Auwahi **Wind**

September 1, 2020

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Via Email

SUBJECT: Auwahi Wind Farm Project Habitat Conservation Plan FY 2020 (Year 8) Annual Report

Dear Ms. Frager and Ms. Taylor:

Please find the attached annual report for the Auwahi Wind Farm Project Habitat Conservation Plan (HCP), prepared in compliance with the conditions of U.S. Fish and Wildlife Service Incidental Take Permit (ITP) TE64153A-1 and Department of Land and Natural Resources Incidental Take License (ITL) ITL-17. This annual report covers monitoring and mitigation activities conducted from July 1, 2019 through June 30, 2020. The report identifies each HCP requirement and ITP and ITL condition completed, ongoing requirements and conditions, compliance status, and basis for determining compliance. Also, in compliance with HCP monitoring requirements, a post-construction mortality monitoring update is included.

Should you have any questions on this annual report, please feel free to contact me at (808) 876-4100 or via email at gjakau@aepes.com.

Sincerely,

George Akau
Project Biologist/Auwahi Wind Farm

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Auwahi Wind Farm Habitat Conservation Plan FY 2020 Annual Report

Incidental Take Permit TE64153A-1/ Incidental Take License ITL-17

Submitted To:

AEP Renewables
Auwahi Wind

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September 1, 2020

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Acronyms and Abbreviations

Auwahi Wind	Auwahi Wind Energy, LLC
CPT	carcass persistence trial
DKIST	Daniel K. Inouye Solar Telescope
DLNR	Hawai‘i Department of land and Natural Resources
DOFAW	DLNR Division of Forestry and Wildlife
EoA	Evidence of Absence
ESRC	Endangered Species Recovery Committee
FY	Fiscal Year
HCP	Habitat Conservation Plan
ITL	incidental take license
ITP	incidental take permit
Kahikinui PMA	Kahikinui Petrel Management Area
LWSC	low-wind speed curtailment
m/s	meters per second
MBTA	Migratory Bird Treaty Act
met	meteorological
MNSRP	Maui Nui Seabird Recovery Project
NPS	National Park Service
PCMM	post-construction mortality monitoring
PMA	Petrel Management Area
Project	21-megawatt Auwahi Wind Farm Project
SEEF	searcher efficiency
Tetra Tech	Tetra Tech, Inc.
UAD	Ultrasonic Acoustic Deterrent
USFWS	U.S. Fish and Wildlife Service
UAD	ultrasonic acoustic deterrent
USGS	U.S. Geological Survey

1.0 Introduction

In January 2012, Auwahi Wind Energy, LLC (Auwahi Wind) finalized a Habitat Conservation Plan (HCP) for the construction and operation of the 21-megawatt Auwahi Wind Farm Project (Project) in east Maui, Hawai'i (Tetra Tech 2012a). The 2012 HCP was developed to obtain incidental take permit (ITP) number TE64153A-0 from the U.S. Fish and Wildlife Service (USFWS), and incidental take license (ITL) number ITL-17 from the Hawai'i Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW), both of which authorize incidental take for the Hawaiian petrel (*Pterodroma sandwichensis*), Hawaiian goose (*Branta sandvicensis*), Hawaiian hoary bat (*Lasiurus cinereus semotus*), and Blackburn's sphinx moth (*Manduca blackburni*), collectively referred to herein as the Covered Species. DOFAW issued the ITL on February 9, 2012, and USFWS issued the ITP on February 24, 2012, each with a term of 25 years.

The Project observed a higher than expected take of the Hawaiian hoary bat at its facility in the first 2 years of operations. On February 25, 2015, Auwahi Wind met with USFWS and DOFAW to discuss its pursuit of a major amendment to the ITP and ITL, respectively. In FY 2020, Auwahi Wind was actively engaged with USFWS, DOFAW, the Endangered Species Recovery Committee (ESRC), and the Board of Land and Natural Resources to finalize a Major Amendment to the Auwahi Wind HCP. The HCP Amendment was limited exclusively to address take of the federally and state-listed Hawaiian hoary bat, incidental to activities associated with the operation, maintenance, and decommissioning of the Project. USFWS and the Board of Land and Natural Resources approved the HCP Amendment (Tetra Tech 2019), and amended ITP (TE64153A-1) and ITL (ITL-17 amended August 23, 2019) permits have been issued; USFWS issued the ITP on September 4, 2019, and DOFAW issued the ITL on August 23, 2019. Hereafter, the 2012 HCP and HCP Amendment are referred to as the HCP.

This report provides a summary of monitoring and mitigation activities that have occurred during Fiscal Year (FY) 2020 (from July 1, 2019 to June 30, 2020). The following subsections provide an overview of post-construction mortality monitoring (PCMM) and mitigation activities, address other required annual reporting items as identified in the HCP, review an annual work plan for the upcoming year, and detail annual cost expenditures as required under the ITP and ITL.

2.0 Post-Construction Mortality Monitoring

The HCP includes a detailed description of the monitoring protocol. In FY 2020, standardized carcass searches were performed around all eight turbines and the meteorological (met) tower weekly using a canine search team. Bias trials consisting of carcass persistence trials (CPT), and searcher efficiency (SEEF) trials were conducted during the course of FY 2020. A summary of the search area and frequency of searches performed for FY 2020 is provided in Table 2-1. Results of PCMM in Sections 2.1 and 2.3 are presented for FY 2020 and not the period of take analysis presented in Section 2.4. Take analysis (Section 2.4) is based on a calendar year except when changes to the search protocol were incorporated, as discussed in Section 2.1.

Other permits also required for compliance include a Migratory Bird Special Purpose Utility permit (Permit No. MB92518A-0) for handling migratory bird carcasses reissued by USFWS on April 1, 2018; and a State Protected Wildlife Permit (Permit No. WL17-08) for handling native bird and bat carcasses reissued by DOFAW on April 6, 2018.

Table 2-1. PCMM Search Effort at the Project, FY 2020.

Study Metrics for Fatality Estimates	
Variable	**Systematic (July 2019 – June 2020)**
Total number of Project turbines	8
Number of turbines searched	8
Sample search plot size	Pads and roads within 100-meter radius of turbine
Met tower search plot size	10 meters around the base of the met tower
Search interval	7 days (July 2019 – June 2020)

2.1 Fatality Monitoring

2.1.1 Systematic Carcass Searches

Systematic searches were conducted weekly by the canine search team along all pads and roads within a 100-meter radius of turbines and within 10 meters of the met tower July 1, 2019 – June 30, 2020. Searches were restricted to pads and roads, where regularly scheduled vegetation management improves the detectability of trial carcasses and decreases the risk of searcher injuries. The search area size and configuration varied among turbine pads based on the shape of the pads and roads. Based on carcass fall distributions compiled by Tetra Tech, Inc. (Tetra Tech) from 25 publicly available studies, the areas searched at the Project represented a total of 54 percent of the large-bird fall distribution and 77 percent of the bat fall distribution, which are consistent with results based on a theoretical carcass distribution model (Hull and Muir 2010).

2.1.2 Detections Outside of Designated Searches and Searched Areas

Project staff, contractors, and ranch personnel with access to the Project may detect downed wildlife in the course of their regular activities. Such detections are evaluated according to the USFWS protocol for incidental detections (USFWS 2018) to determine if inclusion in fatality estimates are appropriate with considerations regarding the location of the recovered animal relative to the search area, the timing of the discovery relative to the next search, and the likelihood of detection based on estimates of carcass persistence time from Project-specific bias correction trials.

Table 2-2. Search Interval Between Standardized Carcass Searches at The Auwahi Wind Project, FY 2020.

Month	Search Interval (days)[1]
July	7
August	7
September	7
October	7
November	7
December	7
January	7
February	7
March	7
April	7
May	7
June	7

[1] Includes all operational turbines and met tower

2.2 Downed Wildlife Observations

Twenty-one fatalities were documented and reported in FY 2020; 17 of these fatalities were documented during standardized carcass searches (Table 2-3). Five of the recorded fatalities were Migratory Bird Treaty Act (MBTA) species, including an unidentified storm-petrel. Eight of the recorded fatalities were Covered Species—all Hawaiian hoary bats (*Lasiurus cinereus semotus*). Three of the eight bat fatalities were found incidentally outside of the search area. Additionally, one Hawaiian hoary bat was found injured and was successfully recovered, rehabilitated, and released back into the wild (Table 2-4). The unidentified storm-petrel is believed to be a band-rumped storm-petrel (*Oceanodroma castro*) (pers. comm. J. Penniman, July 10, 2020) and is awaiting genetic lab results for confirmation of species identification (Section 3).

Table 2-3. Documented Fatalities at the Project in FY 2020.

Species	Legal Status	Found Date	Location (Turbine)	Type of Detection	Outside Search Area	Outside Scheduled Search
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	7/8/2019	7	Carcass Survey		
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	9/2/2019	3	Carcass Survey		
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	9/9/2019	1	Incidental Finding	X	
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	9/16/2019	2	Incidental Finding	X	
African Silverbill (*Euodice cantans*)	None	9/16/2019	8	Carcass Survey		
Great Frigatebird (*Fregata minor*)	MBTA	9/20/2019	1	Incidental Finding		X
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	9/30/2019	1	Carcass Survey		
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	9/30/2019	6	Incidental Finding	X	
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	10/7/2019	6	Carcass Survey		
Black Francolin (*Francolinus francolinus*)	None	11/11/2019	3	Carcass Survey		
Spotted Dove (*Spilopelia chinensis)*	None	11/11/2019	5	Carcass Survey		
Black Francolin (*Francolinus francolinus*)	None	11/18/2019	5	Carcass Survey		
African Silverbill (*Euodice cantans*)	None	12/9/2019	2	Carcass Survey		
White-tailed Tropicbird (*Phaethon aethereus*)	MBTA	12/30/2019	1	Carcass Survey		
Gray Francolin (*Francolinus pondicerianus*)	None	2/17/2020	8	Carcass Survey		
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	3/30/2020	6	Carcass Survey		
Black Francolin (*Francolinus francolinus*)	None	4/6/2020	4	Carcass Survey		
Black Francolin (*Francolinus francolinus*)	None	4/6/2020	7	Carcass Survey		
Bulwer's Petrel (*Bulweria bulwerii*)	MBTA	6/8/2020	7	Carcass Survey		
Barn Owl (*Tyto alba*)	MBTA	6/15/2020	1	Carcass Survey		
Unidentified Storm-Petrel	TBD	6/15/2020	2	Carcass Survey		

FE = Federally endangered, SE= State endangered, MBTA=Protected under the Migratory Bird Treaty Act, TBD=To be determined

Table 2-4. Documented Injuries at the Project, Including Threatened and Endangered or Migratory Bird Treaty Act (MBTA) in FY 2020.

Species	Legal Status	Found Date	Location (Turbine)	Type of Detection	Outside Search Area	Outside Scheduled Search
Hawaiian Hoary Bat *(Lasiurus cinereus semotus)*	FE, SE	8/12/2019	8	Carcass Survey		

FE = Federally endangered, SE= State endangered

2.3 Carcass Persistence Trials

Fifty-four CPTs were conducted during FY 2020 and are summarized by carcass size class in Table 2-5. The objective of these trials is to assess the likelihood that carcasses persist to the next search at the Project. Species used for CPTs include cattle egret (*Bubulcus ibis*), rock pigeon (*Columbia livia*), black francolin (*Francolinus francolinus*), and gray francolin (*Francolinus pondicerianus*) as surrogates for HCP-covered bird species trials; medium sized black rats (*Rattus rattus*) and one mouse (*Mus musculus*) were used as surrogates for bats.

Carcasses were placed at randomly generated points on turbine pads and roads within search plots. Carcasses were checked a minimum of twice per week in FY 2020 (every Monday during systematic searches and one additional check weekly), until they were no longer detectable or the trial period was complete. Trial periods were for 28 days, and some carcasses were left out to monitor persistence past the trial period (maximum 65 days). Changes in carcass condition were tracked and documented with photos. A detailed description of field methods is included in Attachment 1 of the 2013 HCP annual report (Tetra Tech 2013). Estimates of carcass probability and 95 percent confidence intervals for each carcass category were calculated using the single class module of Evidence of Absence software (EoA; Dalthorp et al. 2017). CPT results from all years (FY 2014 to FY 2020) have resulted in probabilities of carcass persistence until the next search between 0.96 and 1.00.

Auwahi Wind has continually implemented scavenger control on site since the fall of 2013. The probability that a bat carcass would persist until the next search increased from 0.746 in FY 2019 to 0.974 in FY 2020 (Table 2-5). This is most likely due to the increased scavenger trapping efforts at the Project. Beginning in FY 2019, foothold traps were placed throughout the site to target cats. The success of scavenger trapping efforts at the Project likely also contributed to the rescue of an injured bat within the search area, which may otherwise have been depredated. All large birds persisted through the entire trial period, resulting in a very high probability of persistence until the next search in FY 2020, similar to large bird results in other years of operation.

Table 2-5. Carcass Persistence Estimates for Systematic Searches at The Auwahi Wind Project, FY 2020.

Carcass Size Class	N	Probability of Carcass Persistence until Next Search	95 Percent Confidence Interval	Search Interval
Bats	41	0.974	[0.936, 0.894]	7
Large Birds	13	1	[0.984, 1]	7

2.4 Searcher Efficiency

Seventy-two SEEF trials were conducted during FY 2020 (Table 2-6). The objective of these trials was to assess the effectiveness of the canine search team in finding downed wildlife. Each trial was conducted by the Project biologist or environmental technician (tester) on site. The canine search team had no prior knowledge of the trials; every fatality search day was treated as if it had the potential to be a SEEF trial day. During FY 2020, 57 SEEF trials were performed for bats and 15 trials were performed for large birds. Species used for SEEF trials include cattle egret, rock pigeon, black francolin, and gray francolin as surrogates for HCP-covered bird species trials; medium-sized black rats, and one mouse was used as surrogates for bats.

SEEF carcasses were placed at randomly generated points on turbine pads and roads within search plots. Carcasses found during SEEF trials remained at their placed location and were then monitored for carcass persistence. All trials were found in FY 2020. Estimates of searcher efficiency and 95 percent confidence intervals for each carcass category were calculated using the single class module of EoA (Dalthorp et al. 2017). Searcher efficiency was 100 percent for both large birds and bats.

Table 2-6. SEEF Estimates for Systematic Searches at The Auwahi Wind Project, FY 2020.

Carcass Size Class	Search Method	Number Placed	Number Found	Average Searcher Efficiency	95 Percent Confidence Interval	Overall Average Searcher Efficiency
Bats	Canine	57	57	1	[0.957, 1]	1
Large birds	Canine	15	15	1	[0.848, 1]	1

2.5 Take

2.5.1 Direct Take

To ensure an accurate measurement of take and verify compliance under the ITL and ITP, observed fatalities, the results of bias correction trials (SEEF and CPT), the search interval, and the proportion of the carcass distribution searched are used to estimate unobserved take. During the 7.5 years of monitoring at the Project (January 2013-June 2020), 32 Hawaiian hoary bats and 2 Hawaiian petrels have been found. To account for unobserved fatalities, EoA is used for calculating fatality rates. EoA software was developed to provide an estimate of the probability, with a user-defined level of credibility, that the number of fatalities has not exceeded a given threshold. An 80-percent credibility level has been required by USWS and DOFAW to assess compliance with an ITP and ITL and provides a high level of confidence that actual take would not exceed the estimated take.

Auwahi Wind used the EoA software and ran the model with PCMM data collected over the past 7.5 years for the Hawaiian hoary bat and Hawaiian petrel (Table 2-7). Because the fiscal year does not coincide with Project's operational year, the observed fatalities, carcass persistence, searcher efficiency, and detection bias values in Table 2-7 represent values for calendar years, with the period from January 1, 2020 through June 30, 2020 representing 2020 (Year 8). Therefore, values differ from those reported for the full FY 2020 in the sections above. We estimated an upper limit for potential Project direct take using an 80-percent credibility level for Hawaiian hoary bats and the Hawaiian petrel (Attachment 1).

Table 2-7. Summary of PCMM Data at the Auwahi Wind Project, From the Start of the Project Through June 2020 (FY 2013 - FY 2020).

