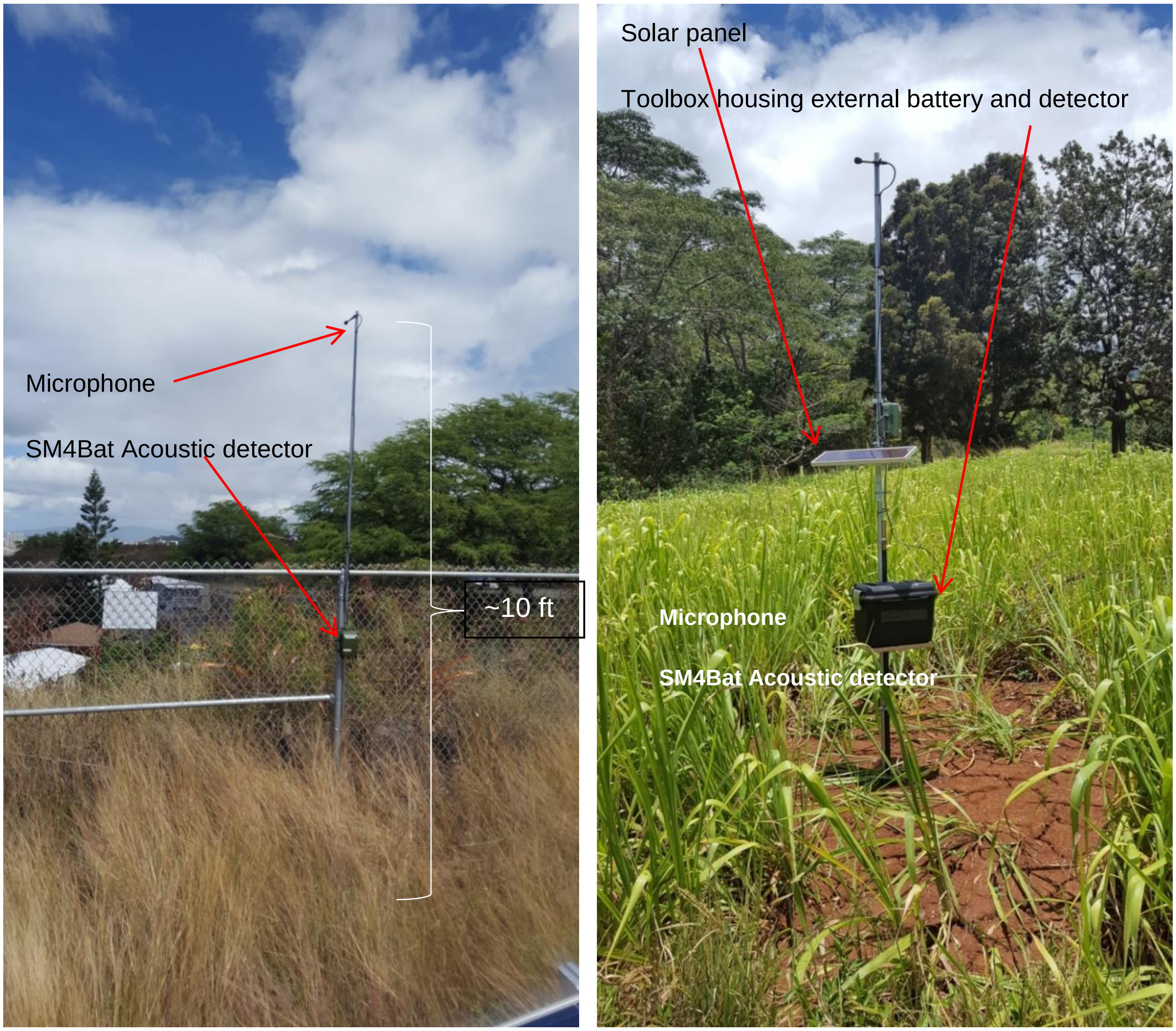


Figure 2. Examples of commonly used set-ups of the Wildlife Acoustics SM4Bat detectors used in the Hawaiian hoary bat Occupancy and Distribution study on Oahu.

Detectors remained in the field year round at the location of original placement. Detectors were programmed to operate nightly, from approximately one hour prior to sunset to approximately one hour after sunrise. Within the SM4 Detector Configurator, the following settings were selected: detector sample rate of 192 kilohertz (kHz); gain of 12 decibels (dB); minimum signal duration of 1.5 milliseconds; maximum signal duration off; minimum trigger frequency of 10 kHz; trigger level of 12 dB; and trigger window of three seconds. Detectors were visited regularly to swap data cards and ensure detectors were functioning properly. Following initial set-up, detectors were checked once seven to 14 days after deployment to ensure proper function and data collection. After these initial checks, sites were checked less frequently. At sites with external power sources, detectors were checked every one to two months, while sites that mandated helicopter access sometimes extended to more than two months between checks. At sites where the detectors were powered by internal batteries, units would be visited every 10−14 days on average.

To expedite call analysis, call recordings were processed with the Kaleidoscope Pro 5 software package (Wildlife Acoustics 2019) to convert the full-spectrum call files to zero-cross files and remove noise (i.e., non-bat) files. For all files classified as containing a bat echolocation call, a biologist manually reviewed the zero-cross call files using program Analook (Titley Scientific) to ensure detections contained a minimum of two distinct pulses and confirm the recording was consistent with that of a HAHOBA. Manual review of all recorded bat calls by a bat biologist helped minimize the potential for false positives to be included in the final dataset. Social calls and feeding buzzes were also noted during the manual review process for later assessment of behavioral activity at sites. Initially, some call files were recorded as having multiple individuals in a single file; however, upon further review and discussion with other acoustic call experts, it was decided these call files be reassigned to a single individual. A subset of noise files was also examined to ensure detectors were functioning properly when several consecutive nights with no recordings occurred.

Occupancy modeling

Nightly detector data were used to model occupancy rates and detection probabilities of HAHOBA on Oahu (MacKenzie et al. 2006), with the appropriate model type depending on model assumptions. Multi-season dynamic occupancy models that account for site-level extinction (the probability an occupied site will be unoccupied the next season) and local colonization (the probability an unoccupied site will be occupied the next season) were implemented to meet the closure assumption within a season. We used the HAHOBA reproductive season definitions of Gorresen et al. (2013, as adapted from Menard 2001) as the basis for our seasonal models: lactation season from mid-June to August, post-lactation season from September to mid-December, pre-pregnancy season from mid-December to March, and pregnancy season from April to mid-June. Differences in detections among seasons could be due to a seasonal detection effect, differences in occupancy by season, or both. We examined two dynamic occupancy models: the multi-season dynamic occupancy model where detections are assumed independent (MacKenzie et al. 2006), and the multi-season dynamic occupancy model that assumes detections are correlated (Hines et al. 2010, 2014). Independent occupancy modeling was conducted with the *unmarked* package (Fiske and Chandler 2011) in R (R Development Core Team 2016).

The multi-season dynamic occupancy model for independent detections (MacKenzie et al. 2006) yields estimates of rates of occupancy (Ψ), detection (p), local extinction (ε), and local colonization (γ). This model requires assumptions of equal probability of occupancy across sites, equal probability of detection across sites, population closure within each season, independence of detections across sites, and independence among detections at a site. The first two assumptions can be relaxed if covariates related to the occupancy and detection processes are included in the models. We assume independence among sites based on the probabilistic and spatially balanced sampling design. Independence among detections at a site may be violated if detections observed over time are temporally correlated. When temporal correlation is present, detection occasions may be separated in time to avoid temporal correlation (Wright et al. 2016). We evaluated the independence of nightly detection data within each reproductive season and year with the join count chi-square test (Wright et al. 2016). The join count test compares the number of temporal "joins" (number of detections in consecutive time periods) to an expected number based on the assumption of independence. We applied the join count test to data sets obtained from systematic random samples of detector nights taken by site at various intervals to determine the appropriate temporal spacing of detector nights to meet the assumption of independent sampling occasions for a given site. We also used the join count test to examine the assumption of a first-order Markov detection process (Hines et al. 2010, 2014) to account for correlated detections. For this model, estimates of occupancy (Ψ), local extinction (ε), and local colonization (γ) are obtained, but the probability of detection (p) is conditional on local presence for the current and previous sampling occasion. The Markov model computes the probability of local presence conditional on presence or absence of HAHOBA during the previous survey occasion, and estimates of the detection probability differ based on the detection of HAHOBA during the previous detection night. Correlated detection occupancy modeling was conducted in program PRESENCE (US Geological Survey [USGS] 2019). Site-level covariates representing elevation, the percentage of trees, and human population density in each grid cell were also examined as predictors in occupancy models.

RESULTS

Data collection began in June 2017 and has been ongoing since. Gaining access to sample sites progressed steadily, but more slowly than anticipated in the original proposal. Ultimately, while our initial goal was to deploy 100 detectors across Oahu, we were unable to do achieve the goal of 100 detectors in Year 1 using the probabilistic sampling design. Land access was the most common reason for not getting units deployed within sequentially selected cells, with lack of suitable sample sites also causing some cells to be skipped. Land access issues were most often associated with cells mostly owned and or managed by larger private landowners (e.g., agricultural entities and developers) that would not grant permission or from whom we could not get a response to our request for access. Lack of suitable sites within cells resulted from a lack of safely accessible sites or simply the lack of a suitable location to mount or locate a detector. As a result, we extended our sample effort to include 19 of the oversample cells; however, these same issues also affected some of the oversample cells.

In total, WEST placed 86 detectors in the field during the study period, with 84 of the 86 located in the randomly selected grid cells and two located at sites not within randomly selected cells (Figure 3). One additional randomly selected grid cell is located in the Kuhuku Wind Project. Data from one detector randomly selected from the two already being monitored in the Kuhuku Wind Project grid cell has been provided by TerraForm Power. This brings the maximum number of detectors being monitored at any one time to 87. Due to vandalism and repeated theft, detectors at two locations (Malekahana State Park and Ewa Beach Park) are no longer in service, having been eliminated from the sample after the last theft at each location. Of the two detectors not placed in randomly selected cells, one was initially used as a test site and is located in Waialua at the home of WEST's field biologist, while the other was placed at Hamakua Ponds at the request of the Department of Forestry and Wildlife staff. WEST has collected, processed, and incorporated data from the 85 detectors placed in randomly selected grid cells into the current analysis.

Detectors were placed in the field as access permissions were obtained, therefore, the temporal distribution of data varied among detectors. As such, seasonal data sets differ in the number of detectors that contributed data.

Detector Data

Total Detections

Data available as of October 2019 were processed and include detections collected between June 8, 2017, and October 7, 2019. Some of the detectors operating through October 7, 2019, were not yet processed at the time of data analysis and will be included in future analyses. At least one bat detection was recorded at 77 of the 87 (89%) sites over the full time period (June 2017 through October 2019). The number of detector nights sampled by site ranged from 106 to 800 (Table 1) for the full time period, and 12,185 HAHOBA detections were recorded; 4,978 detections in Year 1 and 5,315 detections in Year 2. Site-level detections ranged from zero to 2,551 for the full time period (median = 11 detections), with a range of zero to 1,524 for Year 1 (median = two detections; Figure 4a) and zero to 1,592 for Year 2 (median = five detections; Figure 4b).

Detections per Detector Night

The mean number of site-level detections per detector night ranged from zero to 4.18 overall (Table 1), from zero to 4.37 in Year 1 (Figure 5a), and from zero to 5.19 in Year 2 (Figure 5b). Detections were more widespread across Oahu during the post-lactation season relative to the other seasons in both Year 1 (Figure 6a) and Year 2 (Figure 6b).

Proportion of Detector Nights

The proportion of detector nights with detections ranged from zero to 0.40 (Table 1) across all seasons and sites for the full time period, from zero to 0.52 for Year 1 (Figure 7a), and from zero to 0.37 for Year 2 (Figure 7b). The proportion of detector nights with detections for Year 1 (Figure 8a) and Year 2 (Figure 8b) demonstrated similar seasonal patterns to those of mean detections per detector night.

Feeding Buzzes and Social Calls

For the full time period (June 2017 through October 2019), feeding buzzes (1,391 detections) and social calls (101 detections) were identified from call files recorded at 39 detectors (Figure 9). The presence of feeding buzzes and social calls is reported here for informational purposes, but may be incorporated into future analyses in a more formal way.

Table 1. Total detections, total detector nights, mean detections per night, and proportion of nights with detections by site from June 2017 – October 2019.