Calendar Year	Curtailment (5 m/s)	Curtailment (6.9 m/s)[6]	Species	Number of Fatalities Detected	Proportion of Carcass Distribution Searched	Average Search Interval (days)	Probability of Persistence	Average Searcher Efficiency	Detection Bias[1]	Cumulative Direct Take Estimate[3]	Cumulative Indirect Take Estimate (Adult Equivalent)[4]
2013	No	No	Hawaiian Hoary bat	1	0.97	9	0.44	0.57	0.28	8	1 (0.47)
2014	No	No		4	0.94	5	0.75	0.52	0.55	16	1 (0.74)
2015	Yes	No		1	0.76	3	0.73	0.68	0.45	18	1 (0.74)
2016	Yes	No		7	0.76	3	0.76	0.76	0.55	34	4 (3.03)
2017[2]	Yes	No		3	0.76	3-4	0.879	0.667	0.60	39	5 (4.25)
2018	Yes	No		1	0.76	4-7	0.768	1	0.52	41	5 (4.25)
2019	Yes	Yes		7	0.77	7	0.93	1	0.72	52	6 (5.05)
2020[5]	Yes	Yes		1	0.77	7	0.95	1	0.72	52	6 (5.05)
Calendar Year	**Curtailment (5 m/s)**	**Curtailment (6.9 m/s)[6]**	**Species**	**Number of Fatalities Detected**	**Proportion of Carcass Distribution Searched**	**Average Search Interval (days)**	**Probability of Persistence**	**Average Searcher Efficiency**	**Detection Bias[1]**	**Cumulative Direct Take Estimate[3]**	**Cumulative Indirect Take Estimate (Juvenile)[7]**
2013	No	No	Hawaiian Petrel	0	0.91	9	0.79	0.74	0.67	0	0
2014	No	No		1	0.91	5	0.98	0.75	0.84	2	1 (0.63)
2015	Yes	No		0	0.56	3	0.993	0.89	0.55	2	1 (0.63)
2016	Yes	No		0	0.56	3	0.96	0.96	0.48	3	1 (0.63)
2017	Yes	No		0	0.56	3-4	0.99	0.96	0.55	3	1 (0.63)
2018	Yes	No		0	0.56	4-7	0.99	1	0.55	3	2(1.26)
2019	Yes	Yes		0	0.54	7	0.99	1	0.55	3	2(1.26)
2020[5]	Yes	Yes		0	0.54	7	1	1	0.55	3	2(1.26)

1. Detection bias calculated using Evidence of Absence (EoA) software (Dalthorp et al. 2017).
2. Detection bias calculated using pooled data with custom search interval in single class module from EoA software.
3. Calculation of direct take based on EoA for search periods (see Attachment 1).
4. Calculation of indirect take based on USFWS guidance on the calculation of indirect take 2016. Take estimate subjects to change pending genetic analysis of observed fatalities. Calculations based on calendar years. The actual value is presented in parentheses and the value rounded up to the nearest whole number is presented first.
5. Calendar year 2020 includes the dates from January 1 through June 30.
6. 6.9 m/s curtailment from August 1 – November 1.
7. Calculation of indirect take based on calculations in the HCP. Calculations based on calendar years. The actual value is presented in parentheses and the value rounded up to the nearest whole number is presented first.

Hawaiian Hoary Bat

Based on the 25 bat fatalities detected during 7.5 years of PCMM and 7 incidental carcasses found, it can be asserted with 80 percent certainty that the number of direct take ranged from 32 to 52. Auwahi Wind is 80 percent certain that no more than 52 direct Hawaiian hoary bat take have occurred. Based on results from the EoA, up to 20 undetected bat fatalities may also have occurred.

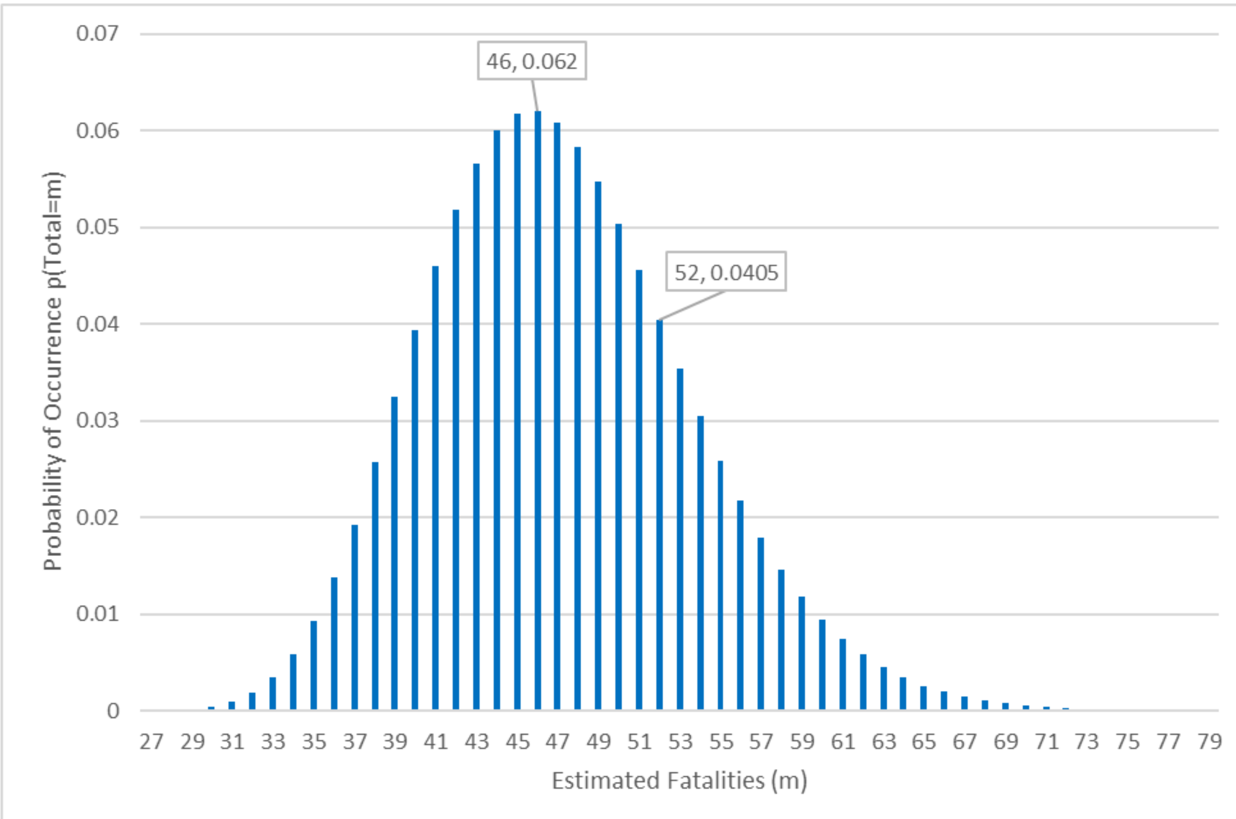

Figure 1. Posterior Probability Distribution for Hawaiian Hoary Bats Using the Evidence of Absence Software (Dalthorp et al. 2017).

On August 12, 2019, Auwahi Wind found a live male bat on the ground during a PCMM search; the injury is assumed to have been the result of wind farm operation. The injured bat was rehabilitated and released alive and in healthy condition on October 6, 2019. As determined in consultation with USFWS and DOFAW (November 20, 2019), this bat is not included in the EoA fatality estimates of take.

Hawaiian Petrel

Based on the one Hawaiian petrel fatality detected during 7.5 years of surveys and one incidental carcass detected in 2018, it can be asserted with 80 percent certainty that the number of direct take ranged between two and three. Auwahi Wind is 80 percent certain that no more than three direct Hawaiian petrel take have occurred.

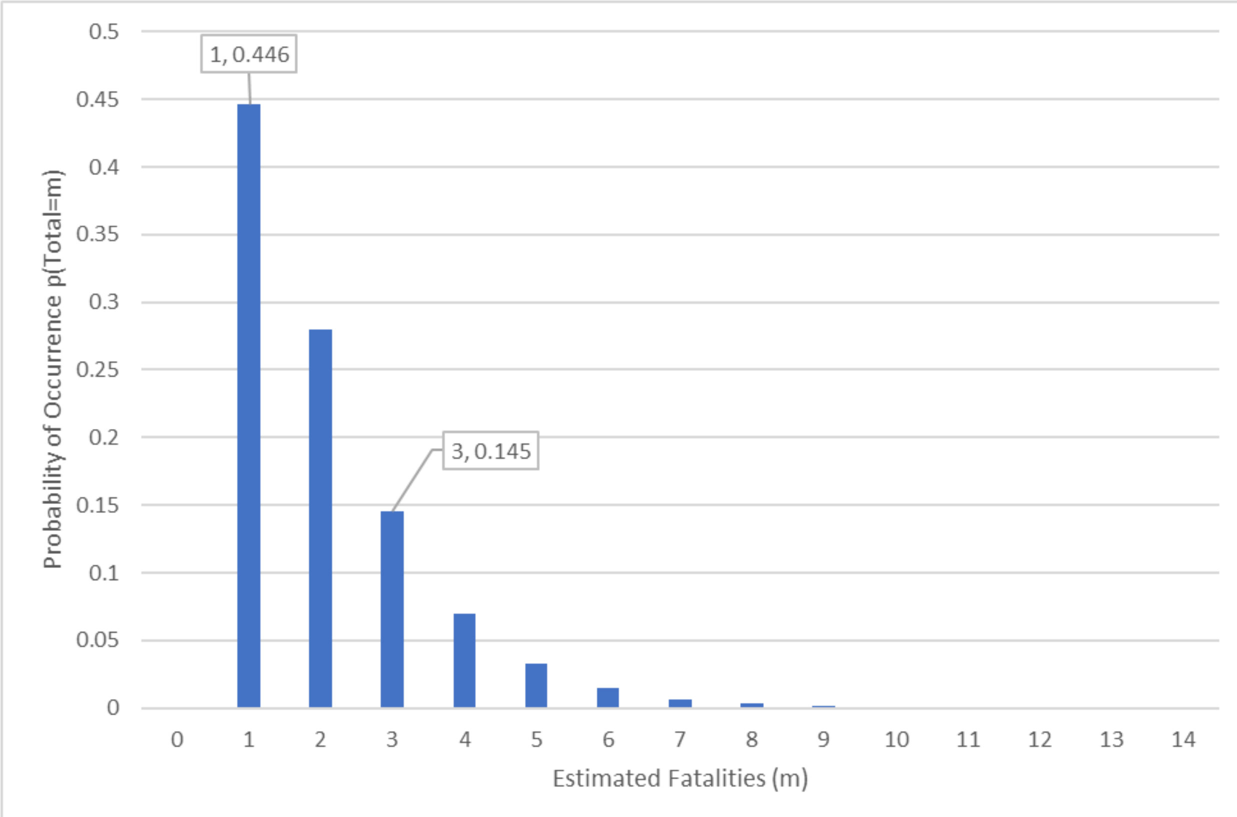

Figure 2. Posterior Probability Distribution for Hawaiian Petrels Using the Evidence of Absence Software (Dalthorp Et al. 2017).

2.5.2 Indirect Take

It is assumed that take of an adult bird or bat during the breeding season may result in the indirect loss of a dependent young. Thus, for every petrel or bat carcass detected during the breeding season, modifiers are applied to estimate indirect take to account for the likelihood that a given adult is reproductively active, the likelihood that the loss of a reproductively active adult results in the loss of its young, and average reproductive success (Tetra Tech 2012a, Section 5.2).

Hawaiian Hoary Bat

The USFWS provided guidance for a standardized process for estimating direct and indirect observed take in the absence of verified sex information (October 2016) This report utilizes the USFWS methodology but also incorporates the results of genetic testing at Auwahi Wind (Pinzari and Bonaccorso 2018, version 4.0 April 2020).The calculation of indirect take differs from the calculation of direct take in that all observed fatalities (both those observed during PCMM and incidental to PCMM) are used to determine indirect Project impacts, because the timing and sex of observed fatalities is known. An estimate of indirect take for FY 2020 calculated as:

Total observed female take assumed to have dependent young (April 1 – September 15)

- 7 (female bats observed in the breeding season) * 1.8 (pups per female) = 12.6 juvenile bats based on observed take

Total observed take of unknown sex assumed to have dependent young (April 1 – September 15)

- 0 (take during breeding season) * 0.47 (sex ratio observed at Auwahi) * 1.8 (pups per female) = 0 juveniles based on observed take

Total unobserved take of unknown sex assumed to have dependent young (April 1 – September 15)

- (52 [80 percent upper credible limit] – 25 [observed direct take]) * 0.47 (sex ratio observed at Auwahi[1]) * 0.25 (proportion of calendar year females could be pregnant or have dependent pups) * 1.8 (pups per female) = 5.71 juveniles based on unobserved direct take

Total Interim Estimate of Juvenile Indirect Take = 18.31 (12.6 + 0 + 5.71)

- Total adult equivalents = 6 (18.31 * 0.3 rounded up to the nearest whole number)
- Total take estimate = 58 (52 direct + 6 indirect)

Hawaiian Petrel

Two Hawaiian petrel fatalities have been observed within the breeding season (May 1 through September 30) at the Project. The one Hawaiian petrel observed on site during systematic monitoring was found in 2014. One Hawaiian petrel was observed incidentally (outside of the search plot) in 2018. Based on results from the EoA, up to 1 additional petrel fatality may have occurred and been undetected. The detection of an adult Hawaiian petrel recorded during the breeding season is assumed to result in the loss of one chick (Tetra Tech 2012a). The average reproductive success for petrels on Maui was previously measured at 63 percent (Simons and Hodges 1998). The final assessment of indirect take at the end of the permit term will round up to the nearest whole number.

Total observed take assumed to have dependent young (May 1 – September 30)

- 2 (individuals observed in the breeding season) * 0.63 (average reproductive success) = 1.26 chicks based on observed take

Total Interim Take Estimate

- Total adult equivalents from indirect take = 1 (1.26 chicks * 0.3 surviving to adulthood rounded up to the nearest whole number)
- Total take estimate = 4 adults (3 direct + 1 indirect)

2.6 Take Projection and Estimated Fatality Rates for Hawaiian Hoary Bat

Auwahi Wind used EoA to project the direct take estimate for the Hawaiian hoary bat for the remainder of the permit term. The direct take estimate does not account for indirect take, which is based on agency guidance, and the timing and gender of observed fatalities. The direct take projection also incorporates substantial uncertainty and therefore likely overestimates take for future years. The take authorization is based on a direct take estimate of 129 bats. The median take projection (as calculated using EoA) is estimated as 129 bats (interquartile range: 116 to 143 bats) in the last year of expected operations, 2032.

1 At Auwahi Wind 47 percent of observed fatalities (n=32) are female based on a genetic determination of gender (Pinzari and Bonaccorso 2018, version 4.0 April 2020); this percentage is used to estimate unobserved or unknown gender bat fatalities.

Table 2-8. EoA Estimated Hawaiian Hoary Bat Baseline Fatality Rate.

Source	Metric	Value
Value calculated from EoA analysis of PCMM data	Baseline Fatality Rate[1]	6.35
Comparison values from the HCP	Threshold Value	6.45
	Average take rate to remain within Tier 4	4.05
	Average take rate to remain within Tier 5	5.75

1. Any estimated Baseline Fatality Rate partially through the sampling year may skew results by estimating bias correction trial results with smaller data sets than would be available after a full year of study.

The estimated Baseline Fatality Rate calculated by EoA is 6.35 (95 percent confidence interval, 4.12 to 9.07), which currently does not exceed the Threshold Value of 6.45, as specified in the HCP. Since the Baseline Fatality Rate exceeded the Threshold Value at the scheduled evaluation in February 2020, the Project has implemented its Adaptive Management Plan (Attachment 2).

2.7 Wildlife Education and Incidental Reporting

Auwahi Wind continues to implement a wildlife education and incidental reporting program for contractors, Project staff members, and ʻUlupalakua Ranch staff who are on site regularly. Annual training enables staff to identify the Covered Species that may occur in the Project area, record observations of these species, and take appropriate steps for documenting and reporting any species encountered during the operation of the Project. Auwahi Wind trained 67 contractors and new staff in FY 2020. The wildlife education program has expanded over the past year to include visits by educational groups, summer internships, and outreach events within the community.

2.8 Avoidance and Minimization

Avoidance and minimization measures outlined in the HCP continue to be implemented in FY 2020. Actions taken for avoidance and minimization measures for Hawaiian hoary bat and Blackburn's sphinx moth are described below.

2.8.1 Hawaiian hoary bat

Auwahi Wind continues to implement low-wind speed curtailment (LWSC) at cut in speeds of 5 meters per second (m/s) from November through July. August through October, LWSC cut-in speeds are increased to 6.9 m/s. For all periods, LWSC is implemented from 30 minutes before sunset to 30 minutes after sunrise.

In addition to LWSC, Auwahi Wind installed NRG ultrasonic acoustic deterrents (UAD) at all Project turbines in June of 2020. UADs operate from 1 hour before sunset until 1 hour after sunrise, year-round.

2.8.2 Blackburn's Sphinx Moth

Areas within 10 meters of roadsides and edges of turbine pads are targeted for tree tobacco (*Nicotiana glauca*) removal because they may present a hazard for the moth due to exposure to dust, possible trampling, and increased chance of collisions with vehicles (USFWS and DOFAW email instructions Feb 7, 2014). Through continued maintenance on-site, there has been a decrease in plants within hazard areas. During FY 2020, 11 plants were removed from the Project with most plants observed to be in the immature vegetative state. The removal of the plants followed USFWS guidance for avoidance and minimization (USFWS 2020). Auwahi continued monthly field surveys for Blackburn's Sphinx Moth (BSM) in FY 2020. The presence of BSM was not detected during any monthly surveys, and no BSM were translocated in FY 2020.

3.0 Mitigation

3.1 Hawaiian Petrel Mitigation

Beginning in August 2013, Auwahi Wind implemented a predator control strategy within Kahikinui Petrel Management Area (Kahikinui PMA). This strategy includes predator assessments using tracking tunnels, grid spaced traps targeting areas within a 200-meter buffer of Hawaiian petrel nesting burrows, and deployment of game cameras to monitor for Hawaiian petrel and predator activity. Results of the 2020 breeding season and predator control will be included and summarized in the FY 2021 HCP annual report.

3.1.1 Petrel Burrow Monitoring

Petrel burrows within Kahikinui PMA continued to be monitored during the 2019 breeding season to obtain an estimate of the number of active petrel burrows and reproductive (fledging) success. Four new burrows were located in 2019. In the 2019 breeding season, 76 petrel burrows were monitored, 39 showed signs of activity sometime during the breeding season, and 28 burrows were consistently active through the breeding season. By the end of the breeding season, nine burrows had successfully fledged a chick. The number of burrows known to have fledged a chick per number of active burrows within the management area ranged between 32 and 82 percent.