Site ID	Site Name	Detections	Nights with Detections	Detector Nights‡	Mean Detections Per Detector Night	Proportion of Detector Nights with Detections
Site-000	Goodale Tribe*	37	34	745	0.0497	0.0456
Site-002	TTHTT	31	27	754	0.0411	0.0358
Site-004	Army Nat Res	20	19	767	0.0261	0.0248
Site-006	Waihee Res	0	0	420	0	0
Site-008	Ewa Beach Park[a]	0	0	106	0	0
Site-009	Waianae HS	14	13	666	0.0210	0.0195
Site-011	Burn Camp	40	32	713	0.0561	0.0449
Site-013	KAW Gate	357	157	698	0.5115	0.2249
Site-016	Radar Hill Rd	8	7	350	0.0229	0.0200
Site-018	Dillingham Air	30	28	673	0.0446	0.0416
Site-020	Wahiawa botanical	17	16	765	0.0222	0.0209
Site-021	Lualualei 1	183	76	660	0.2773	0.1152
Site-022	Kahana Wedding	8	5	673	0.0119	0.0074
Site-023	Waimea Valley	630	241	754	0.8355	0.3196
Site-024	Ft Shafter	3	3	747	0.0040	0.0040
Site-025	Schofield	127	94	767	0.1656	0.1226
Site-026	Kawainiui	0	0	693	0	0
Site-029	KAW Rd	84	70	598	0.1405	0.1171
Site-030	Sacred Falls	1	1	584	0.0017	0.0017
Site-031	Plantation Village	4	4	737	0.0054	0.0054
Site-032	Nuuanu Watershed	0	0	588	0	0
Site-033	Camp Erdman	36	28	745	0.0483	0.0376
Site-034	Barbers Point	2	2	604	0.0033	0.0033
Site-035	Helemano	42	39	717	0.0586	0.0544
Site-036	Kroc Center	3	3	650	0.0046	0.0046
Site-038	Moanalua Trail	1	1	706	0.0014	0.0014
Site-039	Pupukea	2391	215	767	3.1173	0.2803
Site-040	Hickham AFB	0	0	549	0	0
Site-041	Schofield 3	339	180	730	0.4644	0.2466
Site-043	Manana Trail 1	2	2	800	0.0025	0.0025
Site-044	Royal Hawaiian Golf	2	2	668	0.0030	0.0030
Site-046	Poamoho	11	10	721	0.0153	0.0139
Site-048	Chaminade Univ.	6	6	789	0.0076	0.0076
Site-049	Lualualei NAVY	23	19	590	0.0390	0.0322
Site-050	HECO Kahe Point	5	3	786	0.0064	0.0038
Site-053	Kumaipo LZ	2551	247	610	4.1820	0.4049
Site-054	Anchor Church	2	2	591	0.0034	0.0034
Site-055	Schofield Waikane	24	18	696	0.0345	0.0259
Site-057	McCarthy Field	147	109	767	0.1917	0.1421
Site-058	Kailua Heights	4	3	618	0.0065	0.0049

Table 1. Total detections, total detector nights, mean detections per night, and proportion of nights with detections by site from June 2017 – October 2019.

Site ID	Site Name	Detections	Nights with Detections	Detector Nights‡	Mean Detections Per Detector Night	Proportion of Detector Nights with Detections
Site-059	Moanalua Red Hill	2	2	574	0.0035	0.0035
Site-060	Hawaii Loa Booster	11	11	605	0.0182	0.0182
Site-061	Mt Kaala	294	206	767	0.3833	0.2686
Site-064	Kamehameha Res	16	14	456	0.0351	0.0307
Site-065	Makua Valley	18	14	620	0.0290	0.0226
Site-066	Wheeler	37	32	711	0.0520	0.0450
Site-067	Honouliuli FR	14	11	644	0.0217	0.0171
Site-068	Waikane Valley	1	1	552	0.0018	0.0018
Site-069	MitchDetector	6	4	721	0.0083	0.0055
Site-070	Iroquois Pt	6	5	519	0.0116	0.0096
Site-071	Makaha Res	12	8	524	0.0229	0.0153
Site-072	Waihee Wells	0	0	482	0	0
Site-073	Kipapa North Fence	0	0	271	0	0
Site-074	Hawaii Loa	37	20	605	0.0612	0.0331
Site-075	Peerson	2386	272	715	3.3371	0.3804
Site-076	Kaipapau FR	31	8	712	0.0435	0.0112
Site-077	Manana Trail 2	4	4	760	0.0053	0.0053
Site-078	Sand Island	1	1	728	0.0014	0.0014
Site-079	Makua Ridge	229	113	724	0.3163	0.1561
Site-081	KAW 2	66	60	710	0.0930	0.0845
Site-083	Lualualei 2	128	71	680	0.1882	0.1044
Site-084	Aiea Loop Ridge	4	4	664	0.0060	0.0060
Site-085	Kaw 1	51	48	774	0.0659	0.0620
Site-087	Schofield 1	86	67	718	0.1198	0.0933
Site-088	Kawainui Marsh 1	0	0	739	0	0
Site-089	Waiawa Snot	6	3	790	0.0076	0.0038
Site-090	Kau Crater Trail	1	1	656	0.0015	0.0015
Site-093	Pouhala Marsh	7	7	702	0.0100	0.0100
Site-094	Manoa Falls	6	5	787	0.0076	0.0064
Site-095	Kuaokala Game Area	30	21	632	0.0475	0.0332
Site-097	Malaekahana SP	152	14	509	0.2986	0.0275
Site-098	West Loch Golf	8	8	632	0.0127	0.0127
Site-100	Heeia State Park	5	4	694	0.0072	0.0058
Site-101	Pupukea Paumalu	348	163	413	0.8426	0.3947
Site-102	Pearl Harbor	4	4	586	0.0068	0.0068
Site-103	Schofield Forest	483	116	743	0.6501	0.1561
Site-105	Aiea Loop Trail 1	170	37	745	0.2282	0.0497
Site-106	Puu Pia Trail	2	2	556	0.0036	0.0036
Site-109	Central Oahu Park	9	9	550	0.0164	0.0164

Table 1. Total detections, total detector nights, mean detections per night, and proportion of nights with detections by site from June 2017 – October 2019.

Site ID	Site Name	Detections	Nights with Detections	Detector Nights‡	Mean Detections Per Detector Night	Proportion of Detector Nights with Detections
Site-110	Halone Blowhole	0	0	580	0	0
Site-111	YMCA Waianae	11	9	410	0.0268	0.0220
Site-112	Barbers Point	0	0	520	0	0
Site-113	Hauula Dist. Park	2	2	562	0.0036	0.0036
Site-114	Waipio Soccer	1	1	531	0.0019	0.0019
Site-115	Waianae Valley	274	63	714	0.3838	0.0882
Site-119	Makua Cave	37	32	550	0.0673	0.0582
Site-999	Hamakua Pond*	4	4	672	0.0060	0.0060

* Denotes subjectively selected grid cells.

‡ Denotes nights that the detector was functional.

[a] data from a single season only.

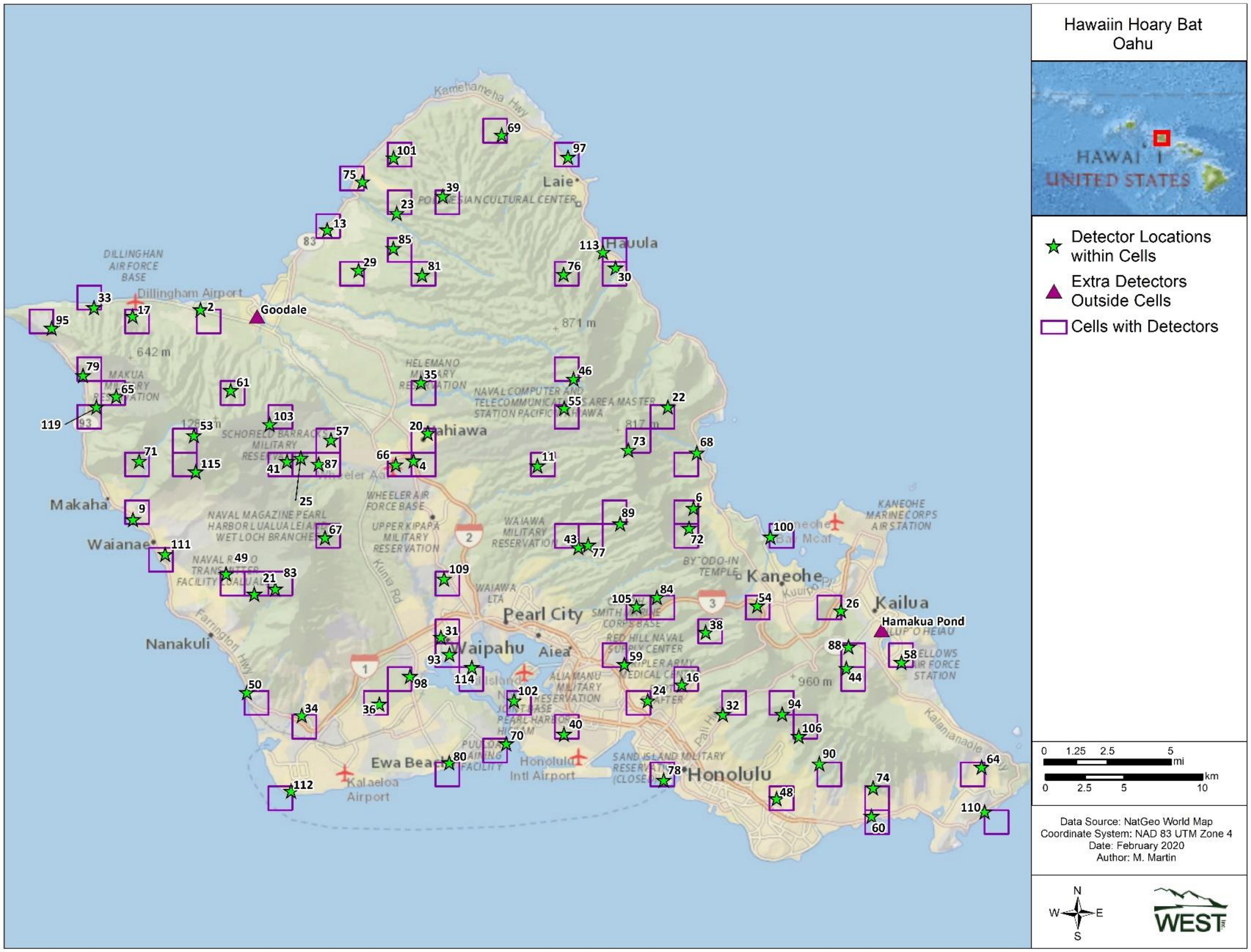


Figure 3: Distribution of acoustic bat detectors used in the island-wide occupancy study of Hawaiian hoary bats on Oahu. Site identification numbers are provided for each sample location.

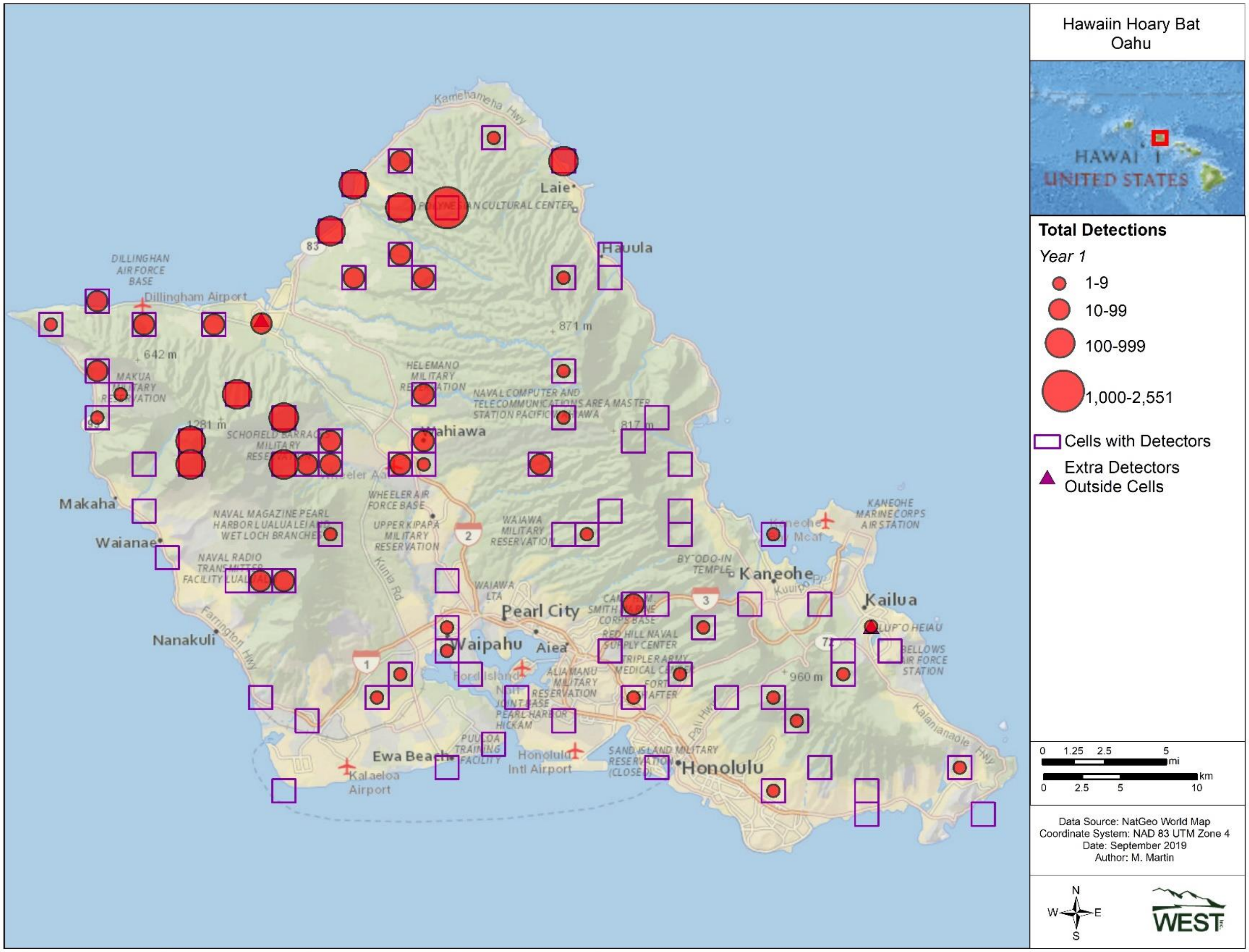


Figure 4a: Total detections by site between June 2017 and June 2018.

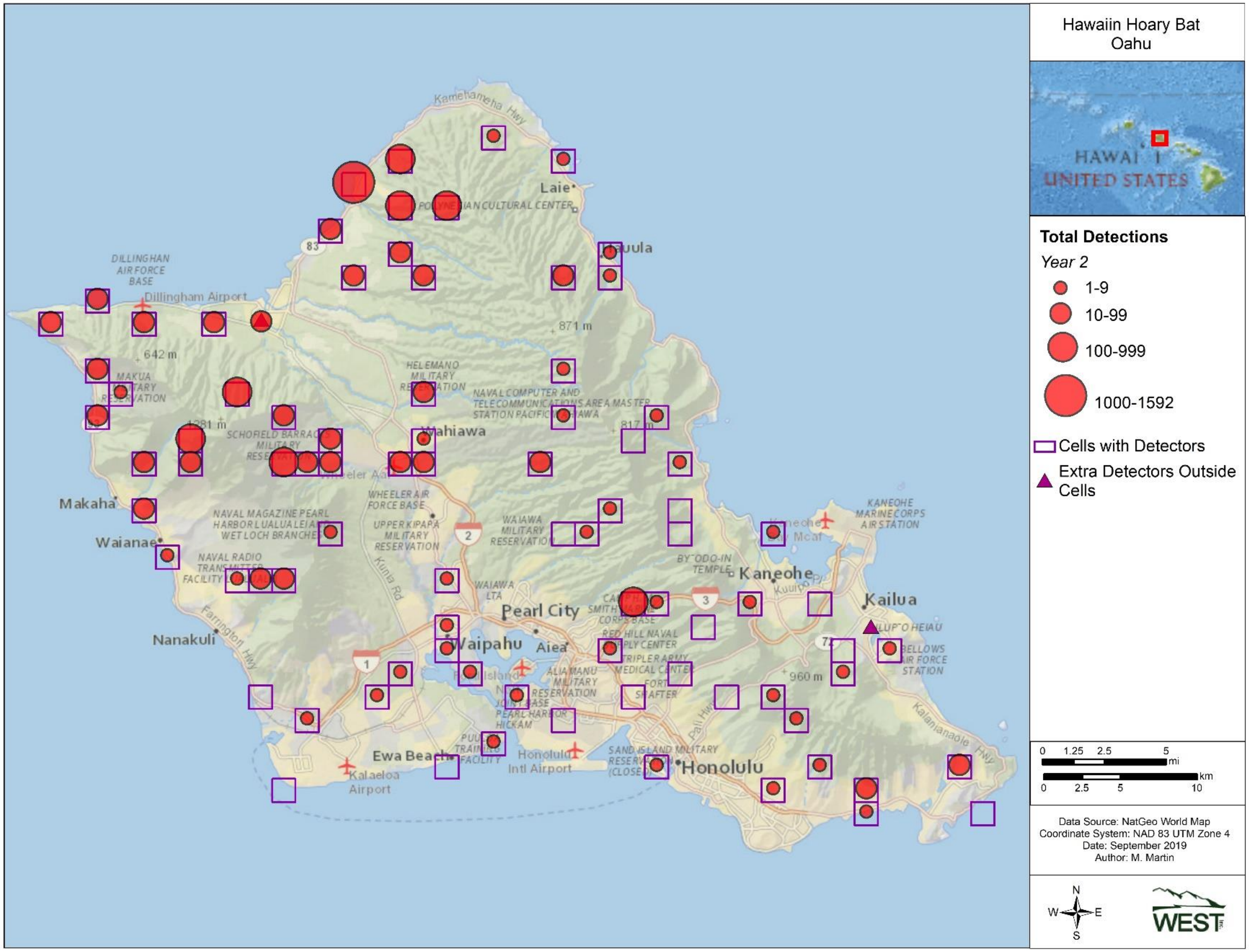


Figure 4b: Total detections by site between June 2018 and June 2019.

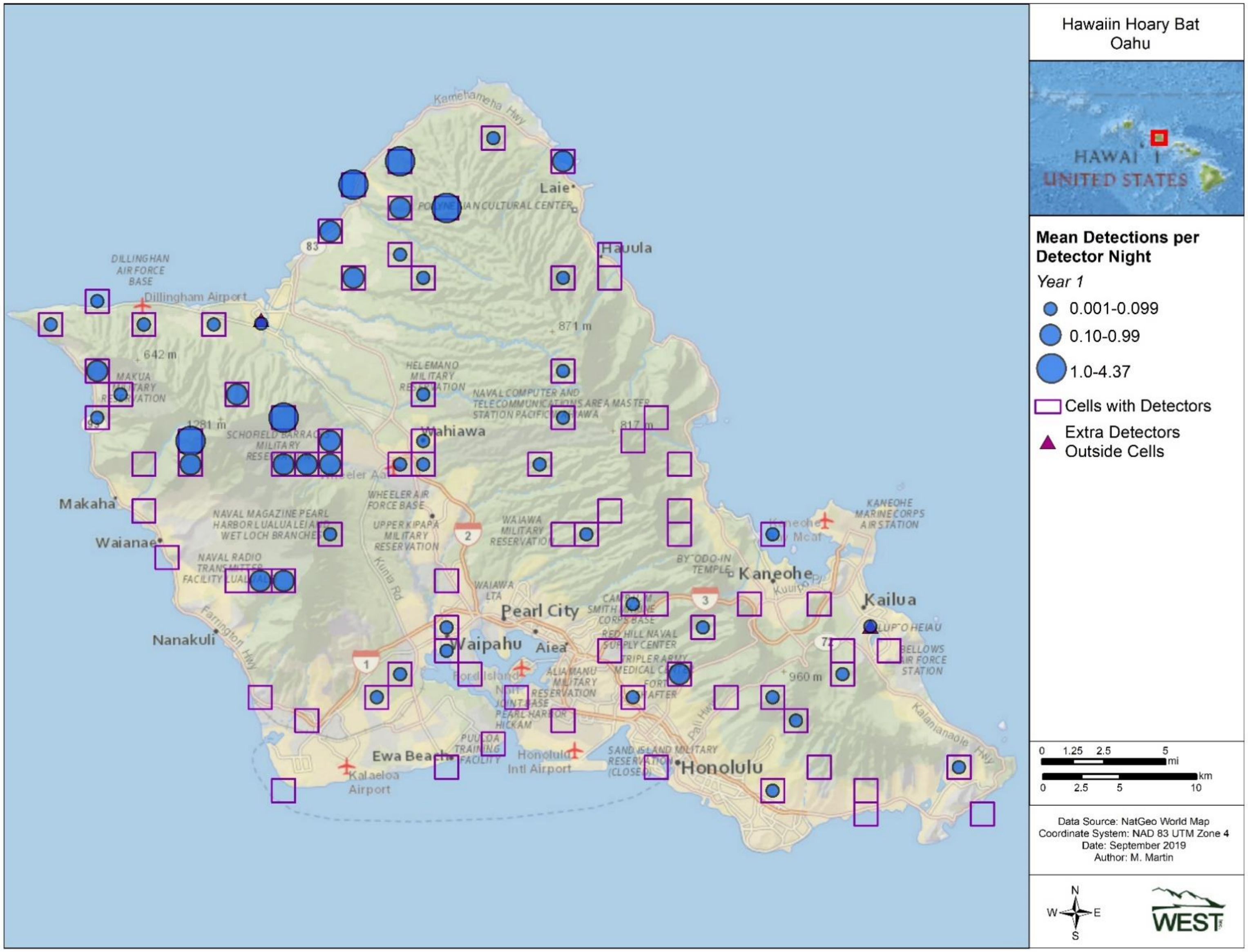


Figure 5a: Mean detections per night by site between June 2017 and June 2018.

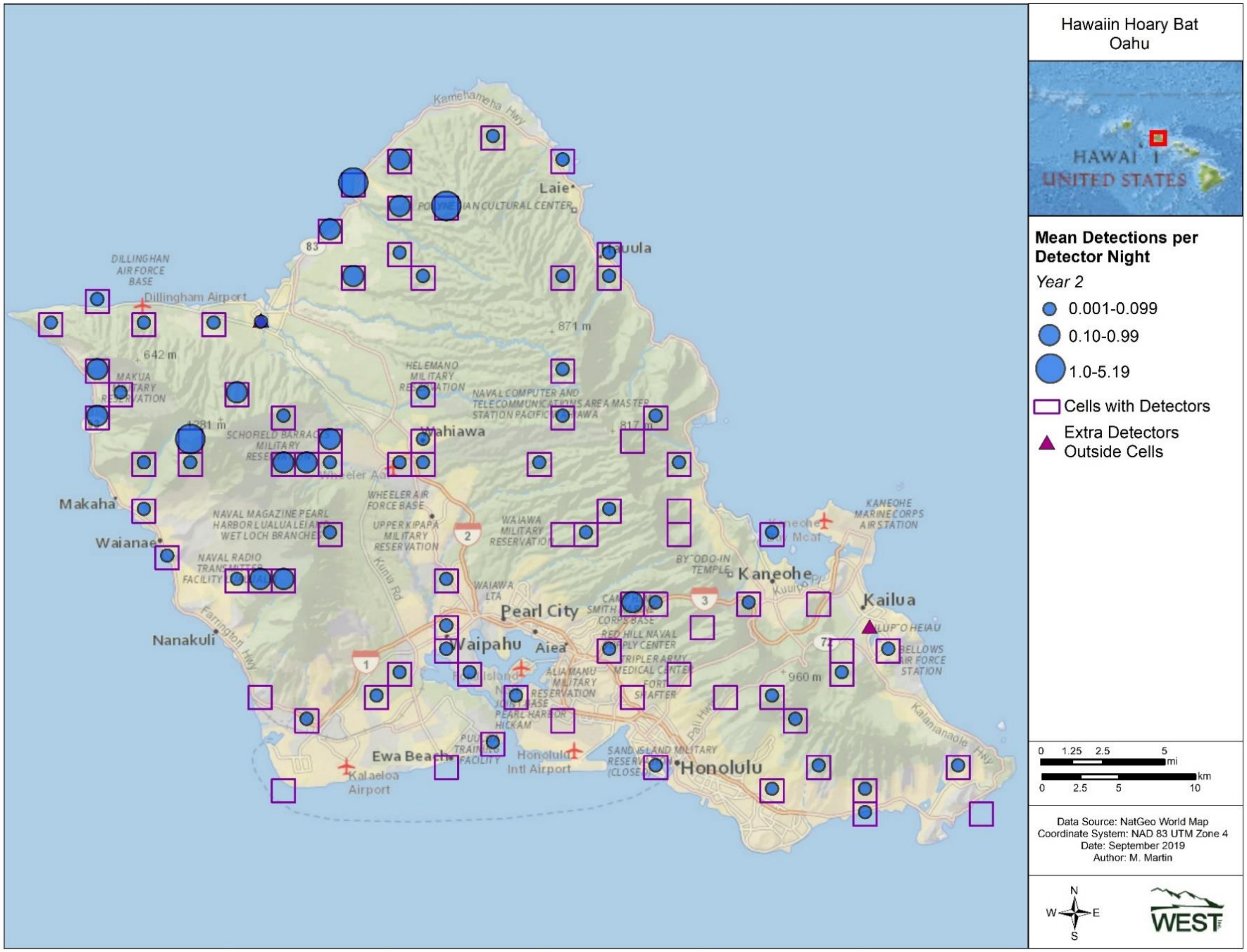


Figure 5b: Mean detections per night by site between June 2018 and June 2019.