3.1.2 Predator Control

Auwahi Wind continued to implement predator control and monitoring in FY 2020. The 1-day tracking index was 6.4 percent for rodents in early February. The tracking tunnel index for rodents was 7.5 percent (14 of 187) in August. No mongoose were detected along any of the transects in February or August, with the 3-day tracking index of zero percent. The predator control grid was operational year-round in 2019. Predator control efforts removed 109 targeted mammalian predators from Kahikinui PMA. All traps were checked and baited every 2 weeks in FY 2020. Trapping continued past November, after the chicks fledged, till the start of the following nesting season, when Hawaiian petrel adults started returning in February. All trapping continued past the last fledgling dates in 2019, and trapping will continue year-round for future years. In past years of managing Kahikinui PMA, the trapping grid was suspended while Hawaiian petrels were away from the nesting area (December – February). Auwahi Wind implemented year-round trapping to further reduce risk of predation; results of this effort will be monitored.

3.1.3 Benefits

Auwahi Wind has measured reproductive success of Hawaiian petrels and predator activity within Kahikinui PMA for the past 7 years. Auwahi Wind describes the rationale for adaptive management and proposed net benefit calculations in the adaptive management section of the 2019 report (Attachment 3). The measures of success and the implementation status are listed in Table 3-1.

Table 3-1. Hawaiian Petrel Mitigation Measures of Success and Implementation Status.

Measures of Success	Implementation Status
Predator control is implemented.	Ongoing
Predator control methods are successful in capturing predators.	Ongoing
Mitigation efforts result in one more fledgling or adult than that required to compensate for the requested take of the required tier.	See discussion of Adaptive Management in Section 4.3 and detailed in Attachment 3.

3.2 Hawaiian Hoary Bat Mitigation and Monitoring

Implementation of Tier 1 bat mitigation is on-going at the Waihou Mitigation Area, located on ʻUlupalakua Ranch. Tier 1 mitigation consists of the restoration of native forest on approximately 53 hectares of pastureland in the Waihou Mitigation Area, specifically the Puʻu Makua parcel (including installation of an ungulate proof fence, ungulate removal, and native reforestation). This parcel was placed into a conservation easement held by the Hawaiian Islands Land Trust on December 18, 2012, and will be protected in perpetuity. Tier 2 mitigation consists of funding Hawaiian hoary bat research to contribute to the overall knowledge of the Hawaiian hoary bat on Maui. Tier 3 mitigation expands on the bat research approved for Tier 2. Within the approved Auwahi HCP Amendment, Tier 4 mitigation focuses on protecting, managing, and enhancing habitat that is suitable for bat foraging and roosting on a 709-hectare parcel within ranch land. All tiers of mitigation are funded and are being implemented in accordance with mitigation plans approved by USFWS and DOFAW.

3.2.1 Tier 1 Mitigation

Auwahi Wind is in its sixth year of habitat restoration efforts at Pu'u Makua mitigation site. The habitat restoration included ungulate fence installation, ungulate removal, invasive plant species removal, and plantings of native trees and shrubs. The ungulate fence, installed in 2013, is in good condition. The 2.4-meter tall ungulate exclusion fence surrounding the parcel was inspected quarterly in FY 2020, and the parcel remains ungulate-free. Follow-up management within the plots continued in FY 2020 and included target invasive plant species removal.

Management

In January 2020, Auwahi Wind continued vegetation monitoring (Year 5 of monitoring with baseline conditions established in 2014 and 2015), with the objectives of assessing the effectiveness of invasive species removal and out-planting management activities. The follow-up survey used the same methods as the original baseline monitoring (Sempra Energy 2014). The interim target for native woody vegetation cover was set at 15 percent, and the interim target for non-native plant cover was set at less than 65 percent. For FY 2020 (Year 5), monitoring of percent vegetative cover along three transects showed an overall percent cover of native woody vegetation of 27.7 percent, and non-native vegetation of 23.9 percent. Auwahi Wind has exceeded interim success criteria for Year 5 (FY 2020) and is on its way to meet success criteria for the permit.

Bat habitat enhancements and additional work has continued at Pu'u Makua; supplemental outplanting of native Hawaiian plants and the addition of blackberry (*Rubus argutus*) to the list of target invasive species to control within the management unit. Koa (*Acacia koa*) has proven to be the fastest native Hawaiian tree species to establish in this area of Ulupalakua Ranch.

Benefits

The measures of success as defined in the HCP and current status of each measure of success are presented below in Table 3-2.

Table 3-2. Hawaiian Hoary Bat Tier 1 Measures of Success and Implementation Status.

Measures of Success	Implementation Status
After 6 years, mitigation fencing is completed and ungulates have been removed from within the fenced area.	Completed in FY 2014
Over the 25-year permit term, the fence is maintained and the area is kept free of ungulates.	Ongoing. Fence inspections continued in FY 2020. Pu'u Makua continues to be free of ungulates in FY 2020.
After 25 years, the cover of invasive species (excluding kikuyu grass) in the managed areas is less than 50 percent.	Ongoing. Invasive species are below 50 percent in FY 2020.
After 25 years, reforested areas within the Waihou mitigation area have greater than 50 percent cover dominated by native woody species.	Ongoing.

3.2.2 Tier 2 and 3 Mitigation

Auwahi Wind worked with Tetra Tech and Dr. Frank Bonaccorso from the U.S. Geological Survey (USGS) to develop a research project combining radio telemetry and acoustic monitoring. The goal of this study is to contribute to the knowledge of the Hawaiian hoary bat on Maui and track the success of restoration efforts in the Waihou Mitigation Area. In FY 2020, Tier 2/3 mitigation was completed and the final report was presented at the ESRC bat workshop. Information from this study suggest foraging, roosting, and reproduction are all occurring at the mitigation site (Pinzari et al. 2019). At the end of the field work, Auwahi Wind donated telemetry equipment to USGS for future Hawaiian hoary bat research. The measures of success as defined in the HCP and current status of each measure of success are presented below in Table 3-3.

Table 3-3. Hawaiian Hoary Bat Tier 2 and Tier 3 Measures of Success and Implementation Status.

Measures of Success	Implementation Status
The bat research plan is finalized and the study is initiated within 2 years of the issuance of the ITP and ITL.	Completed in FY 2019
Radio-transmitter monitoring (or other measures as appropriate) is conducted in three separate years to detect changes in bat use and home range core area size as the site is restored.	Results subject to adaptive management. Results published in FY 2019

3.2.3 Tier 4 Mitigation

Tier 4 Mitigation is also located on 709 hectares (1752 acres) of 'Ulupalakua Ranch land. The objective of the Tier 4 Mitigation is to protect, manage, and enhance habitat that is suitable for bat foraging and roosting through the addition of features necessary for those stages of the Hawaiian hoary bat life cycle. These features include hedgerows, ponds, and watering troughs.

Auwahi Wind provided a Letter of Credit in the amount of $200,000 on January 9, 2020, to ensure mitigation occurred. The 709 hectares of ranch land has been identified to be placed in a conservation easement held by the Hawaiian Islands Land Trust. The draft of the conservation easement was provided to USFWS and DOFAW on October 4, 2019. The final conservation easement is expected to be executed by September 4, 2020. In addition, Auwahi Wind formalized contracts and agreements with contractors assisting with mitigation actions (fencing, plants, acoustic monitoring, insect monitoring, thermal monitoring, and pond creation). Auwahi Wind also identified fenceline and pond locations compatible with ʻUlupalakua ranching operations and initiated acoustic and insect monitoring throughout the mitigation site. Although only in its first year, Auwahi Wind is on its way to meet its success criteria for Tier 4 Bat Mitigation. The measures of success as defined in the HCP and current status of each measure of success are presented below in Table 3-4.

Table 3-4. Hawaiian Hoary Bat Tier 4 Mitigation Measures of Success and Implementation Status.

Measures of Success	Implementation Status
Protect the mitigation parcel in perpetuity through a conservation easement with oversight of the parcel by Hawaiian Islands Land Trust (or other appropriate conservation entity).	Anticipated FY 2021
Install two additional ponds in the Mitigation Area according to the HCP, or other number as specified through adaptive management.	Anticipated FY 2021
Increase forest cover to 20 percent within the pasture parcels through hedgerow reforestation at approximately 500 trees per hectare, or other cover and parcels as specified through adaptive management.	Ongoing
Record an increase in bat activity through acoustic monitoring over the baseline monitoring year(s). The statistical power with which the increase is recorded will also be reported.	Ongoing
Summarize and report the results of monitoring in annual reports.	Ongoing

3.2.4 Hawaiian Hoary Bat Occupancy Monitoring

Auwahi Wind is funding a single-year occupancy study of the Hawaiian hoary bat on Leeward Haleakalā. The study area spans from Ahihi-Kinau Natural Area Reserve to Kaupō gap, and from the summit of Haleakalā to the coast. An interim report is included as Attachment 4. The results of the study will be available in FY 2021.

3.3 Blackburn's Sphinx Moth

As stated in the 2012 HCP annual report (Tetra Tech 2012b), Auwahi Wind developed a Memorandum of Understanding (MOU) and made a one-time payment of $144,000 to the Leeward Haleakalā Watershed Restoration Project on April 17, 2012, to restore 2.4 hectares of dryland forest at the Auwahi Forest Restoration Project. Blackburn's sphinx moth mitigation was completed in FY 2019. A total of 1,500 ʻaiea (*Nothocestrum latifolium*) have been out-planted fulfilling Auwahi Wind's mitigation obligation. The measures of success as defined in the HCP and current status of each measure of success are presented below in Table 3-5.

Auwahi Wind met with USFWS November 20, 2019, to discuss the proposed reclassification of Blackburn's sphinx moth from endangered to threatened based on the analysis and recommendation in the species' most recent (2018) status review. Auwahi Wind provided Project experience regarding types of management activities that are likely to support the recovery of the species. The discussion also covered management of tree tobacco or other potential moth habitat to minimize potential for negative impacts to the species at the Project.

Table 3-5. Blackburn's Sphinx Moth Mitigation Measures of Success and Implementation Status.

Measures of Success	Implementation Status
Funding is provided to Leeward Haleakalā Watershed Restoration Partnership.	Completed in FY 2013
USFWS and DOFAW received annual updates until the restoration is completed.	Completed in FY 2019
The specified restoration is carried out, including the planting of approximately 620 stems of ʻaiea per hectare of mitigation.	Completed in FY 2019

3.4 Hawaiian Goose

Hawaiian goose mitigation was completed in FY 2013. Auwahi Wind provided a one-time payment on April 17, 2012, of $25,000 to the National Park Service (NPS) for use in building a Hawaiian goose rescue pen and predator fence to support egg, gosling, and adult rescue efforts in Haleakalā National Park. Since construction of the pen, 10 goslings have been raised and released from the pen between years 2011 and 2016 (one in 2011, five in 2013 and four in 2016). The measures of success as defined in the HCP and current status of the measure of success is presented below in Table 2-12.

Table 3-6. Hawaiian Goose Mitigation Measures of Success and Implementation Status.

Measures of Success	Implementation Status
Contribute $25,000 to Haleakalā National Park (Park) to build a rescue pen and predator fence to support egg and gosling (and adult) rescue at the Park.	Completed in FY 2012

3.5 Red ʻIlima

Auwahi Wind has fulfilled its HCP requirement to out-plant 10 Red ʻilima (*Abutilon menziesii*) on ʻUlupalakua Ranch to offset potential Project impacts. Plants were propagated at the ʻUlupalakua Ranch nursery in 2013. The outplanted red ʻilima plants and restoration sites continue to do well—34 of the 37 plants outplanted in the ungulate-free area at Puʻu Hokukano in FY 2018 remain in FY 2020. This plant has shown high success of survivorship from outplanted cuttings. This fenced restoration site has provided a valuable source of native dryland forest propagation material from established native outplantings and helps with species identification serving as an outdoor classroom of the native vegetation that is currently and historically found in the area. The measures of success as defined in the HCP and current status of each measure of success are presented below in Table 3-7.

Table 3-7. Red ʻIlima Mitigation Measures of Success and Implementation Status.

Measures of Success	Implementation Status
ʻUlupalakua Ranch will plant 10 red ʻilima from its on-going conservation efforts.	Completed in FY 2013
Report plant survival (3 years).	Completed in FY 2016

4.0 Adaptive Management

4.1 Minimization

Under adaptive management, Auwahi Wind has made the following changes to improve minimization measures at the Project in FY 2020:

- Auwahi Wind submitted an updated Adaptive Management Plan (AMP) to USFWS and DOFAW according to the timeline in the HCP (Attachment 2). The AMP prioritizes the installation of UADs based on the publication of results from UAD trials in Texas and at Kawailoa Wind (Weaver et al. 2019, Kawailoa Wind presentation to ESRC January 2020).
- The Baseline Fatality Rate exceeded the Threshold Value at the scheduled evaluation in February 2020. Auwahi Wind implemented adaptive management actions according to the AMP; NRG UADs were installed on all turbines in June 2020 and operate from 1 hour before sunset until 1 hour after sunrise, year-round.
- In FY 2020, USGS published research from the project evaluating thermal imagery paired with acoustic monitoring to gather data on the wildlife interactions with the turbines (Attachment 5). The co-occurrence of bat detection obtained from videographic and acoustic monitoring methods was generally low, and in instances when individuals were visually observed, bats were detected acoustically during only 12 percent of the time (Gorresen et al. 2020). Auwahi Wind determined a smart-curtailment strategy (using bat calls to curtail turbines real-time) would not be an effective option moving forward due to the high likelihood of missing a significant amount of time when bats were utilizing areas near the turbines..

4.2 Post-Construction Mortality Monitoring

In FY 2020, through adaptive management, Auwahi Wind has made a change to CPT trials to improve PCMM: USFWS and DOFAW approved a reduction in the number of large bird CPTs to five per fiscal year on June 12, 2020 (Lasha Salbosa pers. comm. June 12, 2020). The past three monitoring years have resulted in estimates of the probability of a carcass persisting until the next search of 1.0. Reducing the large bird trials will reduce the likelihood of attracting scavengers to the site and may increase carcass persistence for bat surrogates.

4.3 Mitigation

The HCP includes specific language to determine if adaptive management is warranted for the Hawaiian petrel success criteria. The HCP states:

> "In order to test the assumption that the baseline conditions presented in this HCP are representative of local conditions, Auwahi Wind will compare the results of monitoring at the [DKIST][2] control site to the baseline population model parameters for the duration of the [DKIST] monitoring. If the conditions at the [DKIST] site differ from the assumptions of the

[2] The name of the Advanced Technology Solar Telescope (ATST) changed to Daniel K. Inouye Solar Telescope (DKIST) in 2013. Following the conclusion of the DKIST HCP and Biological Opinion in 2018, the site is referred to as the Alpine Wildlife Sanctuary.

baseline population model, Auwahi Wind will adjust their mitigation targets accordingly, in consultation with DOFAW and USFWS."

Assumptions within the Hawaiian petrel demographic model used to estimate the benefits of the HCP have not matched the observations from burrow monitoring at the Kahikinui PMA. Auwahi Wind is proposing updated metrics for success criteria to be considered by USFWS and DOFAW. Predator control efforts implemented by Auwahi Wind should have resulted in additional chicks surviving to adulthood and increased adult survivorship that Auwahi Wind believes are measured through these updated metrics. These metrics are described in Attachment 3.

5.0 Changed or Unforeseen Circumstances

An unanticipated take of an unidentified storm-petrel was observed on June 15, 2020. The storm-petrel is believed to be a band-rumped storm petrel (pers. comm. J. Penniman July 10, 2020) and is awaiting genetic lab results for confirmation of species identification. Results of genetic testing will be submitted to USFWS and DOFAW HCP staff as soon as they are received.

6.0 Auwahi Wind Community Involvement

Auwahi Wind has continued to go beyond the requirements of the HCP to promote the survival and recovery of the Hawaiian petrel. Auwahi Wind has continued to provide support (e.g., training, deployment, monitoring) to the Maui Nui Seabird Recovery Project (MNSRP) and NPS relevant to loaned traps used for predator control in the adjacent Kahikinui Natural Area Reserve and Haleakalā National Park. The leg-hold traps donated to MNSBRP by Auwahi Wind successfully removed four feral cats from the MNSRP area during 2019. Auwahi Wind also loaned cellular equipped game cameras to support remote trapping efforts in 2019.

Auwahi Wind teamed up with the MNSRP in 2019 to present data at the Pacific Seabird Group annual meeting held on Kaua‘i. A landscape level approach using both program's datasets showed positive trends in recruitment and reproductive success. The overall results show of the 131 burrows used for analysis indicated low yearly-fledged chicks per total active burrow rates but an increasing trend of fledged chicks per breeding burrow, suggesting a sub-colony in the early stages of recruitment via immigration.

Auwahi Wind funded bat research (Gorresen et al. 2020, Pinzari et al. 2019), presented at the ESRC bat workshop demonstrating Auwahi Wind's commitment in providing accurate information on the Hawaiian hoary bat. A resource letter identifying best available information to help with the bat guidance document was submitted to the ESRC (Attachment 6). Auwahi Wind also regularly supports local college students, many who have gone on to working in the renewable energy and environmental fields in Hawai‘i.