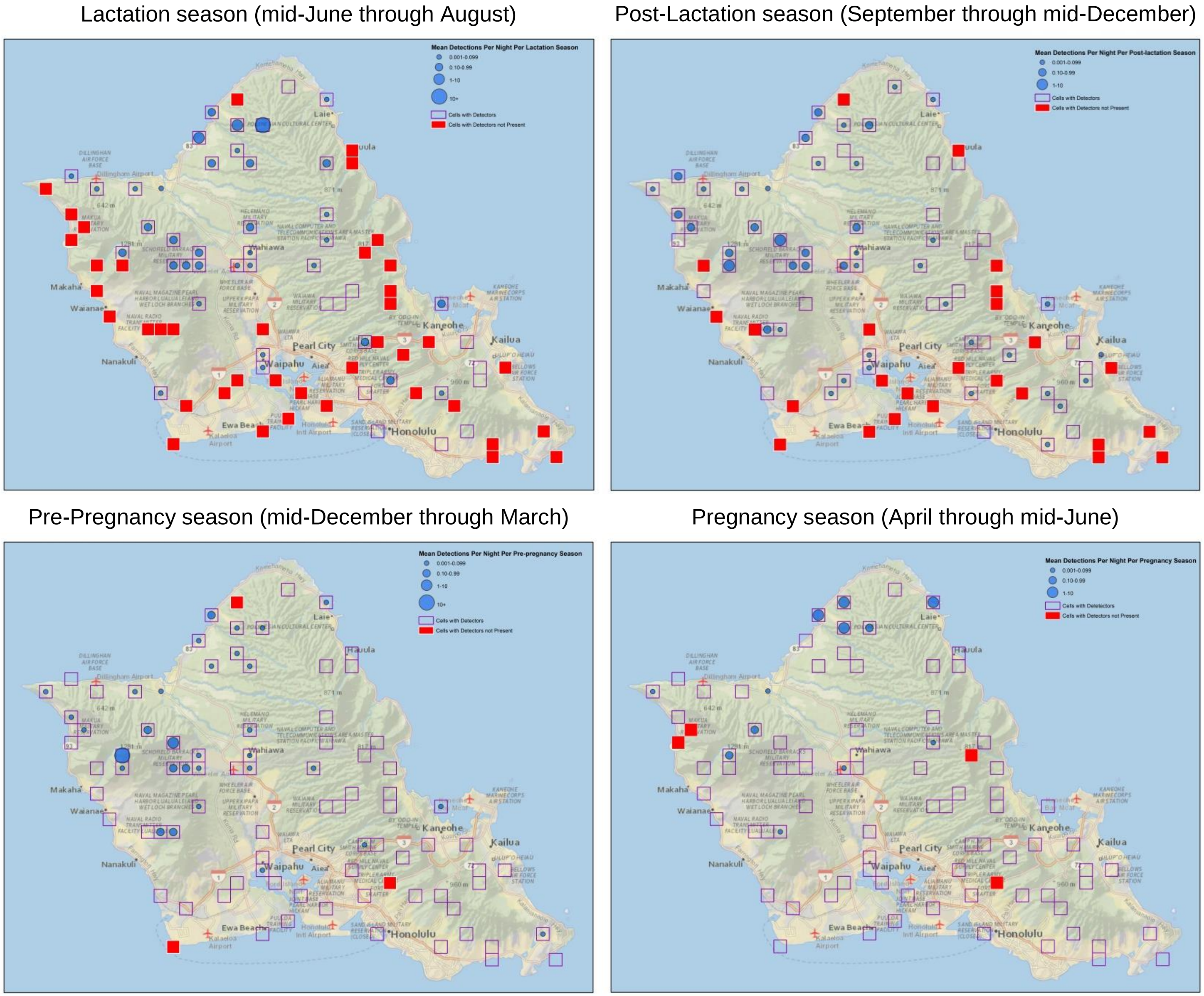


Figure 6a: Mean detections per night by site and season. June 2017 – June 2018.

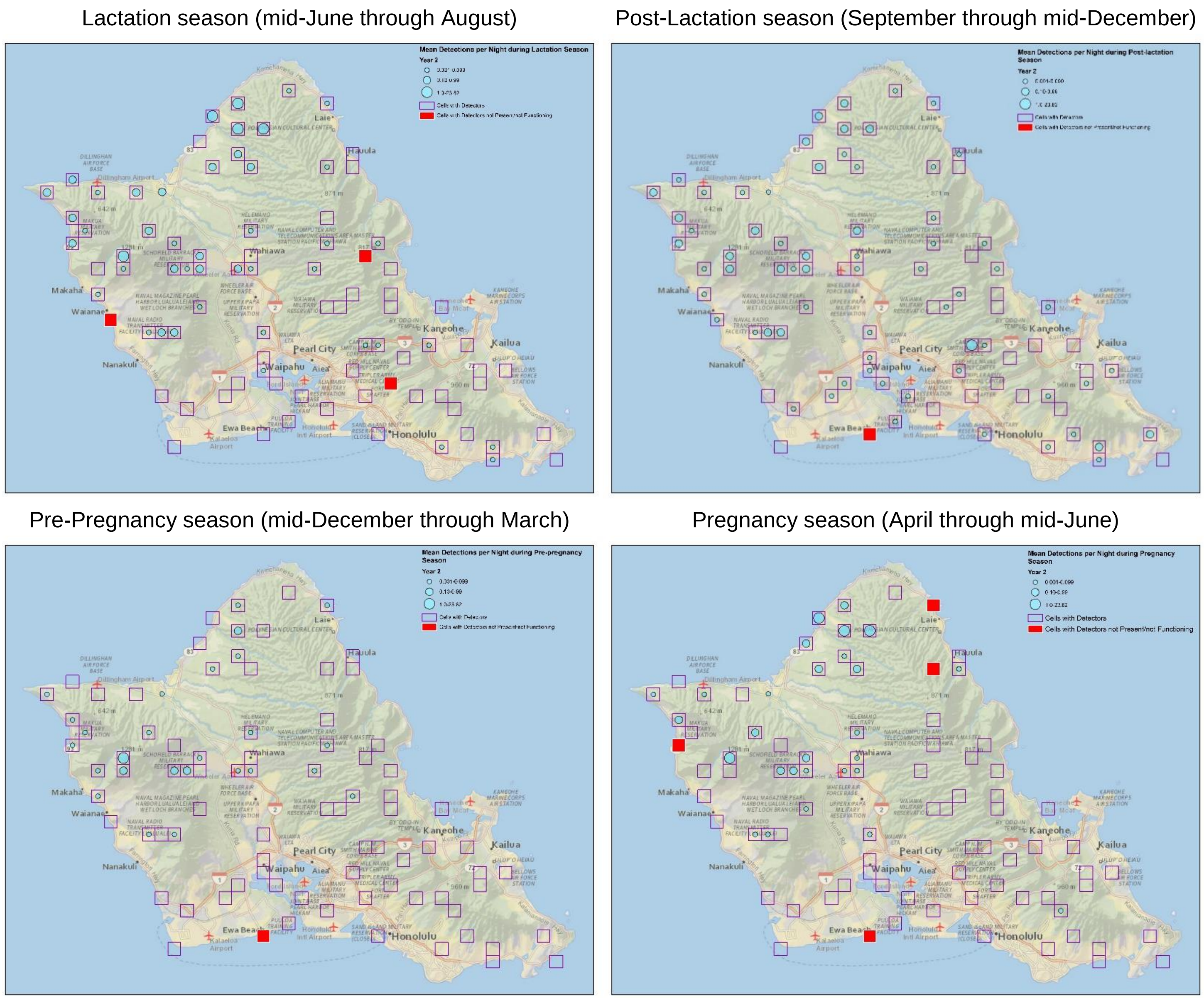


Figure 6b: Mean detections per night by site and season. June 2018 – June 2019.

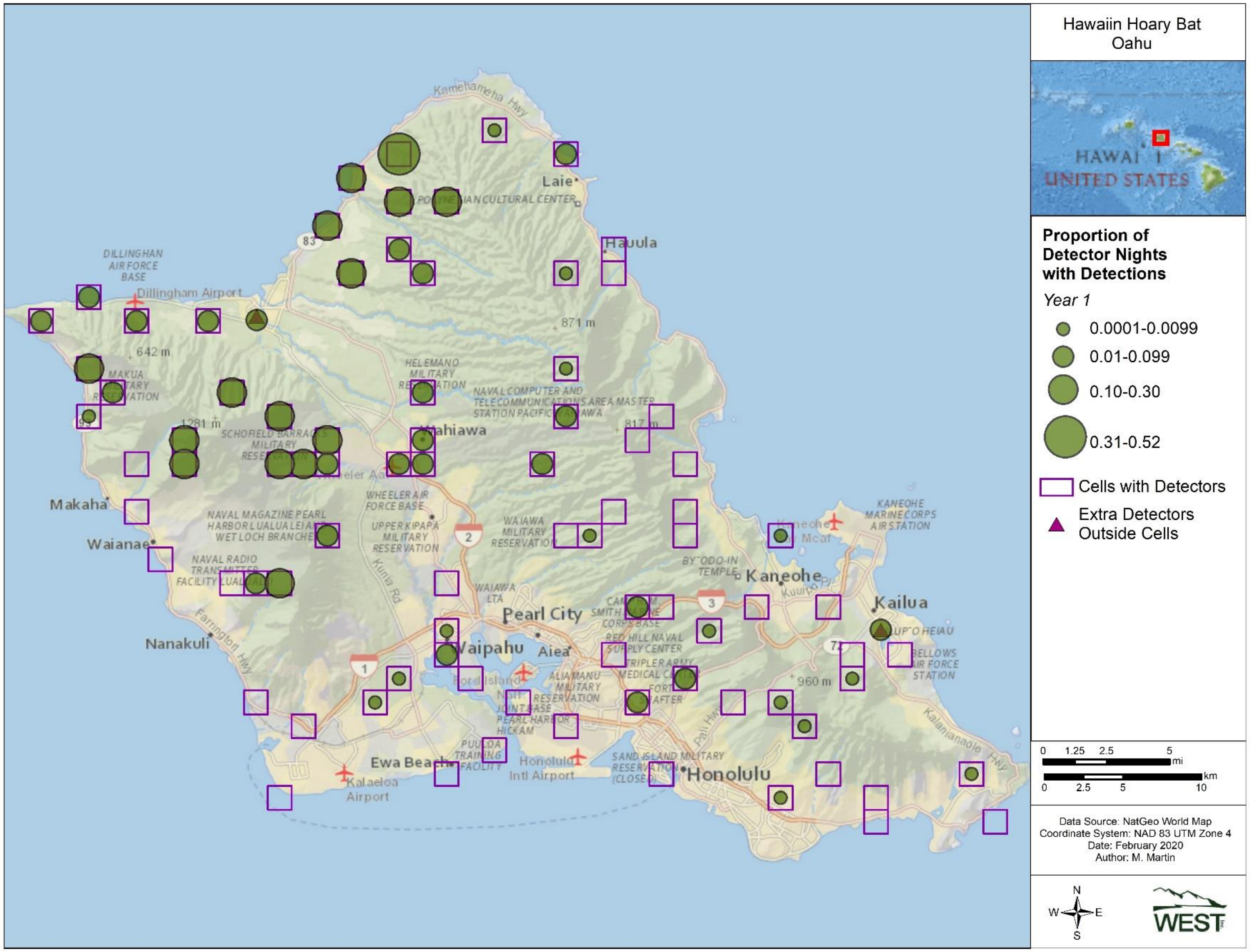


Figure 7a: Proportion of nights with detections by site between June 2017 and June 2018.

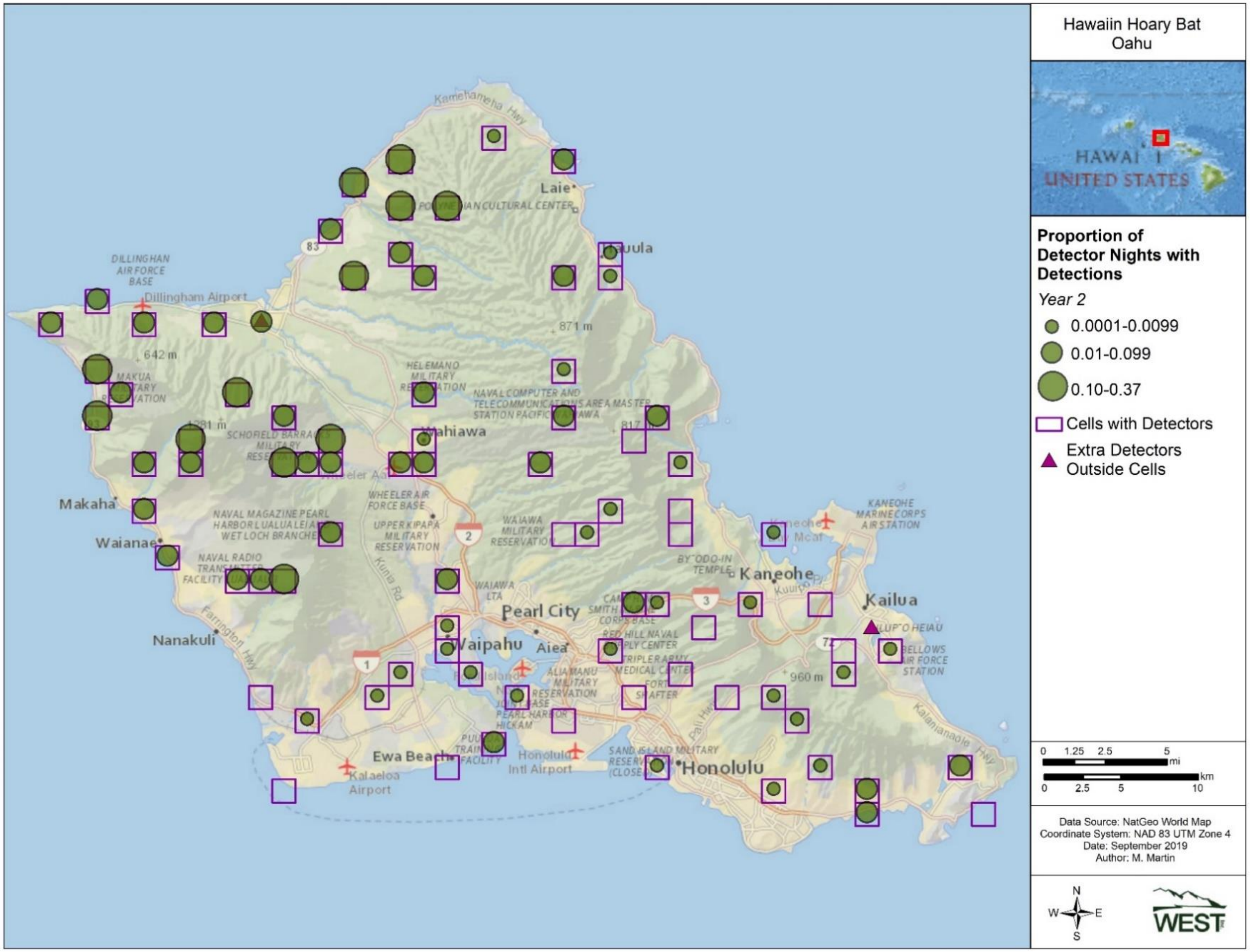
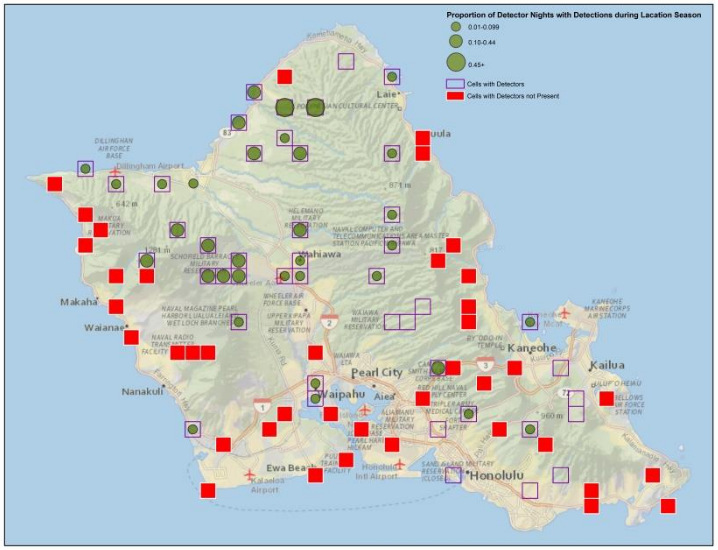
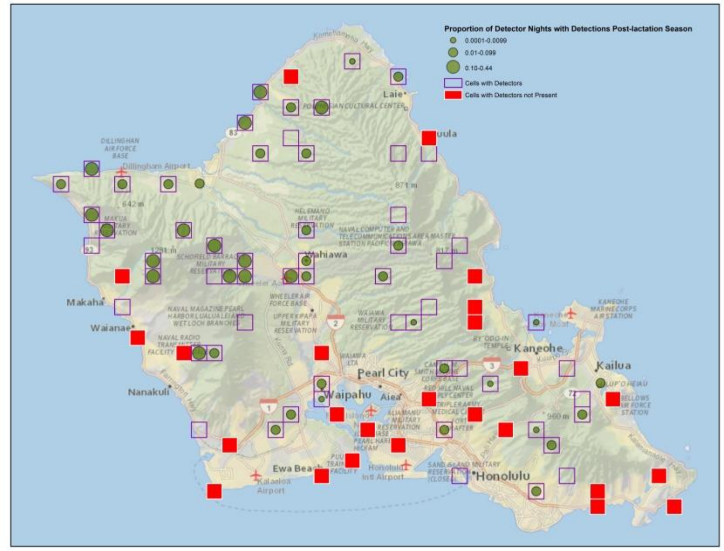


Figure 7b: Proportion of nights with detections by site between June 2018 and June 2019.

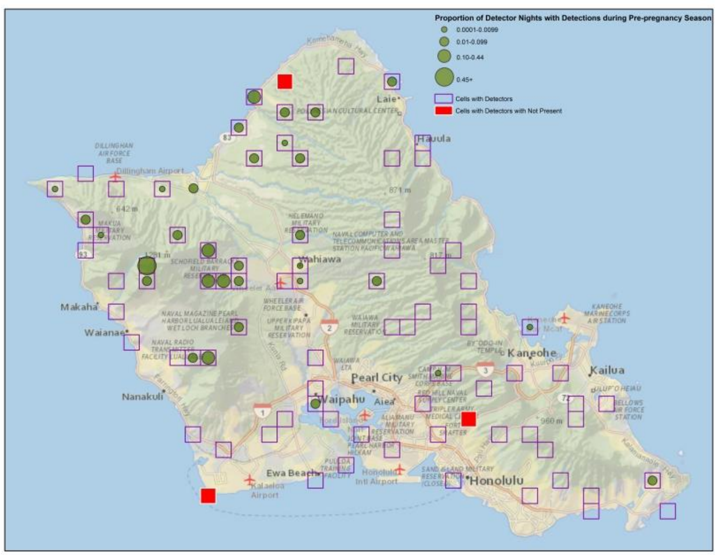
Lactation season (mid-June through August)



Post-Lactation season (September through mid-December)



Pre-Pregnancy season (mid-December through March)



Pregnancy season (April through mid-June)

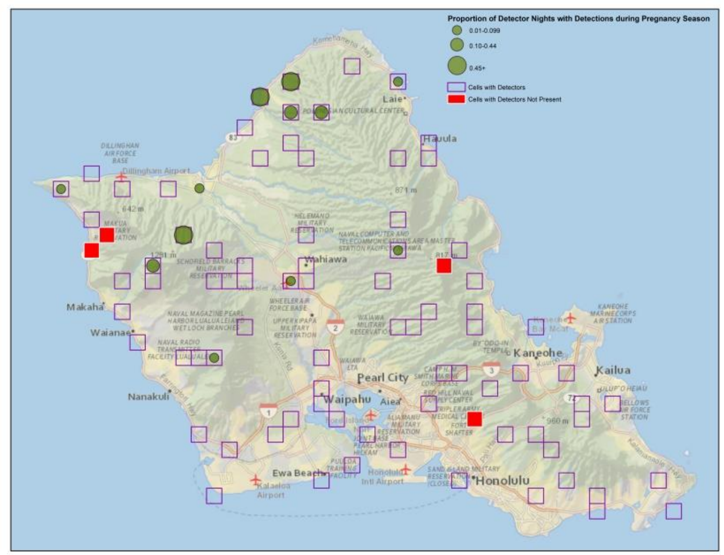
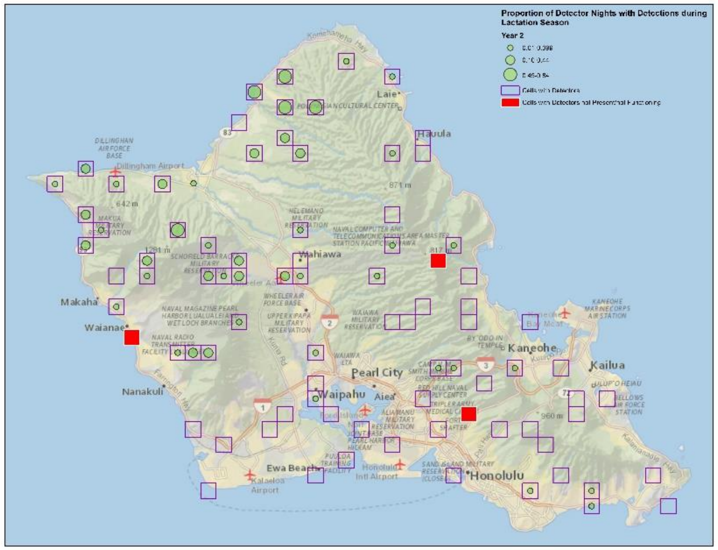
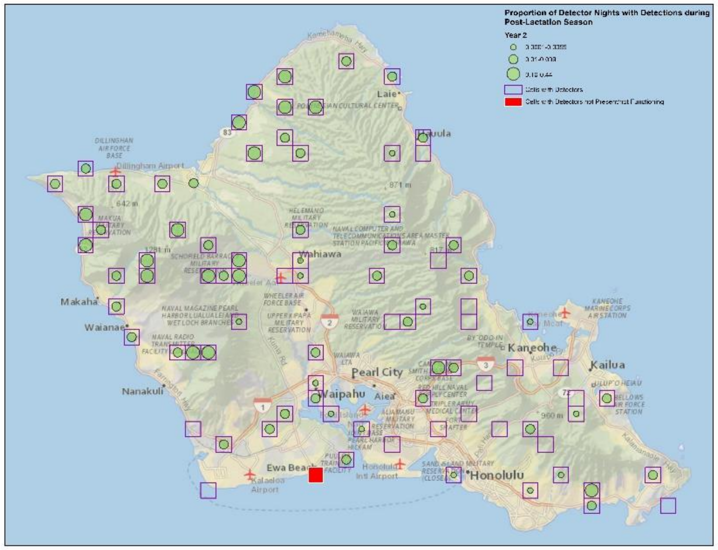


Figure 8a: Proportion of detector nights with detections by site and season between June 2017 and June 2018.

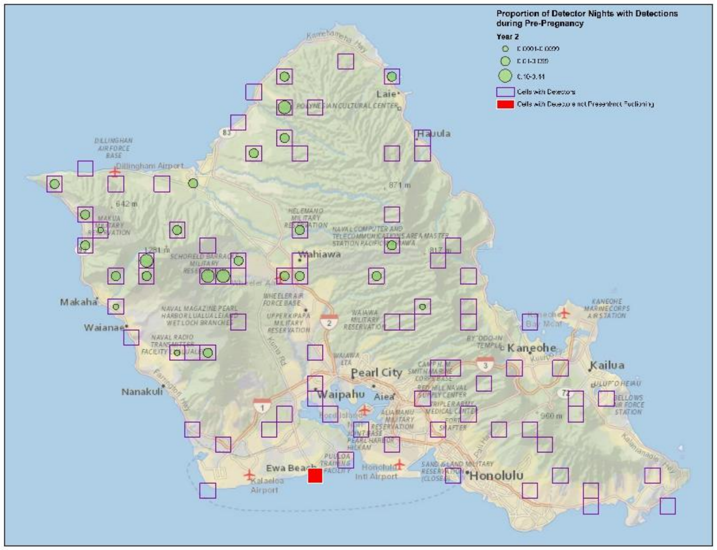
Lactation season (mid-June through August)



Post-Lactation season (September through mid-December)



Pre-Pregnancy season (mid-December through March)



Pregnancy season (April through mid-June)

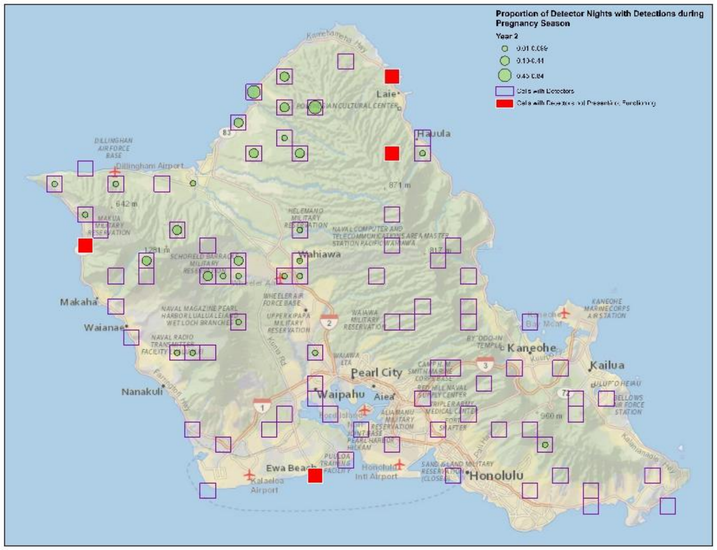


Figure 8b: Proportion of detector nights with detections by site and season between June 2018 and June 2019.