7.0 Annual Workplan and Schedule

A work plan for FY 2021 is provided in Attachment 7. This work plan identifies major monitoring and mitigation activities and their associated timelines.

8.0 Cost Expenditures and Budget

A summary of HCP-related expenditures for FY 2020 is provided in Attachment 8. This summary lists costs (including staff labor) that Auwahi Wind has expended toward fulfilling the terms of the HCP in FY 2020, as well as cumulatively, and compares them against the budgeted amounts specified in the HCP.

9.0 References

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Attachment 1

Evidence of Absence Software Inputs and Outputs – Fatality Estimation

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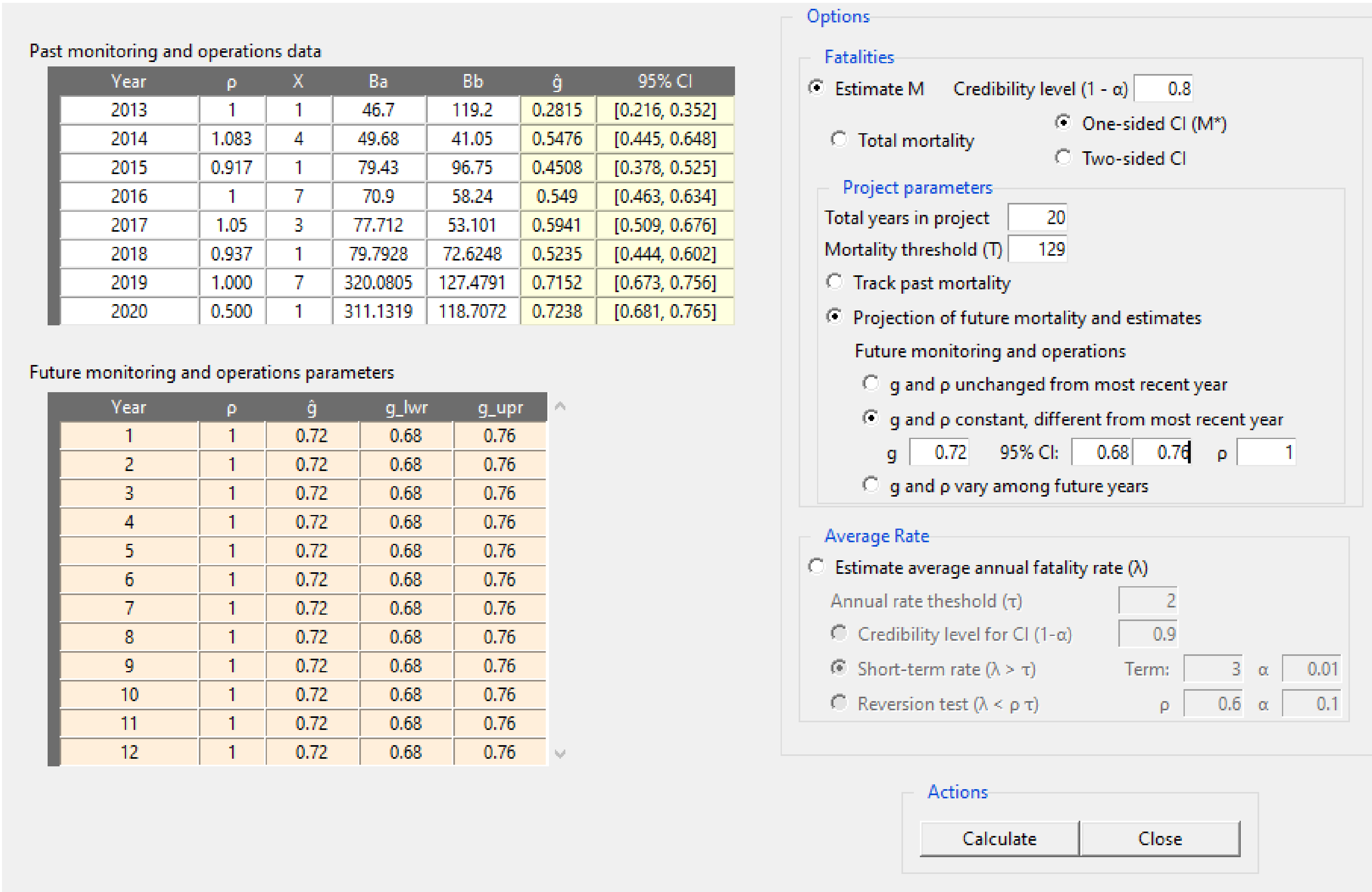

Figure 1. Evidence of Absence Software Input for Hawaiian Hoary Bats Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

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Summary statistics for total mortality through 8 years
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Results
M* = 52 for 1 - a = 0.8, i.e., P(M <= 52) >= 80%

Estimated overall detection probability: g = 0.536, 95% CI = [0.508, 0.564]
   Ba = 649.27, Bb = 562.31

Estimated baseline fatality rate: lambda = 6.351, 95% CI = [4.12, 9.07]


Test of assumed relative weights (rho) and potential bias              Fitted rho
Assumed rho     95% CI
      1     [0.060, 2.102]
   1.08     [0.362, 2.361]
  0.917     [0.033, 1.413]
      1     [0.883, 3.268]
   1.06     [0.218, 1.879]
   0.94     [0.028, 1.223]
      1     [0.683, 2.674]
    0.5     [0.024, 0.914]

p = 0.27518 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.028

Posterior distribution of M
m      p(M = m) p(M > m)
0       0.0000   1.0000
1       0.0000   1.0000
2       0.0000   1.0000
3       0.0000   1.0000
4       0.0000   1.0000
5       0.0000   1.0000
6       0.0000   1.0000
7       0.0000   1.0000
8       0.0000   1.0000
9       0.0000   1.0000
10      0.0000   1.0000
11      0.0000   1.0000
12      0.0000   1.0000
```

Figure 2. Evidence of Absence Output for Hawaiian Hoary Bats Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

13	0.0000	1.0000
14	0.0000	1.0000
15	0.0000	1.0000
16	0.0000	1.0000
17	0.0000	1.0000
18	0.0000	1.0000
19	0.0000	1.0000
20	0.0000	1.0000
21	0.0000	1.0000
22	0.0000	1.0000
23	0.0000	1.0000
24	0.0000	1.0000
25	0.0000	1.0000
26	0.0000	1.0000
27	0.0000	1.0000
28	0.0000	0.9999
29	0.0001	0.9998
30	0.0004	0.9994
31	0.0009	0.9985
32	0.0019	0.9966
33	0.0035	0.9932
34	0.0059	0.9873
35	0.0093	0.9780
36	0.0138	0.9641
37	0.0193	0.9448
38	0.0257	0.9192
39	0.0325	0.8867
40	0.0394	0.8473
41	0.0460	0.8012
42	0.0519	0.7494
43	0.0566	0.6927
44	0.0600	0.6328
45	0.0618	0.5710
46	0.0620	0.5090
47	0.0608	0.4482
48	0.0583	0.3899
49	0.0548	0.3351
50	0.0504	0.2847
51	0.0456	0.2391
52	0.0405	0.1986
53	0.0354	0.1631

Figure 2 (Cont.) Evidence of Absence Output for Hawaiian Hoary Bats Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

54	0.0305	0.1326
55	0.0259	0.1067
56	0.0217	0.0850
57	0.0179	0.0671
58	0.0146	0.0525
59	0.0118	0.0406
60	0.0094	0.0312
61	0.0074	0.0238
62	0.0058	0.0180
63	0.0045	0.0135
64	0.0035	0.0100
65	0.0026	0.0074
66	0.0020	0.0054
67	0.0015	0.0039
68	0.0011	0.0028
69	0.0008	0.0020
70	0.0006	0.0014
71	0.0004	0.0010
72	0.0003	0.0007
73	0.0002	0.0005
74	0.0002	0.0003
75	0.0001	0.0002
76	0.0001	0.0001
77	0.0001	0.0001
78	0.0000	0.0000
79	0.0000	0.0000
80	0.0000	0.0000

==

Input

Year (or period)	rel_wt	X	Ba	Bb	ghat	95% CI
2013	1.000	1	46.7	119.2	0.281	[0.216, 0.352]
2014	1.083	4	49.68	41.05	0.548	[0.445, 0.648]
2015	0.917	1	79.43	96.75	0.451	[0.378, 0.525]
2016	1.000	7	70.9	58.24	0.549	[0.463, 0.634]
2017	1.060	3	77.71	53.1	0.594	[0.509, 0.676]
2018	0.940	1	79.79	72.62	0.524	[0.444, 0.602]
2019	1.000	7	314.8	133	0.703	[0.660, 0.744]
2020	0.500	1	295.8	118	0.715	[0.670, 0.757]

Figure 2 (Cont.) Evidence of Absence Output for Hawaiian Hoary Bats Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

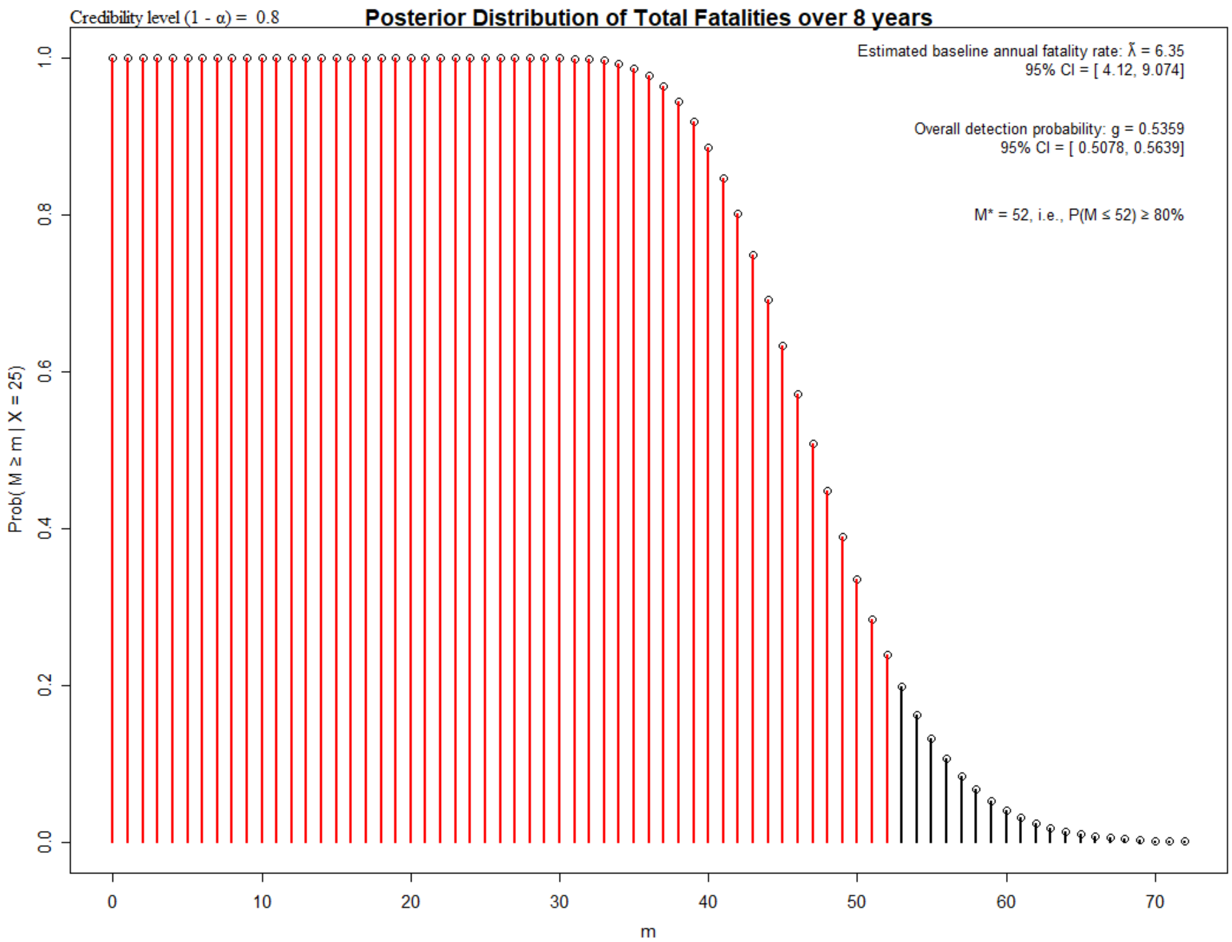
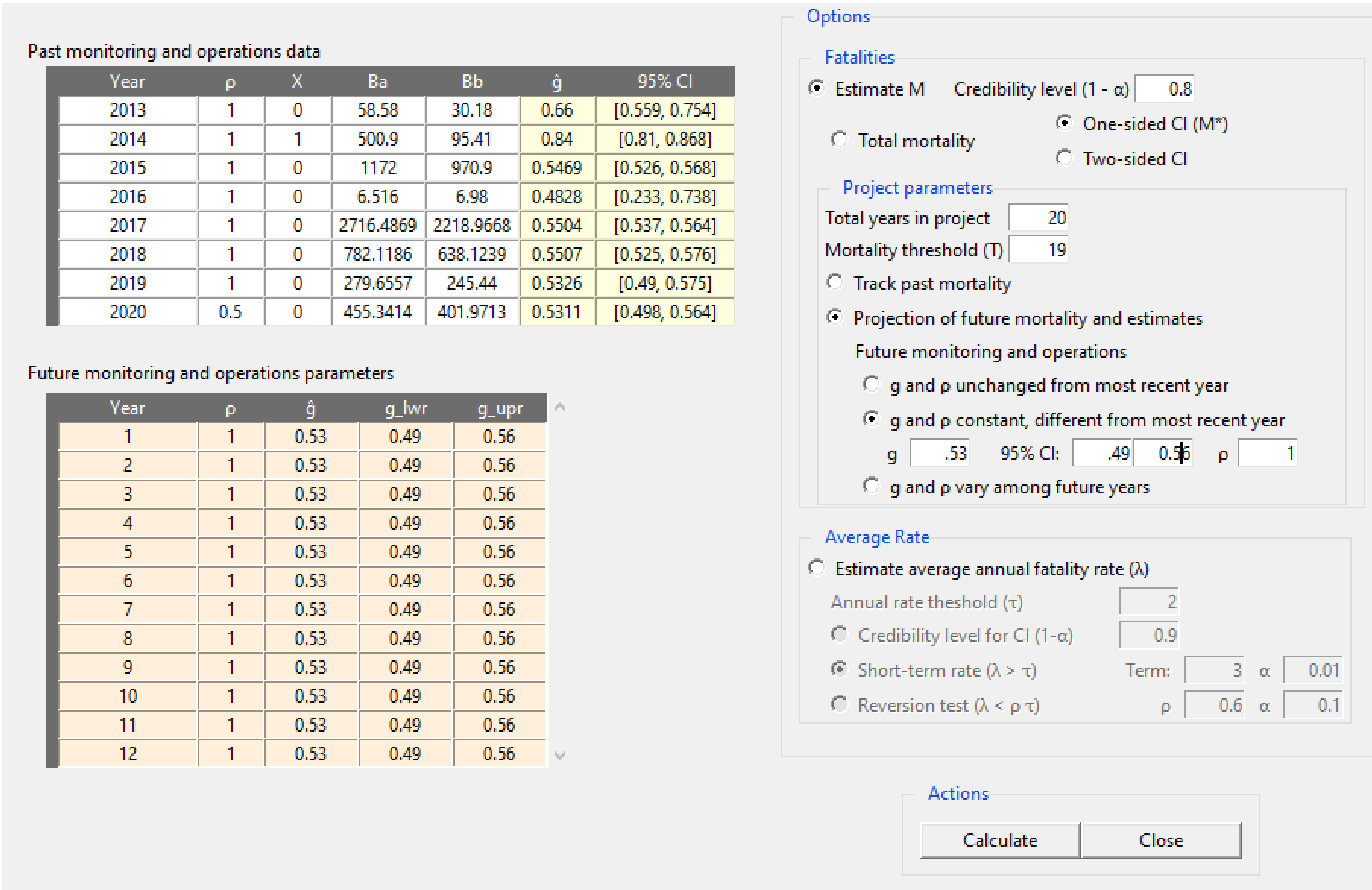


Figure 3. Evidence of Absence Posterior Probability Distribution Output for Hawaiian Hoary Bats Multi-Year Analysis for FY 2020 (Dalthorp et al. 2017).



Past monitoring and operations data

Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	1	0	58.58	30.18	0.66	[0.559, 0.754]
2014	1	1	500.9	95.41	0.84	[0.81, 0.868]
2015	1	0	1172	970.9	0.5469	[0.526, 0.568]
2016	1	0	6.516	6.98	0.4828	[0.233, 0.738]
2017	1	0	2716.4869	2218.9668	0.5504	[0.537, 0.564]
2018	1	0	782.1186	638.1239	0.5507	[0.525, 0.576]
2019	1	0	279.6557	245.44	0.5326	[0.49, 0.575]
2020	0.5	0	455.3414	401.9713	0.5311	[0.498, 0.564]

Future monitoring and operations parameters

Year	ρ	ĝ	g_lwr	g_upr
1	1	0.53	0.49	0.56
2	1	0.53	0.49	0.56
3	1	0.53	0.49	0.56
4	1	0.53	0.49	0.56
5	1	0.53	0.49	0.56
6	1	0.53	0.49	0.56
7	1	0.53	0.49	0.56
8	1	0.53	0.49	0.56
9	1	0.53	0.49	0.56
10	1	0.53	0.49	0.56
11	1	0.53	0.49	0.56
12	1	0.53	0.49	0.56

Figure 4. Evidence of Absence Software Inputs for Hawaiian Petrels Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