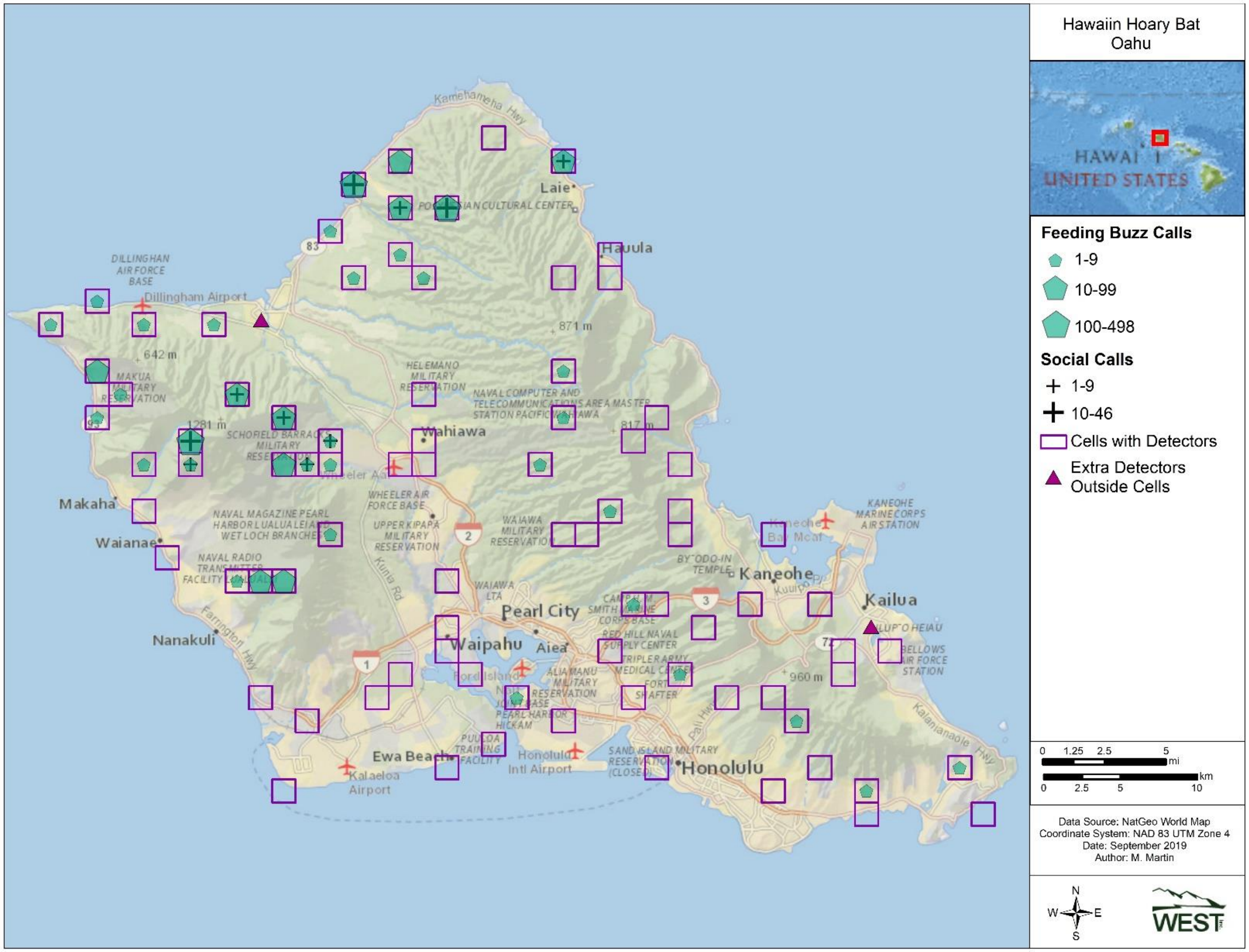


Figure 9: Distribution of feeding buzzes and social calls recorded between June 2017 and October 2019.

Occupancy modeling

The sample data available as of October 2019 were examined in an occupancy analysis to obtain estimates of occupancy and detection rates. The results presented herein are preliminary and are for informational purposes only. The results should not be cited outside of project planning discussions or without permission of the authors. We begin with an assessment of the assumptions for occupancy modeling, report the results of the occupancy modeling exercise, and determine if the current sample size of detectors is sufficient to meet the goal of estimating the HAHOBA occupancy rate on Oahu.

The independence of nightly detection data was evaluated by applying join count chi square tests of adjacent survey nights to data sets obtained by systematically sampling the nightly detector data every 7th, 10th, 14th, and 21st night. We attempted to apply the test to the nightly data and data systematically selected every four days, but the dimension of the resulting data set was often too large to process. In the cases where the join count test ran successfully for 4-day interval data, the test result indicated correlated data. For all data subsets, the join count test was conducted independently by reproductive season and year, assuming an independent detection model and a correlated detection model.

Small p-values from the join count test indicate the number of adjacent temporal joins exceeded the expectation under the independence assumption (Table 2). The assumption of independence resulted in a poor fit for at least one season in all subsample data sets. Based on the results of the join count tests for the independent detection model, we assume temporal correlation is substantial when examining detections from every data subset. We found the correlated detections model adequately accounted for the correlation between adjacent detections for a subsampling interval of seven days for the post-lactation, pre-pregnancy, and pregnancy breeding seasons. However, an interval of 14 days was required to adequately model detections in the lactation season. To both meet the assumptions of the correlated detections occupancy model and retain as much detection data as possible for precise estimation, the dataset used for occupancy modeling was developed using an interval of seven days for the post-lactation, pre-pregnancy, and pregnancy breeding seasons, and an interval of 14 days for the lactation season.

Table 2: Join count test results for two models (independent detection or correlated detections), four seasons, and four sampling intervals across three survey years.

Season	Interval (days)	Model	Year 1		Year 2		Year 3	
			Join count χ^2	p-value	Join count χ^2	p-value	Join count χ^2	p-value
Lactation	7	Ind.	46.52	0.007	9,7493.79	<0.001	225.04	<0.001
	10	Ind.	2032.34	<0.001	59.30	0.002	23.89	0.012
	14	Ind.	11.93	0.039	10.67	0.038	17.06	0.018
	21	Ind.	3.71	0.181	2.93	0.303	21.24	0.011
Post-Lactation	7	Ind.	35.92	0.005	14.81	0.029	-	-
	10	Ind.	26.09	0.010	11.01	0.032	-	-
	14	Ind.	4.97	0.155	3.00	0.149	-	-
	21	Ind.	0.32	0.806	4.26	0.066	-	-

Table 2: Join count test results for two models (independent detection or correlated detections), four seasons, and four sampling intervals across three survey years.

Season	Interval (days)	Model	Year 1		Year 2		Year 3	
			Join count χ^2	p-value	Join count χ^2	p-value	Join count χ^2	p-value
Pre-Pregnancy	7	Ind.	7.42	0.097	0.07	0.966	-	-
	10	Ind.	29.09	0.005	1.82	0.308	-	-
	14	Ind.	1.30	0.622	0.27	0.739	-	-
	21	Ind.	3.79	0.089	1.27	0.891	-	-
Pregnancy	7	Ind.	55.26	0.003	23.25	0.007	-	-
	10	Ind.	5.62	0.197	3.27	0.233	-	-
	14	Ind.	7.14	0.089	0.55	0.832	-	-
	21	Ind.	1.29	0.803	1.38	0.476	-	-
Lactation	7	Corr.	13.89	0.029	699.87	0	23.75	0.024
	10	Corr.	146.86	<0.001	11.65	0.062	8.73	0.190
	14	Corr.	5.50	0.145	4.82	0.144	4.19	0.267
	21	Corr.	1.38	0.475	2.83	0.194	9.10	0.024
Post-Lactation	7	Corr.	4.06	0.436	1.28	0.906	-	-
	10	Corr.	5.56	0.152	2.15	0.627	-	-
	14	Corr.	2.09	0.395	0.94	0.402	-	-
	21	Corr.	0.30	0.590	4.22	0.054	-	-
Pre-Pregnancy	7	Corr.	2.79	0.893	0.08	0.367	-	-
	10	Corr.	7.73	0.094	0.94	0.415	-	-
	14	Corr.	1.51	0.382	0.49	0.694	-	-
	21	Corr.	1.65	0.303	1.54	0.848	-	-
Pregnancy	7	Corr.	10.48	0.187	4.82	0.417	-	-
	10	Corr.	2.32	0.625	2.28	0.313	-	-
	14	Corr.	3.69	0.412	0.43	0.880	-	-
	21	Corr.	0.21	0.990	0.81	0.715	-	-

Ind. = independent detection; Corr. = correlated detections.

Site-level covariates (Table 3) were used to model occupancy, local extinction and colonization, and the probability of local presence in an occupied site just prior to the first survey period. Site-level covariates included the human population per square mile (US Census Bureau 2019), mean elevation of the grid cell in meters (USGS 2017), and the percentage of the grid cell covered in tree-dominated land cover classes (Landfire Existing Vegetation Type 2017). Each of the three site-level covariates was also discretized into a 2-level category of low/high based on the median value and are indicated as covariates ending in “Class.”

Table 3: Site-level covariates for occupancy modeling

Site-level Covariate	Description
PopSqMi	Human population per square mile (mi) in each grid cell.
PopSqMiClass	0 if population density <64.60 people per square mi, 1 otherwise.
Elev	Mean site elevation in meters in each grid cell.
ElevClass	0 if Elevation <141.43 m, 1 otherwise.
PctTrees	Percent tree cover in grid cell.
PctTreesClass	0 if percent tree cover <20.68%, 1 otherwise.

The dynamic occupancy model for correlated detections was then applied to the subsampled detection data set and covariates were examined in a model selection process. Local extinction and colonization parameters were modeled by season, but these models did not converge. Visit-level and coarser covariates (season- and site-level) were used to model detection probabilities. Visit-level covariates included the month of the survey and the microphone model used with the bat detector. Microphones were swapped between February and June of 2019. To avoid confounding effects of microphone and season, microphone model effects will be omitted from detection probability models until a full year of data has been collected with the SMM-U2 microphone. Model parameters are defined in Table 4, and the results of the modeling exercise are provided in Table 5 for the subset of models that converged.

Table 4: Occupancy parameters for the multi-season dynamic occupancy model for correlated detections (Hines et al. 2014)

Occupancy Model Parameter	Description
psi	Occupancy rate.
th0	Probability the species is available at a survey occasion given the site is occupied and the species was **not** available at the previous survey occasion.
th1	Probability the species is available at a survey occasion given the site is occupied and the species **was** available at the previous survey occasion.
gam	Probability a site not occupied during a given season is colonized during the next season.
eps	Probability a site occupied during a given season is not occupied during the next season.
p	Probability a species is detected given the site is occupied and the species is currently available.
th0pi	Probability a site is occupied and the species is available just prior to the first survey occasion.

Table 5: Occupancy modeling results for the multi-season dynamic occupancy model for correlated detections

Model	AIC	Delta AIC	AIC wgt	no. Par.
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMiClass)	2120.24	1.06	0.3031	11
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMi)	2123.64	4.46	0.0554	11
psi,th0(),th1(),gam(2SeasonPostLact),eps(2SeasonPostLact),p(),th0pi()	2123.82	4.64	0.0506	9
psi,th0(),th1(),gam(),eps(),p(),th0pi(PopSqMiClass)	2125.82	6.64	0.0186	8
psi(ElevMn)th0(),th1(),gam(),eps(),p(Season),th0pi()	2126.72	7.54	0.0119	11
psi(PopSqMiClass)th0(),th1(),gam(),eps(),p(Season),th0pi()	2127.10	7.92	0.0098	11
psi(ElevMn)th0(),th1(),gam(PctTreesClass),eps(PctTreesClass),p(Season),th0pi()	2127.23	8.05	0.0092	13
psi(PopSqMi)th0(),th1(),gam(),eps(),p(Season),th0pi()	2127.93	8.75	0.0065	11
psi,th0(),th1(),gam(),eps(),p(Season),th0pi()	2129.21	10.03	0.0034	10
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PctTreesClass)	2129.26	10.08	0.0033	11
psi(ElevMn)th0(),th1(),gam(PopSqMiClass),eps(PopSqMiClass),p(Season),th0pi()	2129.39	10.21	0.0031	13
psi,th0(),th1(),gam(PctTreesClass),eps(PctTreesClass),p(Season),th0pi()	2130.01	10.83	0.0023	12
psi(PctTrees)th0(),th1(),gam(),eps(),p(Season),th0pi()	2130.86	11.68	0.0015	11
psi(PctTreesClass)th0(),th1(),gam(),eps(),p(Season),th0pi()	2131.14	11.96	0.0013	11
psi(ElevClass)th0(),th1(),gam(),eps(),p(Season),th0pi()	2131.21	12.03	0.0013	11
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(ElevClass)	2132.96	13.78	0.0005	11
psi(PopSqMiClass),th0(),th1(),gam(),eps(),p(),th0pi()	2142.94	23.76	0	8
psi,th0(),th1(),gam(),eps(),p(Month),th0pi()	2144.03	24.85	0	8
psi,th0(),th1(),gam(),eps(),p(),th0pi()	2145.26	26.08	0	7
psi,th0(),th1(),gam(PctTreesClass),eps(PctTreesClass),p(),th0pi()	2145.67	26.49	0	9
psi,th0(),th1(),gam(),eps(),p(),th0pi(PctTreesClass)	2145.69	26.51	0	8
psi,th0(),th1(),gam(PopSqMiClass),eps(PopSqMiClass),p(),th0pi()	2146.79	27.61	0	9
psi(PctTreesClass),th0(),th1(),gam(),eps(),p(),th0pi()	2147.20	28.02	0	8

AIC = Akaike Information Criterion; wgt = weight; no. Par. = no parameter.

The top model based on Akaike Information Criterion described detection probabilities by reproductive season and the initial probability HAHOBA was locally present prior to the first survey as a function of low or high human population density (see Appendix A for PRESENCE model output). Occupancy estimates were modeled as stable over the full survey period and ranged from 0.4317 to 0.4465 (Table 6, Figure 10). The probability HAHOBA was locally present at an occupied grid cell just prior to the first survey was 0.2062 (Standard Error [SE] = 0.0665, 95% confidence interval [CI]: 0.1048, 0.3654) for cells with high human population density and 0.6042 (SE = 0.1277, 95% CI: 0.3489, 0.8130) for cells with low human population density. The probability HAHOBA was locally present at an occupied site given the species was locally present in the previous survey occasion was estimated to be 0.8241 (SE = 0.0354, 95% CI: 0.7437, 0.8833). The probability of local presence at an occupied site where the species was not locally present in the previous survey occasion was 0.0623 (SE = 0.0142, 95% CI: 0.0396, 0.0967). The estimated detection probabilities conditional on local presence varied by season (Table 6, Figure 11) and ranged from 0.25 in the pre-pregnancy season to 0.53 in the lactation season.