```
 Summary statistics for total mortality through 8 years
------------------------------------
Results
M* = 3 for 1 - a = 0.8, i.e., P(M <= 3) >= 80%

Estimated overall detection probability: g = 0.591, 95% CI = [0.553, 0.628]
   Ba = 384.89, Bb = 266.89

Estimated baseline fatality rate: lambda = 0.3392, 95% CI = [0.0244, 1.06]


Test of assumed relative weights (rho) and potential bias              Fitted rho
Assumed rho     95% CI
      1      [0.003, 3.138]
      1      [0.151, 4.505]
      1      [0.005, 3.804]
      1      [0.006, 4.242]
      1      [0.006, 3.447]
      1      [0.003, 3.332]
      1      [0.004, 3.725]
    0.5      [0.004, 3.633]

p = 0.85352 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.026

Posterior distribution of M
m      p(M = m) p(M > m)
0       0.0000   1.0000
1       0.4460   0.5540
2       0.2798   0.2742
3       0.1450   0.1292
4       0.0699   0.0592
5       0.0325   0.0267
6       0.0148   0.0119
7       0.0066   0.0053
8       0.0030   0.0023
```

Figure 5. Evidence of Absence Output for Hawaiian Petrel Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

```
9       0.0013   0.0010
10      0.0006   0.0004
11      0.0003   0.0002
12      0.0001   0.0001
13      0.0000   0.0000
14      0.0000   0.0000
===============================================================================
Input
Year (or period) rel_wt  X    Ba     Bb   ghat    95% CI
2013             1.000   0  58.58  30.18 0.660 [0.559, 0.754]
2014             1.000   1  500.9  95.41 0.840 [0.810, 0.868]
2015             1.000   0   1172  970.9 0.547 [0.526, 0.568]
2016             1.000   0  6.516   6.98 0.483 [0.233, 0.738]
2017             1.000   0   2716   2219 0.550 [0.537, 0.564]
2018             1.000   0  782.1  638.1 0.551 [0.525, 0.576]
2019             1.000   0  279.7  245.4 0.533 [0.490, 0.575]
2020             0.500   0  455.3    402 0.531 [0.498, 0.564]
```

Figure 5 (Cont.) Evidence of Absence Output for Hawaiian Petrel Multi-Year Analysis in FY 2020 (Dalthorp et al. 2017).

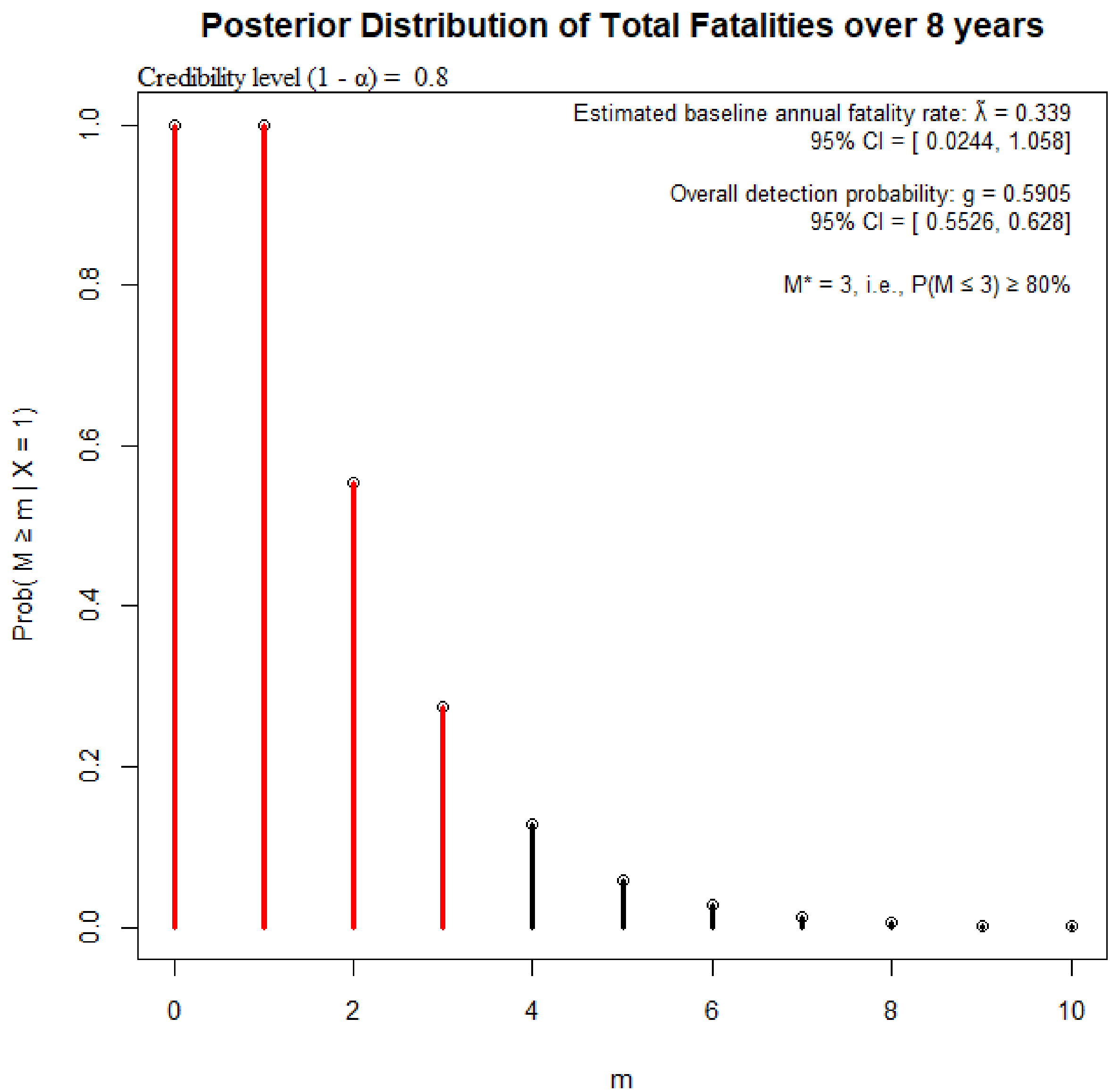


Figure 6 **Evidence of Absence Posterior Probability Distribution for Hawaiian Petrels Multi-Year Analysis (Dalthorp et al. 2017).**

Attachment 2

Adaptive Management Plan

Auwahi **Wind**	**Adaptive Management Plan 2020**	
	REVISION NUMBER:	3
	EFFECTIVE DATE:	7/29/2019
	REVISION DATE:	6/10/2020
	REVIEWED DATE:	6/10/2020
	REVIEW CYCLE:	12 MONTHS

Auwahi Wind

Adaptive Management Plan

2020

Auwahi Wind	Adaptive Management Plan 2020	
	REVISION NUMBER:	3
	EFFECTIVE DATE:	7/29/2019
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1.0 Introduction

This Adaptive Management Plan (AMP) was initially approved in the Auwahi Wind Farm HCP Final Amendment; Incidental Take Permit Number: TE64153A-1 issued September 4, 2019 and Incidental Take License Number: ITL-17 issued August 23, 2019. It identifies specific measures that Auwahi Wind will implement if the estimated fatality rate, evaluated as described below, exceeds the value needed to ensure compliance with the permitted take value over the permit term. As discussed in Section 4.1.7 of the HCP Amendment, Auwahi Wind implemented baseline minimization measures in 2018 and will continue to apply these measures for the duration of the permit, unless specific adaptive management triggers are reached that would initiate an adaptive management action. The AMP will be in effect upon permit issuance and until it is superseded by the AMP. The AMP will be developed using the results of the ongoing risk analysis (Section 7.4.1.3 of the HCP Amendment) and will be provided to the US Fish and Wildlife Service (USFWS) and State of Hawaii Department of Land and Natural Resources: Division of Forestry and Wildlife (DOFAW) for review by April 30, 2020. All terms and acronyms are defined in the Auwahi Wind HCP Amendment. Preliminary results of the risk analysis study was presented by USGS at the ESRC March 5-6 meeting (ESRC, March 5-6, 2020).

2.0 Evaluation Schedule

The effectiveness of the minimization measures in place at Auwahi Wind will be evaluated on a routine basis to ensure compliance with the permitted take value. These evaluations will take place as part of routine reporting tasks and scheduled agency reviews, as well as in response to observed take.

Table 1. Schedule for Regular Evaluation of Minimization Measures.

Period	Action	Timeframe
Immediate Evaluations	Summary of Take Report	Due within 3 weeks of observed take
Semi-Annual Evaluation	HCP Semi-Annual Compliance Report	Due January 31
Annual Evaluations	HCP Annual Compliance Report	Due September 1
	AMP Review	Scheduled with USFWS and DOFAW after Annual Report
	Adaptive Management Action Review	Due February 28

Scheduled Evaluations	If adaptive management actions are required, implement adaptive management actions[1]	Due March 31
1. See Follow-up Evaluation in Section 2.4.		

To track compliance, Auwahi Wind will use Evidence of Absence (EoA) to evaluate the Post-Construction Mortality Monitoring (PCMM) data and calculate the Baseline Fatality Rate (BFR) which is then compared to the Threshold Value (TV). The TV for Auwahi Wind is 6.45 based on analysis presented in Section 7.4.1.1 of the HCP Amendment.

Additionally, Auwahi Wind will track the BFR relative to each of the tiers of take (Table 2) to support agency discussions during routine reviews.

Table 2. Average Take Rates for Each Tier Over 20 Years.

Tier	Maximum Take	Average BFR
4	81	4.05
5	115	5.75

The details from the schedule are described in the following subsections.

2.1 Immediate Evaluations

Summary of Take Report (on Observed Fatalities): Auwahi Wind notifies USFWS and DOFAW of any bat fatality observed during PCMM or incidentally and submits a Summary of Take report within 3 weeks. The Summary of Take report is described in Appendix E and will include the following items related to adaptive management (in addition to other reporting requirements):

- Direct Take estimate;
- Direct Take projection;
- Calculation of the BFR and comparison of BFR to TV; and
- Comparison of BFR to tier based rates.

2.2 Semi-Annual Evaluations

HCP Compliance Report: Auwahi Wind summarizes the HCP compliance in a semi-annual report provided to USFWS and DOFAW in January each year. The semi-annual report will include the following items related to adaptive management (in addition to other reporting requirements):

- Direct Take estimate;
- Direct Take projection;
- Calculation of the BFR and comparison of BFR to TV; and
- Comparison of BFR to tier based rates.

2.3 Annual Evaluations

HCP Compliance Report: Auwahi Wind summarizes HCP compliance in an annual report provided to USFWS and DOFAW in August each year. In an annual meeting, Auwahi Wind reviews the HCP compliance status summary and take estimate projections with USFWS and DOFAW. The annual reports will include the following items related to adaptive management (in addition to other reporting requirements):

- Direct Take estimate;
- Direct Take projection;
- Calculation of the BFR and comparison of BFR to TV;
- Comparison of BFR to tier based rates; and,
- Adaptive management actions triggered or taken during the reporting year.

AMP Review: The AMP is intended to be a living document and will be updated as new information becomes available. Auwahi Wind will review the current AMP during the annual meeting with USFWS and DOFAW. Prior to the annual meeting, Auwahi Wind will review and summarize new literature relating to the development and effectiveness of minimization measures for the Hawaiian hoary bat and similar bat species. Literature to be reviewed includes: site-specific data, peer-reviewed literature, annual reports, industry publications, literature recommended by USFWS and DOFAW, or other sources. If Auwahi Wind determines, in consultation with USFWS and DOFAW, that new minimization measures are applicable and likely to be an improvement over those currently implemented or proposed in the AMP, the AMP will be updated to include the new measures and provided to the agencies for approval.

2.4 Scheduled Evaluations

Adaptive Management Action Review: Auwahi Wind will evaluate the PCMM data from the start of monitoring through December 31 of the preceding year (the most recent complete calendar year) to calculate the BFR using EoA in years 2020, 2025, and 2030. Auwahi Wind will then compare the BFR to the TV.

- If the BFR exceeds the TV, adaptive management actions, as described in Section 3 of the AMP, will be implemented no later than March 31. See Follow-up Evaluation below.
- If the BFR does not exceed the TV, no action will be required.

Should a projection predict that the Project will exceed the permitted take authorization between scheduled evaluations, Auwahi Wind, in coordination with USFWS and DOFAW, will determine if adaptive management actions are warranted.

Follow-up Evaluation: When adaptive management actions are implemented, the effectiveness of the actions will be assessed after two years using PCMM data. At that time, the BFR will be compared to the TV to determine if additional adaptive management actions are warranted. Should the BFR exceed the TV at that time, adaptive management actions will be implemented as described in Section 3 of the Interim AMP, and the BFR will be re-evaluated again at 2-year intervals until the BFR is equal to or less than the TV. Should adaptive management actions be implemented less than 2 years from a scheduled evaluation year (2025 or 2030), the next evaluation will occur 2 years after the adaptive management actions instead of at the scheduled evaluation.

3.0 Adaptive Management Actions

Auwahi Wind has identified initial adaptive management actions based on understanding of Hawaiian hoary bat life history, PCMM, observations at the site, peer reviewed literature, and preliminary results of nacelle-level acoustic and thermal imagery studies conducted in 2018 and 2019. These findings demonstrate:

1. The majority of bat activity occurs in the first 6 hours of the night.
2. The months of May through October represent the highest continuous months of observed fatalities.
3. The geographic distribution of fatalities shows Turbines 1-4 have a higher proportion of observed fatalities than Turbines 5-8.
4. Only between 10-15% overlap in bat acoustic detections and thermal observations at the turbine nacelles. To be updated with published report

Adaptive management actions will be required if, at a Scheduled Evaluation or Follow-up Evaluation, the BFR exceeds the TV. If adaptive management actions are required, Auwahi Wind will implement adaptive management actions in the order listed below.

1. Temporal redistribution of curtailment nights: Curtailment at 6.9 m/s would be continued for the first 6 hours of the night for the months of August through October. Cut-in speeds for the remaining hours of the night would be 5.0 m/s. This would provide an additional 704 Curtailment Nights (see definition in Section 7.4.1.1 of the HCP Amendment), with cut- in speeds of 6.9 m/s for the first 6 hours of the night, to be redistributed. These additional Curtailment Nights would be applied May 5 through July 31 to address the intermediate risk months.
2. Spatial redistribution of curtailment nights: A higher proportion of fatalities have been observed at turbines 1-4 than at turbines 5-8. Redistribution of curtailment nights from turbines 5-8 to turbines 1-4 would be the second adaptive management action. The redistribution will allocate Curtailment Nights from turbines 5-8 from May 5 through July 31 to turbines 1-4 either nightly or seasonally. Selection of nightly or seasonal application would be based on post construction monitoring results following the implementation of the redistribution described above in action 1.
3. Should a redistribution of curtailment nights not provide sufficient minimization to keep the Project within the total take authorization, Auwahi Wind will implement an acoustic deterrent system or an alternative minimization technology (provided they are commercially available, demonstrated to be effective in Hawai'i, and determined not to negatively impact other wildlife).

An adaptive management action was triggered at the 2020 Scheduled Evaluation. Auwahi Wind proposed to implement adaptive management action 3, implementing an acoustic deterrent system. DOFAW and USFWS were notified the adaptive management action had been triggered and were in support of Auwahi Wind installing NRG bat deterrents (March 9, 2020). At the ESRC meeting held on January 15-16, 2020, Auwahi Wind notified the ESRC an adaptive management action was triggered and the project intended to move forward with the purchase and installation of deterrents. Adaptive management was implemented January of 2020 with the finalization of a NRG contract to install a bat deterrent system at all turbines, installation is scheduled for Q2 2020.

4.0 Adaptive Management of Baseline Minimization

The suite of minimization measures available to reduce the risk to bats may change over time because of ongoing industry research and development of new technology. Auwahi Wind may propose a change to baseline minimization measures identified in the HCP Amendment (Section 4.2.7) or adaptive management actions in the AMP, such as replacement of low wind speed curtailment with bat deterrent technology. Such a change would be subject to review and approval by USFWS and DOFAW prior to being implemented at the Project.

NRG bat deterrent system became commercially available in 2020 to deter bats using 6 ultrasonic speakers mounted on the turbine nacelle. USFWS and DOFAW is reviewing the proposal of Auwahi Wind to replace low wind speed curtailment with the installation of the NRG bat deterrent system.

Auwahi Wind	Adaptive Management Plan 2020	
	REVISION NUMBER:	3
	EFFECTIVE DATE:	7/29/2019
	REVISION DATE:	6/10/2020
	REVIEWED DATE:	6/10/2020
	REVIEW CYCLE:	12 MONTHS

REVISION HISTORY LOG			
Rev.	**Date**	**Description**	**By Initials**
0	7/29/2019	Auwahi Wind Habitat Conservation Plan Amendment	MVZ
1	3/20/2020	Edits, Additions, Formatting	GA
2	4/2/20	Remove the term "Interim" for clarification and update HCP annual report due date to reflect ITP due dates	GA
3	6/10/20	Adding ITL permit number	GA

Recoverable Signature

X

George Akau
Auwahi Wind Biologist
Signed by: gjakau@aepes.com

X

Lauren Taylor
DOFAW Protected Species Habitat Conserva...

X

Lasha-Lynn Salbosa
USFWS Alternative Energy Program/HCP Co...

Attachment 3

Kahikinui Management Area Hawaiian Petrel Monitoring Report

AUWAHI WIND ENERGY PROJECT

2019 Auwahi Wind Energy Hawaiian Petrel Report

Prepared for:

&

Auwahi Wind Energy, LLC
20100 Piilani Hwy
Kula, HI 96790

Prepared By:

August 2020

Table of Contents

Tables

Figures

1.0 Introduction

1.1 Background