Table 6: Estimates of occupancy and detection rates for the top multi-season dynamic occupancy model for correlated detections.

Year	Season	Est. Occupancy Rate	SE	95% CI	Est. Detection Probability Given Local Presence	SE	95% CI
1	Lactation	0.4465	0.0951	(0.2750, 0.6317)	0.5347	0.0795	(0.3806, 0.6825)
1	Post-Lactation	0.4435	0.0798	(0.2872, 0.5999)	0.3977	0.0485	(0.3076, 0.4954)
1	Pre-Pregnancy	0.4410	0.0693	(0.3051, 0.5769)	0.2500	0.0485	(0.1673, 0.3562)
1	Pregnancy	0.4388	0.0635	(0.3145, 0.5632)	0.4204	0.0655	(0.2998, 0.5512)
2	Lactation	0.4370	0.0614	(0.3167, 0.5573)	0.5347	0.0795	(0.3806, 0.6825)
2	Post-Lactation	0.4354	0.0620	(0.3138, 0.5570)	0.3977	0.0485	(0.3076, 0.4954)
2	Pre-Pregnancy	0.4340	0.0644	(0.3078, 0.5601)	0.2500	0.0485	(0.1673, 0.3562)
2	Pregnancy	0.4328	0.0676	(0.3004, 0.5652)	0.4204	0.0655	(0.2998, 0.5512)
3	Lactation	0.4317	0.0710	(0.2925, 0.5710)	0.5347	0.0795	(0.3806, 0.6825)

Est. = estimated; SE = Standard Error; CI = confidence Interval.

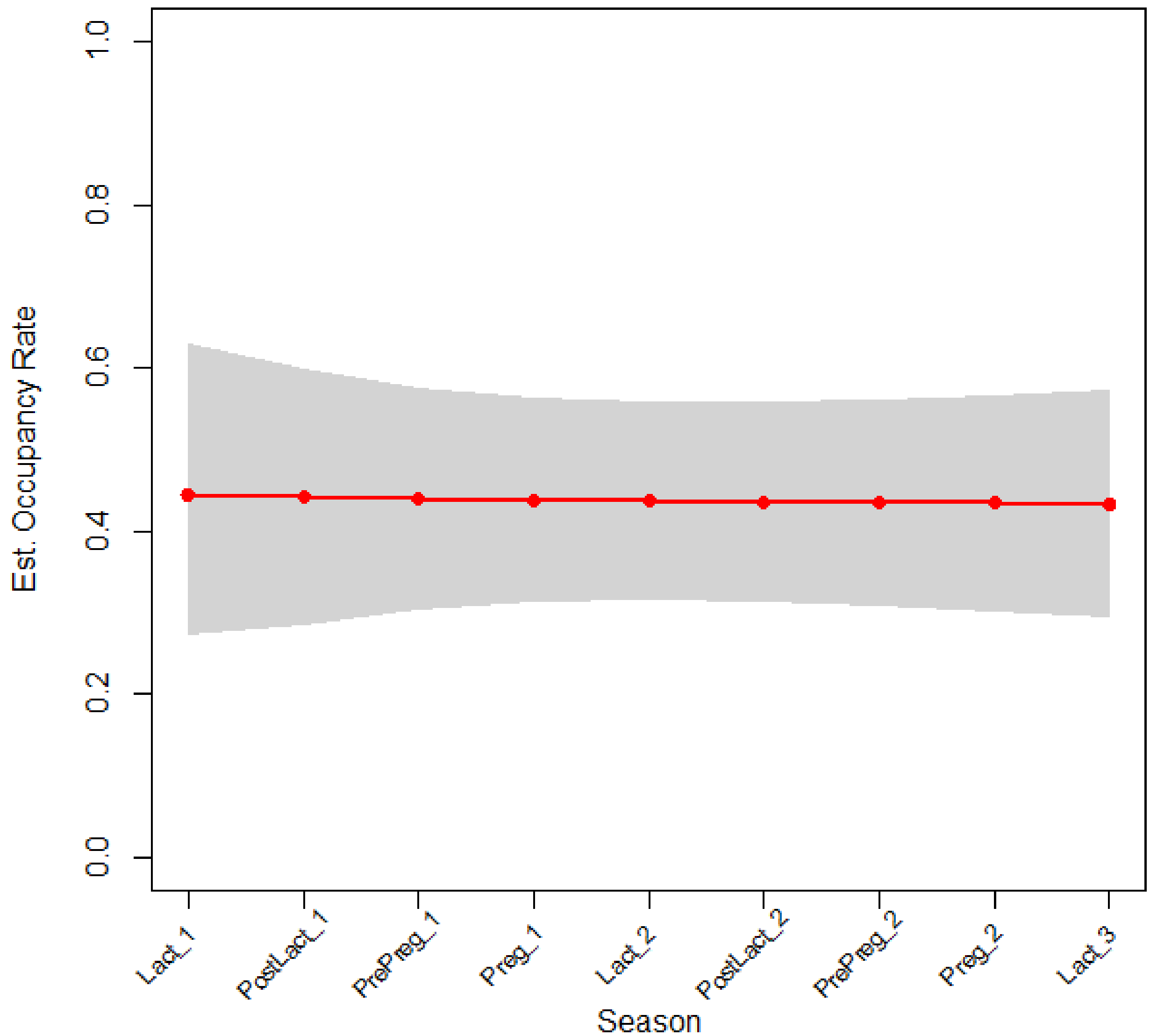


Figure 10: Occupancy estimates and 95% confidence bands by reproductive season and year.

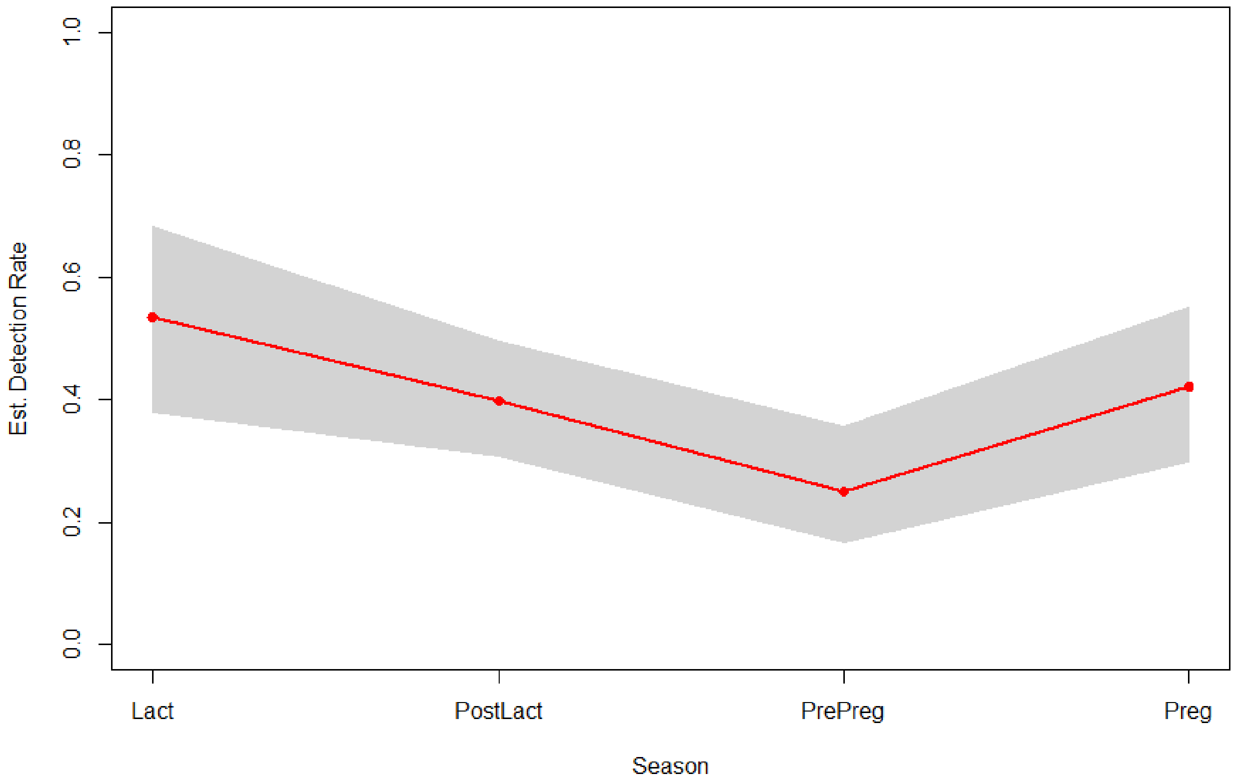


Figure 11: Detection probability estimates and 95% confidence bands by reproductive season.

DISCUSSION

Temporal correlation among detections violates assumptions of independent detections required for standard occupancy modeling. Failure to account for temporal correlation may result in variance underestimation leading to narrow CIs and inappropriately small p-values that indicate a significant effect when none exists. One approach to obtaining independent detections is to reduce the detector nights to a subset of data for which independent detections may be assumed (Wright et al. 2016). Removing detection occasions reduces the sample size of observations, which may make modeling with covariates more difficult. Data reduction may also eliminate incidental detections of HAHOBA that may simply be transiting through a grid cell and not truly occupying the cell for biological reasons, therefore, helping to better address occupancy for grid cells with consistent use. Another approach to address temporal correlation is to implement detection models that apply a first-order Markov process (Hines et al. 2014) to account for temporal correlation. To retain the most data while still meeting the assumptions of independent detections, we subsampled detections recorded every 14 days for the Lactation season and every seven days for the Post-Lactation, Pre-Pregnancy, and Pregnancy seasons and then applied the occupancy model that accounted for correlated detections.

The final occupancy model for our data set assumed closure within each reproductive season, modeled the local colonization and extinction rates as equal across all seasons, and modeled detection by season. Occupancy models describing the extinction and colonization parameters by season did not converge, likely because there are only two replications of each seasonal transition so far (e.g., Lactation to Post-lactation in each of two years). HAHOBA distribution appears to vary by season (Figures 6a, 6b, 8a, and 8b), with the largest extent of the distribution occurring in the Post-Lactation period. These seasonal differences could be explained by changing occupancy or by changes in the detectability of the species across the reproductive seasons. Additional seasonal data may provide more information to assess how occupancy, rather than detection, might change by season. Bayesian analysis may also provide tools to determine if seasonal differences are due to detection differences, distributional changes, or a mixture of both.

Given this study is at roughly the halfway point, an assessment of current effort is warranted. Over two years of data have been collected on HAHOBA distribution and occupancy. At the request of the ESRC, the original sample frame included all grid cells that contained some land area that could provide a sample site for a detector, even if the majority of the cell was over open water (i.e., offshore). This was done to not exclude possible sampling along the coastline. Three detectors were located in cells in beach parks or close to the waterfront in cells mostly (over 85%) represented by open water conditions (see grid cells 110, 112, and 113 in Figure 2). Two of the three cells have had zero detections in more than two years of surveys, while the third has had only five detections over four separate nights (Table 7). Due to the large amount of open water in these three cells, the detector sample sites are not considered representative of the cell, therefore, potentially limiting their contribution to future analyses focused on habitat associations. While the data collected to date in these cells will continue to be used in future analyses of bat distribution and occupancy across the island, we suggest data collection from these detectors could be discontinued at this time. We also plan to cease collecting data at the two non-random detectors (999-Hamakua Ponds and 000 Goodale Tribe) and consider ceasing monitoring of the Kipapa North Fence (Site-073) detector, which is located on a difficult to access ridge along the Koʻolau crest that is regularly inundated with clouds, rarely accessible, and as a result, missing large amounts of data (i.e., only 270 detector nights of data out of more than 700 possible nights). Data from all six of these sites can still be incorporated into analyses, as appropriate, for the time periods in which they were operating. However, we feel resources saved by ceasing data collection at these sites can be better used on analysis or other needs while not compromising the occupancy study.

MacKenzie's (2006) recommendation on survey designs for assessing habitat use when detection probabilities are less than one is to select a single sample and revisit the same sites over time. This survey design provides a basis to estimate the detection probability without confounding habitat and detection variables. Because the detection probability in our study is estimated to be well below one, we recommend continued monitoring of all detectors except those six noted above at their current locations in order to provide the most appropriate data set for incorporating habitat variables into the occupancy analysis.

Table 7. Sites and site characteristics for detectors with five or fewer detections for full time period (June 2017 through October 2019).