In December 2012, Auwahi Wind Energy, LLC (Auwahi Wind) began commercial operations of the Auwahi Wind Farm (Project) in east Maui, Hawaiʻi, consisting of eight 3-megawatt wind turbines. To address potential endangered species impacts associated with the Project, Auwahi Wind developed a Habitat Conservation Plan (HCP), finalized in January 2012 (Tetra Tech 2012a). Based on the anticipated take levels provided in the HCP, Auwahi Wind obtained an incidental take license (ITL) from the Hawaiʻi Department of Land and Natural Resources (DLNR) on February 9, 2012, and an incidental take permit (ITP) from the U.S. Fish and Wildlife Service (USFWS) on February 24, 2012. Auwahi Wind entered into a Memorandum of Understanding (MOU) on August 22, 2012, with the Department of Hawaiian Homelands (DHHL) and established the Kahikinui Petrel Management Area (Kahikinui PMA) with the main objective to benefit the petrel colony by predator management. To address the reporting requirements under the HCP for ʻuaʻu or Hawaiian petrels (Pterodroma sandwichensis; HAPE), this report summarizes the petrel management activities executed in 2019 within the Kahikinui PMA.

As proposed in the Auwahi Wind HCP, take and mitigation levels are represented in tiers such that each subsequent tier has a higher take level and a correspondingly higher level of mitigation. For the initial tier (Tier 1), Auwahi Wind committed to mitigating potential impacts to petrels by implementing predator control within Kahikinui PMA to increase the survival and reproductive success of Hawaiian petrels. Tier 1 mitigation requires predator control at 33 active burrows (see the HCP for additional details). Petrel management activities will be considered successful if (1) predator control is successfully implemented and (2) mitigation efforts result in an increase in reproduction that offsets authorized take, as outlined in the Hawaiian Petrel Management Plan (Management Plan; Tetra Tech 2012b), approved by USFWS and the DLNR-Division of Fish and Wildlife (DOFAW).

A full predator control strategy for Kahikinui PMA, developed in partnership with Island Conservation and Tetra Tech, Inc. (Tetra Tech; Island Conservation and Tetra Tech, Inc. 2013), focused on setting up a grid of traps throughout the entire Kahikinui PMA. The predator control strategy, which began in 2013, achieved full implementation with the deployment of all types of traps including DOC250 and foothold traps by November 2014. The strategy continues to focus on controlling feral cats, mongooses, and rodents within the entire Kahikinui PMA, but modifications made from earlier years now utilize a more focused trapping approach compared to that used initially.

The Kahikinui PMA is located on the DHHL portion of the Kahikinui Forest Reserve (Figure 1 [the tables and figures for this report are located in the back starting on page 16]). The management area consists of approximately 356 hectares (ha) with a moderate density (76 burrows/356 ha= 0.21 burrow per ha) of petrel burrows compared to neighboring management areas (DKIST burrow densities 407 burrows/133 ha = 3.06 burrows per ha; Chen et al. 2019). The DHHL Commission approved a 25-year License Agreement (License No. 772) on April 23, 2012, identifying Auwahi Wind as the responsible party for the management of petrels within the DHHL portion of the KFR (as referenced above). Tetra Tech conducted petrel surveys in 2011 and 2012, to locate active burrows within the Kahikinui PMA.

The Kahikinui PMA is located on a south-facing slope along the southwestern flank of Haleakalā Crater. The elevation within the Kahikinui PMA ranges from 2,560 to 2,972 meters above sea level. The area is subject to rapidly changing weather conditions and fluctuating temperatures. No roads or trails exist in the Kahikinui PMA; the terrain is rocky, and the substrate varies from volcanic cinder to large rock outcrops, including numerous gullies. The slopes are very rugged and steep in some sections and often consist of loose, sharp rock. A large cinder field occurs in the center of Kahikinui PMA. Vegetation is denser at the lower elevations than the higher elevations and consists mostly of native shrubs, primarily pūkiawe (*Styphelia tameiameiae)* and ʻōhelo (*Vaccinium reticulatum*). A small population of the endangered ʻāhinahina (*Argyroxiphium sandwicense* ssp. *macrocephalum*) plant exists at upper elevations within the Kahikinui PMA.

The area is fenced on all sides except the southern section, which allows access to feral ungulates such as goats. Goats are the only ungulates that have been observed in the management area. Old signs of hunting are still present with hunter shelters in caves and bullet casings detected throughout the PMA. Auwahi Wind staff have not encountered any hunters in the area since 2014. Signs of Hawaiian customary traditions and practices are abundant throughout the site. They dot the landscape and include stone-stacked trail markers and walls; coral and shell bits; rock quarries; and rock shelters. Water sources found in some of the caves appear dripping from the ceilings as the landscape warms through the day. Hawaiian families have returned to the lower elevation lands through leases from the state government through the Hawaiian Homes act.

The weather of the area has high sun exposure and blasting winds. The past two years have yielded considerable snow that has blanketed the PMA. In the past, the weight of the snow on the fence with the high winds caused a portion of the boundary fence to collapse. The remoteness of the area, extreme terrain, and weather conditions make working in the area logistically and physically challenging.

1.2 Objectives of 2019

As in previous years, the objectives of the 2019 management season were to continue petrel burrow monitoring to assess the number of active burrows in Kahikinui PMA, evaluate petrel reproductive success, and continue implementation of the current predator control strategy. To achieve these objectives in 2019 Auwahi Wind performed the following actions:

1. Burrow checks conducted at known burrows to estimate the number of active burrows and their reproductive success. While performing burrow checks, trained technicians opportunistically searched nearby suitable habitat for additional burrows.

2. Deployment of game cameras at active burrows to further document activity of petrels and any predation events.
3. A comprehensive predator assessment conducted across Kahikinui PMA prior to nesting (February) and in August (halfway through the year), using 1-day and 3-day tracking tunnel indices for rodents and mongooses, respectively.
4. Continuation of the predator control strategy that included the deployment of traps, and evaluation of trap effectiveness and placement. Conduct trap maintenance in the field.

Additional actions implemented in 2019 to assist the objectives and adaptively manage to increase the fledging success and adult survival were:

1. Monitoring goat-trampling events of petrel burrows using game camera data. Identify months during the year of high activity and trampling events within Kahikinui PMA during the nesting season.
2. Installation of an artificial clay burrow designed by Oikonos to provide protection from goat-trampling events. Record visitation events of HAPE to the artificial burrow.
3. Collaborating with land managers to assist with petrel management on bordering State and Federal lands. Loan traps and share information with neighboring projects
4. Extend predator trapping and burrow monitoring year-round.

2.0 Methods

2.1 Burrow Activity and Reproductive Success

Burrow checks are the primary tool for documenting petrel fledging success at the Kahikinui PMA. Burrow checks are conducted twice a month from March to November 2019 (the full petrel reproductive season: prospecting, laying, and incubating, chick rearing, and fledgling). During each survey, trained surveyors checked the status of known petrel burrows and opportunistically searched nearby suitable habitat for additional burrows. Any new burrows located in 2019 were marked, mapped, and added to the monitoring dataset. All known burrows were monitored using the “toothpick method” (NPS 2012, Tetra Tech 2013) during each check through July, after which only active burrows were monitored. Burrows fell into one of six categories of seasonal status based on the activity pattern observed during the burrow checks and from game cameras (Section 2.2; Table 1). The seasonal status of each burrow determined if it was included in the reproductive success calculations. For all calculations of reproductive success, it was assumed there was a maximum of one egg or fledgling per burrow, and burrows categorized as prospecting or seasonally inactive were excluded.

The metrics of reproductive success utilized to allow for direct comparisons between previous monitoring years at Kahikinui PMA and other local petrel studies are as follows:

1. **Percent Chicks Fledged per Active Burrow**—This metric, represented by Equation 1 below, calculates the reproductive success from all burrows, which were consistently active during the egg-laying season.

   Equation 1

   $$\frac{\#\ \text{Successful} + \#\ \text{Probably Successful}}{\#\ \text{Successful} + \#\ \text{Probably Successful} + \#\ \text{Failed} + \#\ \text{Occupied by Non-breeder/Failed}}$$

2. **Percent Chicks Fledged per Eggs Laid**—This metric is represented by two values, one derived with assumptions providing a minimum value (Low; Equation 2 below) and a second derived with assumptions providing a maximum value (High; Equation 3 below).

   Equation 2

   Low Value

   $$\frac{\#\ \text{Successful} + \#\ \text{Probably Successful}}{\#\ \text{Successful} + \#\ \text{Probably Successful} + \#\ \text{Failed} + \#\ \text{Occupied by Non-breeder/Failed}}$$

   Equation 3

   High Value

   $$\frac{\#\ \text{Successful} + \#\ \text{Probably Successful}}{\#\ \text{Successful} + \#\ \text{Probably Successful} + \#\ \text{Failed}}$$

The trend in the percent chicks fledged per active burrow across the 7 years of monitoring (2013–2019) was investigated using a chi-square test. The result of the chi-square test was used to indicate if there was a relationship between reproductive success and the implementation of predator control. The percentage of chicks fledged per eggs laid was used to compare reproductive success across the seven monitoring seasons for which the entire season was monitored (2013–2019). A discussion of adaptive management of the success criteria is provided in Section 5.1.

2.2 Game Camera Monitoring

Reconyx Hyperfire™ cameras have been used since 2012 to provide supplemental information on burrow activity and reproductive success, and continue to be the main monitoring tool through the nesting season. Cameras were installed at burrows simultaneously monitored with the toothpick method throughout the early season to identify active burrows. Each camera remained at a given burrow until evidence of petrel activity ceased, and then moved to another burrow with indications of recent petrel activity. Observations detected by game cameras of visitation to active burrows by goats, cats, rodents, and mongooses guided targeted predator control efforts throughout the season.

2.3 Tracking Tunnels

Tracking tunnels are used to monitor the presence and distribution of small mammals (rodents and mongooses) within Kahikinui PMA (Brown et al. 1996, Blackwell et al. 2002, Gillies and Williams 2007, Speedy et al. 2007). Auwahi Wind performed tracking tunnel monitoring in February and August 2019. This method provided an indicator of relative abundance of small mammals early in the season, and halfway through the season with active predator control throughout the year. Tracking tunnel and transect spacing methodology are described in the Auwahi Wind (Auwahi Wind 2014). Small mammal relative abundance (i.e., activity index) was calculated as the mean percentage of tunnels with tracks of the target species per transect (Gillies and Williams 2007). Although feral cats documented on game cameras are able to pass through tracking tunnels, no tracking tunnels within the Kahikinui PMA have recorded cat tracks.

2.4 Predator Control

A trapping grid was used to control predators within the Kahikinui PMA (Figure 2). The predator control strategy was informed by the results of the February tracking tunnel study. The trapping grid remained active after the 2018 breeding season and was checked 1-2 times monthly during the winter prior to the start of the 2019 breeding season. A combination of four trap types were used which included 49 DOC250 kill traps, 44 Goodnature A24 traps, 3 Victor foothold traps (equipped with Reconyx cellular cameras), and 39 KaMate traps. Of these traps, 49 trap positions fell within a 200-meter buffer of the petrel burrows using gridded spacing (Island Conservation and Tetra Tech 2013; Figure 2). The Goodnature traps and DOC250 traps were each spaced at 150-meter intervals. All trap types set in the Kahikinui PMA, excluding foothold traps, included housing made of wooden boxes or plastic coverings to reduce the risk of seabird bycatch. Foothold trap deployments occurred clustered in areas where cat activity was documented or mostly likely to occur (fence lines, pathways, etc.) and during times of higher levels of cat activity in the area (March and October-November; Kaholoaa et al. 2019).

Trap checks involved primarily baiting DOC250 traps with tuna/sardines, peanut butter, beef hotdogs, and a variety of other items such as catnip, baby food, and wax bait; checks of Goodnature traps included pre-baiting the trap with cinnamon or peanut butter; foothold trap sets utilized baits of tuna/sardines and fish oils; and KaMate trap baits were primarily macadamia nuts.

3.0 Results

3.1 Burrow Activity and Reproductive Success

During the 2019 breeding season, bi-weekly visits to monitor burrow activity began on March 19, 2019, and ended on November 5, 2019, at which time all the burrows had ceased to be active. Seventy-six burrows were monitored within the Kahikinui PMA (72 initially located prior to the 2019 season and 4 new burrows located during 2019 surveys), with nine Hawaiian petrel chicks successfully fledging.

Thirty-nine (51 percent) of the 76 burrows were active during the 2019 breeding season, and 37 burrows (49 percent) were seasonally inactive (Table 2). Of the 39 active burrows, 28 were consistently active and used to calculate reproductive success for Kahikinui PMA in 2019. The majority of the consistently active burrows occurred in Unit 1. Eleven of the consistently active burrows showed reproductive sign; nine successfully produced a fledgling. Of the two known nest failures, one had an egg roll out and one had a dead chick found at the burrow entrance. The remaining 17 burrows that were consistently active either failed or showed signs of occupation by a non-breeder. The cause of nest failures/abandonment is unclear, but 46 percent (18/39) of active burrows with cameras showed sign of trampling by goats (Figure 3). There were no clear, documented signs of depredation or reproductive sign observed at these burrows, either by the biologist monitoring the burrows or captured on game cameras stationed at the burrows. There were no signs of petrel depredation observed in 2019.