Site ID	Site Name	Detections	Elevation (m)	% Tree Cover	Human Population per Square Mile
Site-006	006 Waihee Res	0	131.28	57.8	402.47
Site-008	008 Ewa Beach Park	0	0.28	0.4	3760.29
Site-026	026 Kapaa Kawainui	0	74.42	23.7	1265.63
Site-032	032 Nuuanu Watershed	0	244.36	61.6	1086.93
Site-040	040 Hickham AFB	0	2.46	0.0	2834.81
Site-072	072 Waihee Wells	0	227.86	79.7	171.94
Site-073	073 Kipapa North Fence	0	421.22	94.9	22.55
Site-088	088 Kawainui Marsh 1	0	42.12	30.9	1658.75
Site-110	110 Halone Blowhole	0	0.37	0.1	0
Site-112	112 Barbers point	0	0.14	0.9	0
Site-030	030 Sacred Falls	1	30.21	37.5	453.92
Site-038	038 Moanalua Trail	1	314.4	96.6	105.03
Site-068	068 Waikane Valley	1	35.85	50.4	210.07
Site-078	078 Sand Island	1	0.69	1.0	32.55
Site-090	090 Kaau Crater Trail	1	315.74	92.0	713.35
Site-114	114 Waipio Soccer Complex	1	5.78	31.5	35.87
Site-034	034 Barbers Point Res	2	33.45	5.0	205.56
Site-043	043 Manana Trail 1	2	260.56	90.7	22.13
Site-044	044 Royal Hawaiian Golf	2	122.30	57.8	97.02
Site-054	054 Anchor Church	2	202.05	52.8	1369.65
Site-059	059 Moanalua Red Hill	2	76.12	4.2	2549.10
Site-106	106 Puu Pia Trail	2	404.42	97.3	77.82
Site-113	113 Hauula District Park	2	1.19	2.5	1126.76
Site-024	024 Ft Shafter	3	18.26	1.1	2586.92
Site-036	036 Kroc Center	3	25.95	0.0	355.17
Site-031	031 Plantation Village	4	17.73	4.5	13758.98
Site-058	058 Kailua Heights Res	4	34.51	2.0	6466.12
Site-077	077 Manana Trail 2	4	329.33	97.0	10.19
Site-084	084 Aiea Loop Ridge	4	307.80	89.3	0
Site-102	102 Pearl Harbor	4	2.20	0.4	281.00
Site-050	050 HECO Kahe Point	5	36.43	1.6	565.41
Site-100	100 Heeia State Park	5	0.06	0.3	5.96

REFERENCES

Fiske, I. J. and R. B. Chandler. 2011. Unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. Journal of Statistical Software 43(10): 1-23. doi: 10.18637/jss.v043.i10.

Gorressen, M. P., F. J. Bonaccorso, C. A. Pinzari, C. M. Todd, K. Montoya-Aiona, and K. Brinck. 2013. A Five-Year Study of Hawaiian Hoary Bat (*Lasiurus cinereus Semotus*) Occu Pancy on the Island of Hawai`I. Technical Report HCSU-041. Hawai`i Cooperative Studies Unit. 2 U.S. Geological Survey, Pacific Island Ecosystems Research Center, Kīlauea Field Station. July, 2013. Available online: https://hilo.hawaii.edu/hcsu/documents/TR41_Gorresen_Bat_occupancy.pdf

Hines, J. E., J. D. Nichols, J. A. Royle, D. I. MacKenzie, A. M. Gopalaswamy, N. S. Kumar, and K. U. Karanth. 2010. Tigers on Trails: Occupancy Modeling for Cluster Sampling. Ecological Applications 20(5): 1456-1466.

Hines, J. E., J. D. Nichols, and C. J. A. 2014. Multiseason Occupancy Models for Correlated Replicate Surveys. Methods in Ecology and Evolution 5: 583-591 pp. doi: 10.1111/2041-210X.12186. Available online: https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/2041-210X.12186

LANDFIRE. 2017. Existing Vegetation Type Layer. Landscape Fire and Resource Management Planning Tools Project (LANDFIRE). Department of the Interior (DOI) US Geological Survey (USGS). Last modified February 2017. Information available online at: http://landfire.cr.usgs.gov/viewer/

MacKenzie, D. I. 2006. Modeling the Probability of Resource Use: The Effect of, and Dealing with, Detecting a Species Imperfectly. Journal of Wildlife Management 70(2): 367-374. doi: 10.2193/0022-541x(2006)70[367:mtporu]2.0.co;2.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Academic Press, Elsevier, Burlington, Massachusetts.

Menard, T. 2001. Activity Patterns of the Hawaiian Hoary Bat (*Lasiurus cinereus Semotus*) in Relation to Reproductive Time Periods. MSc Thesis. Univeristy of Hawaii. Available online: https://www.opeapea.org/paper-blog/2019/2/2/Activity%20patterns%20of%20the%20Hawaiian%20hoary%20bat%20(Lasiurus%20cinereus%20semotus)%20in%20relation%20to%20reproductive%20time%20periods.%20MSc%20Thesis,%20University%20of%20Hawaii.

National Geographic Society (National Geographic). 2018. World Maps. Digital topographic map. PDF topographic map quads. Accessed March 8, 2018. Available online: http://www.natgeomaps.com/trail-maps/pdf-quads

National Geographic Society (National Geographic). 2020. World Maps. Digital topographic map. PDF topographic map quads. Accessed January 2020. Available online: http://www.natgeomaps.com/trail-maps/pdf-quads

North American Datum (NAD). 1983. NAD83 Geodetic Datum.

R Development Core Team. 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Information online: http://www.R-project.org/

Stevens, D. L., Jr. and A. R. Olsen. 2003. Variance Estimation for Spatially Balanced Samples of Environmental Resources. Environmetrics 14(6): 593-610 pp. doi: 10.1002/env.606. Available online: https://onlinelibrary.wiley.com/doi/abs/10.1002/env.606

Stevens, D. L., Jr. and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. Journal of the American Statistical Association 99(465): 262-278. doi: 10.1198/016214504000000250.

US Census Bureau. 2019. 2010 Census - Block Maps. Last update: March 14, 2019. Accessed January 2020. Available online: https://www.census.gov/geographies/reference-maps/2010/geo/2010-census-block-maps.html

US Geological Survey (USGS). 2017. USGS National Elevation Dataset (NED). State of North Dakota, State Water Commission. Last updated February 27, 2019. Information online: https://catalog.data.gov/dataset/usgs-national-elevation-dataset-ned

US Geological Survey (USGS). 2019. PRESENCE Version 12.37- Software to Estimate Patch Occupancy and Related Parameters. Accessed January 2020. Information online: https://www.mbr-pwrc.usgs.gov/software/presence.html

Wildlife Acoustics, Inc. 2019. Kaleidoscope Pro® Version 5.1.0. (Acoustic analysis computer software). Wildlife Acoustics, Maynard, Massachusetts. Information online: www.wildlifeacoustics.com

Wright, W. J., K. M. Irvine, and T. J. Rodhouse. 2016. A Goodness-of-Fit Test for Occupancy Models with Correlated within-Season Revisits. Ecology and Evolution 6(15): 5404-5415 pp. doi: 10.1002/ece3.2292. Available online: https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.2292

Appendix A: Output of Final Occupancy Model

```
PRESENCE - Presence/Absence-Site Occupancy data analysis
Wed Jan 15 12:00:25 2020,       Version 2.12.36.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
==>C:\Progra~2\Presence\presence.exe
==>i=hahoba_7_lact14.pao
==>l=pres_psi_th0()_th1()_gam()_eps()_p(Season)_th0pi(PopSqMiClass).out
==>name=psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMiClass)
==>j=hahoba_7_lact14.dm
seed=-1579118425
varcov: nsig=6 eps=1.000000e-002
no model name N,T-->85,144


********* Input Data summary *******
Number of sites               = 85
Number of sampling occasions   = 144
Number of states              = 2
Number of missing observations = 0
NSiteCovs-->7
site_covname[0]="siteID"
site_covname[1]="ElevMn"
site_covname[2]="PctTrees"
site_covname[3]="PopSqMi"
site_covname[4]="ElevClass"
site_covname[5]="PctTreesClass"
site_covname[6]="PopSqMiClass"
NSampCovs-->2
samp_covname[0]=Model
samp_covname[1]=Month
Primary periods=9 Secondary periods: 16 16 16 16 16 16 16 16 16
- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 file=c:\hahoba_2019_presencefiles\y.pao
- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
N=85 T=144 Groups=1 bootstraps=0

-->9-16

Multi-season-Correlated-Detections model -
=============================================

9 Primary periods
  Secondary periods: 16 16 16 16 16 16 16 16 16

Model(1):psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMiClass)

Open Population Model:

Model has been fit using the logistic link.


Number of parameters           = 11
Number of function calls           = 616
-2log(likelihood)              = 2098.2423
AIC                            = 2120.2423
CPU time to compute varcov matrix: 0.0 min.
```

```
Untransformed Estimates of coefficients for covariates (Beta's)
======================================================================
                                          estimate    std.error
A1   psi.a1                          :  -0.214983    0.384849
A2   th0[9-16].a2                    :  -2.711298    0.243383
A3   th1[9-16].a3                    :   1.544664    0.244483
B1   gam(8).b1                       :  -2.767336    0.426924
C1   eps(8).c1                       :  -2.444308    0.524790
D1   P[9-16].d1                      :   0.139175    0.319486
D2   P[6-16].d2                      :  -0.414862    0.202352
D3   P[7-16].d3                      :  -1.098396    0.258398
D4   P[8-16].d4                      :  -0.321290    0.268766
E1   th0pi(9).e1                     :   0.422792    0.534062
E2   th0pi(1)."PopSqMiClass"         :  -1.771050    0.585476

   Individual Site estimates of <psi>
                Site                 estimate  Std.err   95% conf. interval
psi             1 1                :  0.4465   0.0951     0.2750 -  0.6317

   Individual Site estimates of <th0[1-1]>
                Site                 estimate  Std.err   95% conf. interval
th0[1-1]        1 1                :  0.0623   0.0142     0.0396 -  0.0967

   Individual Site estimates of <th1[1-1]>
                Site                 estimate  Std.err   95% conf. interval
th1[1-1]        1 1                :  0.8241   0.0354     0.7437 -  0.8833

   Individual Site estimates of <gam(1)>
                Site                 estimate  Std.err   95% conf. interval
gam(1)          1 1                :  0.0591   0.0237     0.0265 -  0.1267

   Individual Site estimates of <eps(1)>
                Site                 estimate  Std.err   95% conf. interval
eps(1)          1 1                :  0.0799   0.0386     0.0301 -  0.1953

   Individual Site estimates of <P[1-1]>
                Site                 estimate  Std.err   95% conf. interval
P[1-1]          1 1                :  0.5347   0.0795     0.3806 -  0.6825
P[2-1]          1 1                :  0.3977   0.0485     0.3076 -  0.4954
P[3-1]          1 1                :  0.2500   0.0485     0.1673 -  0.3562
P[4-1]          1 1                :  0.4204   0.0655     0.2998 -  0.5512
P[5-1]          1 1                :  0.5347   0.0795     0.3806 -  0.6825
P[6-1]          1 1                :  0.3977   0.0485     0.3076 -  0.4954
P[7-1]          1 1                :  0.2500   0.0485     0.1673 -  0.3562
P[8-1]          1 1                :  0.4204   0.0655     0.2998 -  0.5512
P[9-1]          1 1                :  0.5347   0.0795     0.3806 -  0.6825

   Individual Site estimates of <th0pi(1)>
                Site                 estimate  Std.err   95% conf. interval
th0pi(1)        1 1                :  0.6042   0.1277     0.3489 -  0.8130
th0pi(1)        2 2                :  0.2062   0.0665     0.1048 -  0.3654


 DERIVED parameters
      th0(1) = th0pi*th0 + (1-th0pi)*th1 = Pr(1st segment is used)

        Site                       th0(1)  Std.err     95% conf. interval
th0(1)          1 1                :  0.5226   0.1017     0.3232 - 0.7220
th0(1)          2 2                :  0.2194   0.0516     0.1182 - 0.3205
```

DERIVED parameters - psi2,psi3,psi4,...

	Site			psi(t)	Std.err	95% conf. interval
psi(2)	1	1	:	0.4435	0.0798	0.2872 - 0.5999
psi(3)	1	1	:	0.4410	0.0693	0.3051 - 0.5769
psi(4)	1	1	:	0.4388	0.0635	0.3145 - 0.5632
psi(5)	1	1	:	0.4370	0.0614	0.3167 - 0.5573
psi(6)	1	1	:	0.4354	0.0620	0.3138 - 0.5570
psi(7)	1	1	:	0.4340	0.0644	0.3078 - 0.5601
psi(8)	1	1	:	0.4328	0.0676	0.3004 - 0.5652
psi(9)	1	1	:	0.4317	0.0710	0.2925 - 0.5710

DERIVED parameters - lam2,lam3,lam4,...

	Site			lam(t)	Std.err	95% conf. interval
lam(2)	1	1	:	0.9934	0.0479	0.8995 - 1.0874
lam(3)	1	1	:	0.9943	0.0418	0.9124 - 1.0762
lam(4)	1	1	:	0.9951	0.0364	0.9238 - 1.0664
lam(5)	1	1	:	0.9957	0.0316	0.9338 - 1.0577
lam(6)	1	1	:	0.9963	0.0274	0.9425 - 1.0501
lam(7)	1	1	:	0.9968	0.0238	0.9502 - 1.0435
lam(8)	1	1	:	0.9972	0.0206	0.9568 - 1.0377
lam(9)	1	1	:	0.9976	0.0178	0.9627 - 1.0326

CPU time= 8 seconds (0.13 min)

PRESENCE - Presence/Absence-Site Occupancy data analysis
Wed Jan 15 12:00:25 2020,   Version 2.12.36.
- -