Reproductive success was between 32 and 82 percent in the 2019 breeding season (Figure 4). Based on the survey findings, the number of burrows estimated to have laid eggs ranged from 11 to 28 of the consistently active burrows; this range represents the difference between using only those burrows where Hawaiian petrel reproductive sign was observed versus assuming all consistently active burrows had eggs laid. There was no significant difference in reproductive success in the seven monitoring seasons for which the entire season was monitored, using the conservatively low value for reproductive success (x^2=3.654, df =12 p=0.989) or the high value for reproductive success (x^2=6.324, df =12 p=0.899).

3.2 Game Camera Monitoring

Game camera deployment took place at 46 burrows in 2019. Game cameras confirmed some activity at 39 of the 76 burrows, with consistent activity at 28 burrows and documented successful fledging of nine chicks. Successful fledging recordings, documented between October 4 and November 1, 2019 (Table 3), occurred at nine burrows. Game cameras recorded a visitation by a cat at two burrows (visitation occurred between October 29 and November 5 checks). These visits occurred at the end of the nesting season and-happened at burrows 55 and 15. The Maui Nui Seabird Recovery Project (MNSRP) reported removing a feral cat from their area around this time. During the same time period, mongooses were recorded visiting three burrows (58, 62, and 15). A mongoose was successfully removed with a DOC250 trap (December 3, 2019).

Game cameras also captured visitation by goats at the entrances of both Successful and Occupied by Non-Breeder/Failed burrows. Goat-trampling events, detected on game cameras, occurred at burrows most frequently between April and October, and peaked in July with 18 burrows showing goat sign (Figure 3). Burrows throughout the Kahikinui PMA recorded observations of goat-trampling events and 39 of 46 (85 percent) of the cameras placed at burrows showed images of trampling events by goats. Other types of feral goat activity observed include resting in the shade, foraging (often on seabird droppings possibly for nutrients), and congregating (more than one).

3.3 Tracking Tunnels

In February, rodents were detected along six of the eight transects, using the 1-day rodent index. The 1-day tracking index was 6.4 percent (12 of 187 cards with activity, mean percentage of tunnels with tracks) for rodents in February. Halfway through the trapping season in August, rodents were detected along six transects as well. The tracking index was 7.5 percent (14 of 187) for rodents in August.

No mongoose detections were recorded in February along any of the monitoring stations, yielding the 3-day tracking index of zero percent. Halfway through the trapping season in August, no mongoose detections were documented while conducting predator assessments. Figure 5 shows tracking tunnel monitoring results for all observation periods.

Investigating the activity index across the entire management period (fall of 2013 – fall of 2018), there appears to be seasonal trends. Rodent activity appears to increase throughout the nesting season and is concentrated in the lower elevations. The overall activity trend for both rodents and mongoose is low across the site and across all monitoring periods. Mongoose activity has stayed low since fall 2013 (Figure 6).

3.4 Predator Control

The predator control grid was operational for all of 2019; including the winter season (November-February) when Hawaiian petrels are absent. Predator control removed 109 targeted mammalian predators during the 2019 season including: 18 rats, 90 mice, and 1 mongoose (Figure 7). Footholds were used to target cats in areas they were observed to be present on game cameras, but no cats were successfully captured in the management area in 2019. Seasonal observations for cats observed on game cameras are shown in Figure 8.

4.0 Discussion

4.1 Reproductive Success

Throughout 2019, 39 burrows showed signs of activity at some point during the breeding season. Since monitoring began in 2012, a regular seasonal decline in active burrows in the month of September is typical (Figure 9). The number of active burrows in August has dropped between 4 and 16 burrows by September depending on the year. According to Simons (1985), both failed breeders and non-breeders typically leave the colony in September. Without confirmation of an egg in the burrow, it is challenging to determine what percentage of the burrows failed or simply contained non-breeders. This results in large confidence intervals surrounding reported reproductive success percentages (e.g., a difference of 48 percent from average low to average high value through all years).

We have seen an increase of 22 in the total number of burrows reported in the PMA from 2012 to 2019. However, the increase in burrows within the colony has not resulted in an increase in the number of active burrows per year. This may be a result of an increase in younger/non-breeding birds investigating the site, which can increase the denominator in the calculation of reproductive success where actual breeding status is uncertain. The number of consistently active burrows has remained relatively constant throughout the 8 years of monitoring (average of 29 active burrows; range = 25–33). This trend in occupancy by breeding adults is most evident in Unit 1, which contains the largest proportion of consistently active burrows and has seen little change in reproductive success since 2014.

Assumptions used within modeled scenarios in the HCP have not been met at the Kahikinui PMA. The Kahikinui PMA and Alpine Wildlife Sanctuary (AWS) sites appear to have low reproductive success compared with historic values from the nearby Haleakalā National Park (42 to 61 percent chicks fledged per active burrow; Natividad Hodges 1994). More current reproductive success data from Haleakalā National Park from 2018 and 2019 provide a comparison. However, the Haleakalā National Park Service (NPS) does not consistently monitor all burrows (less than 1 percent). Recent data from Haleakalā National Park has indicated annual variation in reproductive success (39.5±10.4 percent) from 1993-2013 and similar results for 2018 with 36.9 percent (NPS 2019) and in 2019 a reproductive success of 58.4 percent (C. Bailey pers. comm. July 2020) as compared to the Kahikinui PMA of 32 percent utilizing similar methods. The use of Auwahi Winds game camera data provides insight into the accuracy of the toothpick method. By comparison, monitoring in the Kahikinui PMA using game cameras resulted in an 82 percent success rate (high value) during the same time-period. The game camera results are more accurate, but the toothpick method data continue to be collected to compare with monitoring methods of nearby programs.

A significant increase in the reproductive success within the Kahikinui PMA since predator control implementation began in 2014 is hard to distinguish at the site, but there has been a mostly positive trend (Figure 4, Figure 12). Previous annual reports have discussed alternative explanations for the lower reproductive success in the Kahikinui PMA, including:

- Individual fitness may be correlated with population density (Brown et al. 1990, Danchin and Wagner 1997, Stokes and Boersma 2000, Schreiber and Burger 2001), and Kahikinui PMA has a lower density of burrows across the PMA than neighboring sites;
- Kahikinui PMA may be an example of a population of younger/non-breeding birds predominantly investigating the site, as seen with the mass exodus of potentially non-breeding birds every September. The increase in non-breeders during the first few years will keep the reproductive success low until the first generation reaches breeding age (assuming fledglings return to Kahikinui PMA to breed);
- Pressures occurring away from the colony (i.e., at sea), where changes in climate and fisheries may have an impact on prey abundance and foraging efficiency; and
- Goat-trampling events may be negatively affecting petrel reproductive success. Surrounding areas have reported higher levels of reproductive success with the removal of goats.

The management of the Hawaiian petrel colony within the Kahikinui PMA is one piece of the larger petrel colony of Haleakalā which also includes the AWS, Haleakalā National Park, and the Nakula

Natural Area Reserve (NAR). Growth rates after implementation of predator control at each location have varied; however, data from DKIST (Chen et al. 2018) and Nakula NAR (Learned 2020) indicate greater increases in petrels fledged per year have been observed at each of these sites than have been observed at the Kahikinui PMA. Haleakalā National Park has seen a steady growth in the number of burrows (C. Bailey pers. comm. July 2020); however, only a portion of the burrows are monitored in any given year. One notable difference from the Kahikinui PMA to each of the other colonies is that each of the other colonies are fenced to prevent the ingress of ungulates.

The comparison to DKIST and Haleakalā National Park, as well as the observations from Kahikinui PMA, suggests the calculation of offset needs to be adaptively managed (Section 5.1).

4.2 Predator Control and Interpreting Predator Assessments

The overall decrease in rodent and mongoose activity, using tracking tunnels, has corresponded with a decrease in rodent and mongooses removed with trapping efforts. In the spring of 2014, tracking tunnel data showed a spike in mongoose activity (Figure 6). Over the next year and a half of predator control implementation, eight mongooses were removed from the management area and surrounding area, with efforts either directly or indirectly supported by Auwahi Wind. By the fall of 2015, no mongooses were detected on the tracking tunnels and the activity levels have remained low in the subsequent years. Since then, mongoose-tracking tunnel results remain low and there have consistently been no mongoose detections in tracking tunnels of Unit 1. This is the unit with the highest concentration of active burrows and the most interior nesting area within the Kahikinui PMA, protected by neighboring burrows and trap clusters bordering the exterior (Figure 2).

Rodent activity appears to have seasonal pulses, based on the tracking tunnel and trapping results (Figure 6). Pulses in rodent activity within the management area in the fall (September – November) are typical, and the observed increase in rodent activity generally coincides with an increase in trapping of mice over that same time-period. Goodnature traps have proven successful at removing rodents when this occurs, with up to four carcasses found underneath one trap at one check.

No cats were caught during trapping at Kahikinui PMA in 2019 ; however, four cats were trapped in neighboring management areas by partners using foothold traps with Reconyx trap reporting system, provided by Auwahi Wind. Detections of cats by game cameras in Kahikinui PMA were similar to previous years (Figure 8) despite removal by trapping. This suggests the site may experience a stable rate of immigration of new individuals to replace those removed by trapping.

The October-March months have had the highest visitation of cats and mongoose. Game camera data show there is a peak of cat visitations at burrows that coincides with petrel fledglings leaving the burrows (Figure 9) in October. The results of monitoring cat visitations to burrows provide valuable information in guiding targeted cat trapping efforts during this period and efficiency of the predator control program. All cat visitation events indicate that there is no resident population of cats in the area and main egress is from the lower elevations in the south. Similar results were observed from the mongoose tracking tunnel results. The interior burrows of the Kahikinui PMA are highly protected from cat and mongoose predation whereas the boundary burrows, especially along the southern boundary, have higher risk of predation events. The northern and eastern boundaries of the Kahikinui PMA have added protection with predator control also taking place on those lands (NPS 2019). The probability of catching mongoose was highest from November-January for Haleakalā National Park (NPS 2019).

4.3 Summary and Recommendations for 2020

- Since completion of comprehensive surveys in 2012, there has been a net increase of 22 burrows (40 percent) within the breeding colony. The total number of burrows has increased but the number of active burrows in a given year has remained relatively static. Reproductive success remains low but comparable to surrounding management areas.
- The use of Reconyx Hyperfire game cameras provides burrow data that allows Auwahi Wind to have a more definitive understanding of activity and breeding success within Kahikinui PMA."Game cameras have also led to a better understanding of predator activity and activity by goats near burrows (Figure 10). Ungulate managers could use the game camera data and target the month of July when goat-trampling peaks at burrows.
- Predator assessments (tracking tunnels) from 2013 through 2019 point toward a fluctuation in rodent and mongoose activity within the site, with generally low levels of activity. These assessments are also helpful in interpreting predator-trapping results.
- Goodnature traps continue to be able to remove the highest number of rodents within Kahikinui PMA, followed closely by KaMate traps. Foothold traps have removed the highest number of cats. Footholds have proven effective and are easy to deploy in the field due to their small size and light weight compared to other traps.
- Auwahi Wind has discontinued the use of OMNI M2M sensors for monitoring foothold traps and has started to assess the effectiveness of Reconyx game cameras with text message reporting within the management area. Reconyx was successful in reporting on daily trap status and trapping events.
- Auwahi Wind deployed an artificial clay burrow (Figure 11) in an area prone to goat-trampling events. A petrel visited the clay burrow but no adult pairs or chicks appeared on game camera data.
- Auwahi Wind is pursuing a major amendment to reduce total requested take. Mitigation efforts will remain the same within Kahikinui PMA. See Section 5.2.

5.0 HCP Administration

5.1 Adaptive Management

As mentioned above, assumptions within the demographic model used to estimate the benefits of Auwahi Wind's mitigation in the HCP have not matched the observations from burrow monitoring at the Kahikinui PMA. For example, fewer burrows are active than the 33 anticipated in the HCP; an average of 28.4 burrows have been active at the PMA from 2013-2019. Petrel burrow density demonstrates a statistically significant clustering (spatial autocorrelation) at both the AWS (Moran's I z-score: 7.68, p-value: 0.0) and the Kahikinui PMA (Moran's I z-score: 6.18, p-value: 0.0). However, the burrow density of the PMA (0.21 burrows per ha) is lower than that of the adjacent management areas at the AWS (3.06 burrows per ha; Chen et al. 2018) and likely Haleakalā National Park (NPS 2019). The vital rates provided by USFWS (Greenlee, pers. comm., 2011) assumed a growth rate less than one (0.933) resulting in assumed annual reductions in the number of breeding individuals. However, all colonies within areas of predator control have demonstrated an increase in active burrows and fledglings. Experiments in social attraction for Hawaiian petrel and other Procellarid seabirds have demonstrated the importance of strong acoustic signals, which attract seabirds to potential nesting sites (Sawyer and Fogle 2010, Buxton and Jones 2012, KWP 2019). Distributed burrows are less likely to provide this strong acoustic attraction. Less experienced individuals, such as juveniles, are likely unable to compete for desirable burrows in higher density areas, leading them to prospect within lower density areas like the Kahikinui PMA and leaving for more desirable burrows once their competitive fitness has increased. This may be the cause of the observed lower reproductive rates, fewer active burrows, and lower recruitment at the PMA than observed at the AWS and Haleakalā National Park. These deviations from the assumptions made to estimate the benefits of Auwahi Wind's predator control program mean that benefits cannot be accurately gauged using the metrics in the HCP and adaptive management is required. Auwahi Wind has outlined below a proposed alternative to calculate the benefit for the Kahikinui PMA.

The HCP includes specific language to determine if adaptive management is warranted. The HCP states:

> "*In order to test the assumption that the baseline conditions presented in this HCP are representative of local conditions, Auwahi Wind will compare the results of monitoring at the [DKIST]* [1] *control site to the baseline population model parameters for the duration of the ATST monitoring. If the conditions at the [DKIST] site differ from the assumptions of the baseline*

[1] The name of the Advanced Technology Solar Telescope (ATST) changed to the Daniel K. Inouye Solar Telescope (DKIST) in 2013. Following the conclusion of the DKIST HCP and Biological Opinion in 2018, the site is referred to as the Alpine Wildlife Sanctuary. The HCP refers to this site as ATST. Where information references data collected under the DKIST HCP, DKIST is referenced. References to the site use the name Alpine Wildlife Sanctuary (AWS).

population model, Auwahi Wind will adjust their mitigation targets accordingly, in consultation with DOFAW and USFWS."

The data from the DKIST control site illustrate the number of active burrows was between 8 and 14 for all years (Table 4; Chen et al. 2018). The data show a flat trend over the monitored years, although a linear regression is not significant (p=0.92), which is expected when the sample size is small (n=8 years) and variation is high (mean=10.38, Std. Dev.=2.1, CV=0.2). This illustrates the baseline number of active burrows is likely to be stable which differs from the assumptions of the baseline population model and triggers adaptive management. Through Auwahi Wind's monitoring of the mitigation site, the "number of active burrows" remained stable similar to the DKIST site. As stated in the DKIST Final Report (Chen et al. 2019), "In consultation with DOFAW and USFWS, the DKIST Team determined that the most accurate way to determine whether Net Recovery Benefit has been achieved is to use rates of predation 'before and after' implementation of the mitigation measures." The calculated offset of Auwahi Wind's mitigation at the Kahikinui PMA must consider the observed increases in adult survivorship and fledging success, rather than the modeled benefits of predator control (Figure 12).

The mitigation credit for Auwahi Wind must account for the additional chicks surviving to adulthood as a result of predator control. Data collected in 2012 were intended to serve as a baseline for the number of fledglings produced at the Kahikinui PMA. However, the monitoring methods used in 2012 were not consistent with methods employed from 2013 onwards where game cameras provided improved data for evaluating fledging success. To be conservative, Auwahi Wind proposes using results from the 2013-2014 breeding seasons (the first monitoring years utilizing game camera monitoring) as the baseline value for fledging success. In 2013 and 2014, 13 fledglings were produced at Kahikinui PMA, or an average of 6.5 a year. The benefit of additional chicks surviving to adulthood will be calculated by Auwahi Wind receiving credit for each fledgling produced above 6.5 per year. Each fledgling will be converted to an adult equivalent at a rate of 30 percent based on findings from Simons (1984) and Ainley et al. (2001). For example, 8 fledglings produced in a given year would equate to a benefit of 1.5 fledglings, or 0.45 adults. For the monitored years with predator control (2015 to 2019), an average of 8.8 chicks fledged per year for an estimated increase in fledging success of 11.5 fledglings or 3.5 adult equivalents (Table 5). This assessment of increased fledging success is conservative in favor of the petrel, as the baseline includes benefits from some predator control effort and does not calculate a benefit associated with the 2013 and 2014 years in which some predator control was implemented.

In addition to helping with increased fledging success, the predator control increases the likelihood of adult survival. The benefit of increased adult survivorship will be calculated by comparing the average adult predation rate documented in years 2011 and 2012 to the adult survival after predator control was implemented. The use of 2011 and 2012 as a baseline for adult predation events differs from the use of 2013 and 2014 for chicks, because the monitoring methods used could detect adult predation events in all years, and 2011 and 2012 had no predator control. To estimate the reduction in adult predation, the number of adult predation events documented per consistently active burrow. A consistently active burrow year is one active burrow for one year and excludes prospecting burrows visited only occasionally early in the breeding season (March – July) and thereby more accurately estimates the number of adults present at the site and at risk of predation (Table 1). The average adult predation rate prior to predator control (4 adults predated per 66 consistently active burrow years or 6.1 percent of consistently active burrows) is compared to the average adult predation rate documented after implementation of predator control (0 adults predated in 199 consistently active burrow years). This rate (6.1 percent) is then multiplied by the number of consistently active burrows in a given year to estimate the increased adult survivorship, for a total of approximately 12 adults prevented from predation (see Table 6).

Combining the benefits to fledglings and adults provides an estimate of the total benefit of Auwahi Wind's predator control at the Kahikinui PMA. These two benefit calculations result in an estimated 11.5 additional petrel chicks fledged from 2015 to 2019 (equaling 3.45 adults), and 12.06 adult petrels prevented from predation for a total of 15.51 adult petrel equivalents through the 2019 breeding season.

It is important to note that there are also unquantifiable benefits provided by Auwahi Wind's efforts at the Kahikinui PMA. The predator control conducted by Auwahi Wind results in fewer predators impacting burrows in the adjacent AWS, Nakula NAR (Learned 2020), and Haleakalā National Park, providing benefits to these management areas. The species clearly benefits from predator control reducing the negative impacts of predators throughout the entire colony. Additionally, the continued discovery of new burrows suggests more burrows are likely present and benefiting from predator control but are not documented. These benefits provide additional certainty that the Auwahi Wind HCP has provided a net environmental benefit and continues to aid in the recovery of this species.

5.2 HCP Amendment

In FY 2019, Auwahi Staff met with USFWS and DOFAW HCP staff to discuss the status of Hawaiian petrel mitigation and current take levels (March 9, 2020). Based on current Evidence of Absence modeling from post-construction mortality monitoring results, Auwahi Wind will not exceed Tier one take levels for Hawaiian petrel and most likely will not exceed 20 petrels over the life of the Project. Auwahi Wind is working with USFWS/DOFAW staff on a major HCP Amendment to reduce permitted take of Hawaiian petrel. Mitigation efforts at the Kahikinui PMA will remain the same. The Hawaiian petrel HCP amendment will be discussed in the next Endangered Species Recovery Committee HCP annual review to gather input. An application will be submitted following receipt their recommendations with the goal of submitting in Fiscal Year (FY) 2021.

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Tables and Figures

Table 1. Seasonal Status Categories of Hawaiian Petrel Burrows at the End of the Breeding Season, based on Visit Data and Game Camera Data

<table>
<tr><th>Seasonal Status</th><th>Definition</th><th colspan="3">Categories for Assessing Reproductive Success</th></tr>
<tr><td>Successful</td><td>Chick fledged, indicated on a game camera, no signs of predation.</td><td rowspan="5">Active</td><td rowspan="4">Consistently Active</td><td rowspan="3">Breeding Activity</td></tr>
<tr><td>Probably Successful</td><td>Toothpick disturbance and reproductive sign[2] present at active burrow entrance in October and no sign of depredation.</td></tr>
<tr><td>Failed</td><td>Observed depredation, or reproductive sign observed but ceased before fledging period in October.</td></tr>
<tr><td>Occupied by Non-breeder/Failed</td><td>Initial signs of activity, no reproductive sign observed and activity ceased before the October fledging.</td><td>Excluded</td></tr>
<tr><td>Prospecting</td><td>Burrows that were visited by adults only occasionally during the start of the season (March – July).</td><td colspan="2">Excluded</td></tr>
<tr><td>Seasonally Inactive</td><td>No toothpick disturbance or activity sign[1] during any burrow checks.</td><td colspan="3">Excluded</td></tr>
<tr><td colspan="5">[1] Activity sign includes: bird on camera, droppings, tracks, feathers, and odor
[2] Reproductive sign includes: egg, eggshell, chick down, chick</td></tr>
</table>

Table 2. Seasonal Status of Hawaiian Petrel Burrows in 2019

<table>
<tr><th>Seasonal Status</th><th>No. of Burrows</th><th colspan="3">Categories for Assessing Reproductive Success</th></tr>
<tr><td>Successful</td><td>9</td><td rowspan="5">39 Active</td><td rowspan="4">28 Consistently Active</td><td rowspan="3">11 Breeding Activity</td></tr>
<tr><td>Probably Successful</td><td>0</td></tr>
<tr><td>Failed</td><td>2</td></tr>
<tr><td>Occupied by Non-breeder/Failed</td><td>17</td><td>Excluded</td></tr>
<tr><td>Prospecting</td><td>11</td><td colspan="2">Excluded</td></tr>
<tr><td>Seasonally Inactive</td><td>37</td><td colspan="3">Excluded</td></tr>
<tr><td>TOTAL</td><td colspan="4">76</td></tr>
<tr><td colspan="5">Total number of burrows was 76 in 2019. 39 refers to the number of those 76 burrows that showed some sort of activity. 28 of those 39 were consistently active, and then 11 of those 28 showed breeding activity.</td></tr>
</table>

Table 3. Game Camera Hawaiian Petrel Burrow Monitoring Summary, 2019

Burrow Number	Seasonal Status	Last Date of Activity	Successfully Fledged Date
3	Successful	01-Nov-19	01-Nov-19
6	Successful	29-Oct-19	29-Oct-19
15	Successful	14-Oct-19	14-Oct-19
32	Successful	22-Oct-19	22-Oct-19
33	Successful	12-Oct-19	12-Oct-19
42	Successful	14-Oct-19	14-Oct-19
51	Successful	22-Oct-19	22-Oct-19
68	Successful	21-Oct-19	21-Oct-19
75	Successful	04-Oct-19	04-Oct 19
1	Seasonally inactive		
2	Seasonally inactive		
5	Seasonally inactive		
7	Seasonally inactive		
8	Seasonally inactive		
11	Seasonally inactive		
12	Seasonally inactive		
14	Seasonally inactive		
16	Seasonally inactive		
17	Seasonally inactive		
18	Seasonally inactive		
19	Seasonally inactive		
20	Seasonally inactive		
24	Seasonally inactive		
26	Seasonally inactive		
28	Seasonally inactive		
29	Seasonally inactive		
36	Seasonally inactive		
37	Seasonally inactive		
38	Seasonally inactive		
40	Seasonally inactive		
41	Seasonally inactive		
43	Seasonally inactive		
44	Seasonally inactive		
45	Seasonally inactive		
46	Seasonally inactive		

Table 3. Game Camera Hawaiian Petrel Burrow Monitoring Summary, 2019 (continued)

Burrow Number	Seasonal Status	Last Date of Activity	Successfully Fledged Date
47	Seasonally inactive		
48	Seasonally inactive		
49	Seasonally inactive		
53	Seasonally inactive		
56	Seasonally inactive		
57	Seasonally inactive		
60	Seasonally inactive		
61	Seasonally inactive		
64	Seasonally inactive		
66	Seasonally inactive		
69	Seasonally inactive		
9	Failed or Occupied by Non-breeder	21-Jul-19	
23	Failed or Occupied by Non-breeder	03-May-19	
25	Failed or Occupied by Non-breeder	31-Jul-19	
27	Failed or Occupied by Non-breeder	23-Oct-19	
30	Failed or Occupied by Non-breeder	16-Aug-19	
31	Failed or Occupied by Non-breeder	07-Aug-19	
54	Failed or Occupied by Non-breeder	22-Aug-19	
55	Failed or Occupied by Non-breeder	30-Jun-19	
58	Failed or Occupied by Non-breeder	12-Aug-19	
62	Failed or Occupied by Non-breeder	05-Sep-19	
63	Failed or Occupied by Non-breeder	13-Sep-19	
65	Failed or Occupied by Non-breeder	13-Aug-19	
67	Failed or Occupied by Non-breeder	12-Aug-19	
71	Failed or Occupied by Non-breeder	16-Jul-19	
74	Failed or Occupied by Non-breeder	04-Aug-19	
78	Failed or Occupied by Non-breeder	19-Jul-19	
34	Failed[1]	19-Aug-19	
39	Failed[2]	03-Sep-19	

[1] Dead chick found on 8/8/19.

[2] Egg found outside burrow on 8/8/19.

Table 4. Monitoring of Active Burrows from DKIST 2011-2018

Year	DKIST Active Petrel Burrows at the Control Site
2011	14
2012	9
2013	8
2014	10
2015	9
2016	10
2017	10
2018	13

Table 5. Estimated Increased Fledging Success at Kahikinui PMA Resulting from Mitigation

Year	Period	Chicks Fledged	Total Chicks Fledged	Average Chicks Fledged Per Year	Estimated Increase in Fledged Chicks Over Baseline	Total Estimated Additional Chicks Fledged	Estimated Adult Equivalents
2013	Baseline	7	13	6.5			
2014		6					
2015	Active Manageme nt	8	44	8.8	1.5	11.5	**3.45**
2016		8			1.5		
2017		10			3.5		
2018		9			2.5		
2019		9			2.5		

Table 6. Estimated Increased Adult Petrel Survival at Kahikinui PMA Resulting from Mitigation

Year	Period	Consistently Active burrows	Total Burrow Years	Adult Predation Events	Total Adult Predations Observed	Average Adult Predation Per Burrow Year	Estimated Adult Predations Prevented Per Year	Total Estimated Adults Predations Prevented
2011	Baseline	33	66	2	4	0.06		
2012		33		2				
2013	Active Management	26	199	0	0	0	1.58	**12.06**
2014		29		0			1.76	
2015		31		0			1.88	
2016		25		0			1.52	
2017		29		0			1.76	
2018		31		0			1.88	
2019		28		0			1.70	

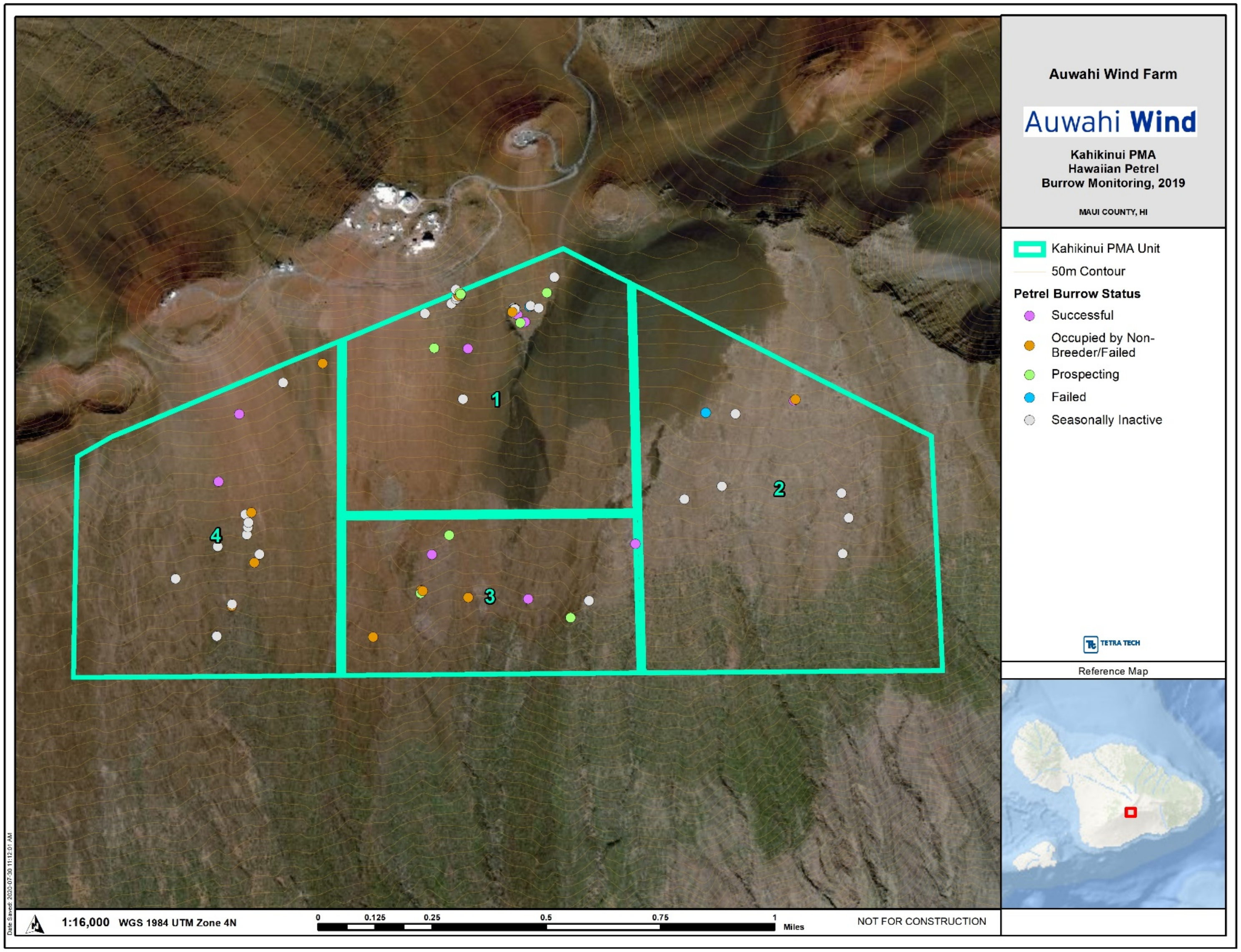


Figure 1. Kahikinui Petrel Management Area, 2019

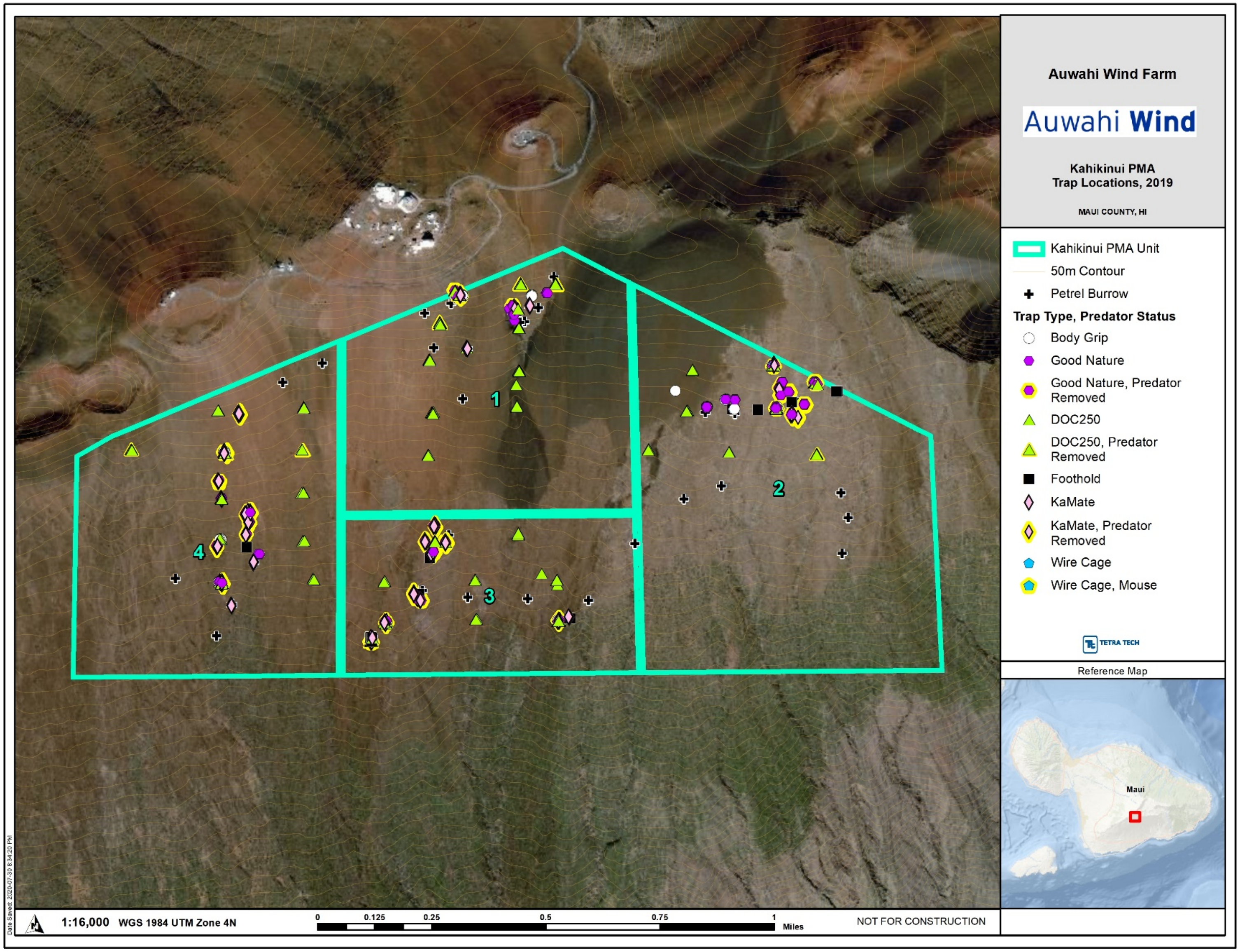


Figure 2. Trap Locations at the Kahikinui PMA, 2019

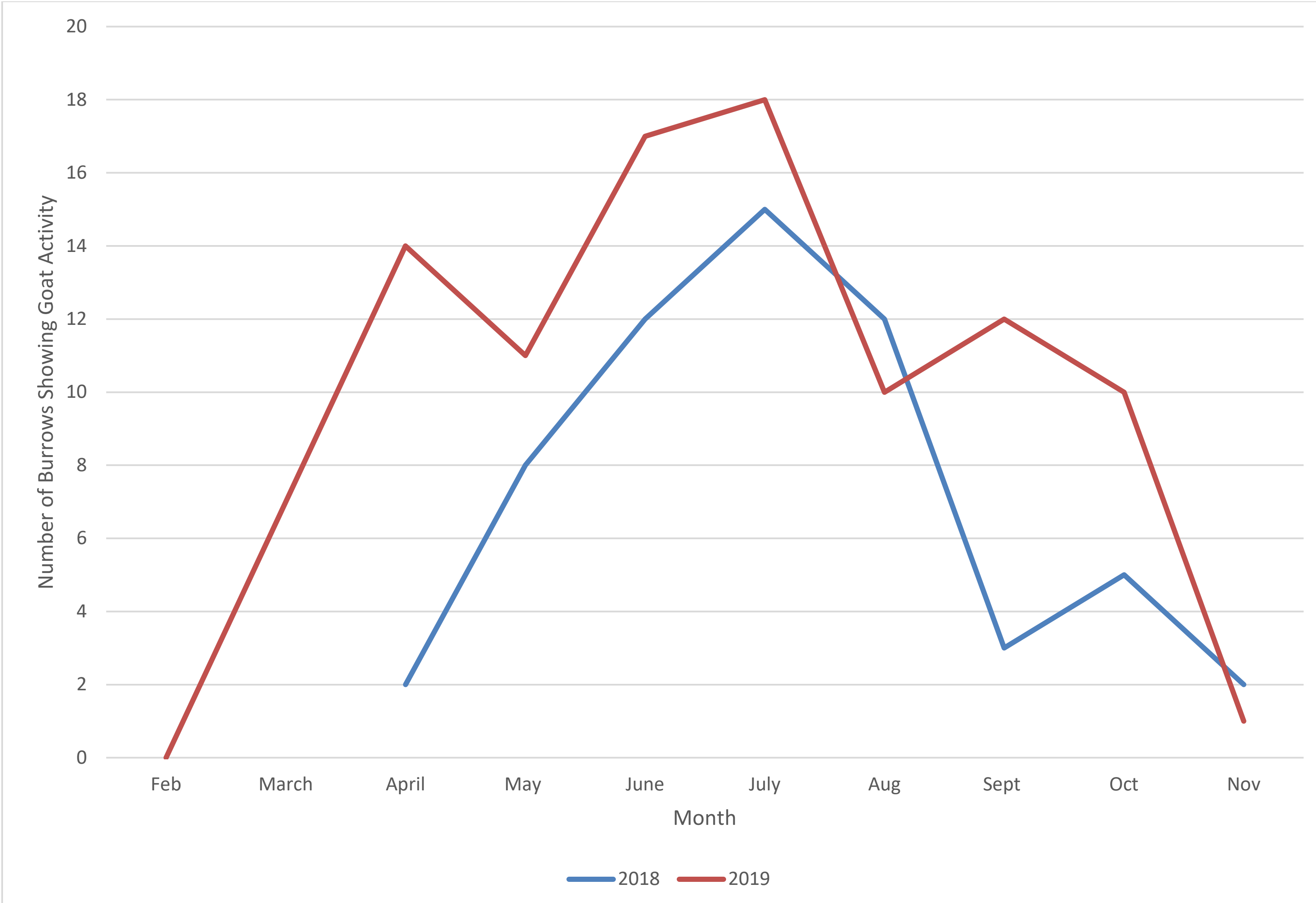


Figure 3. Seasonal Occurrence of Goats Detected at Burrows by Game Cameras 2018 and 2019

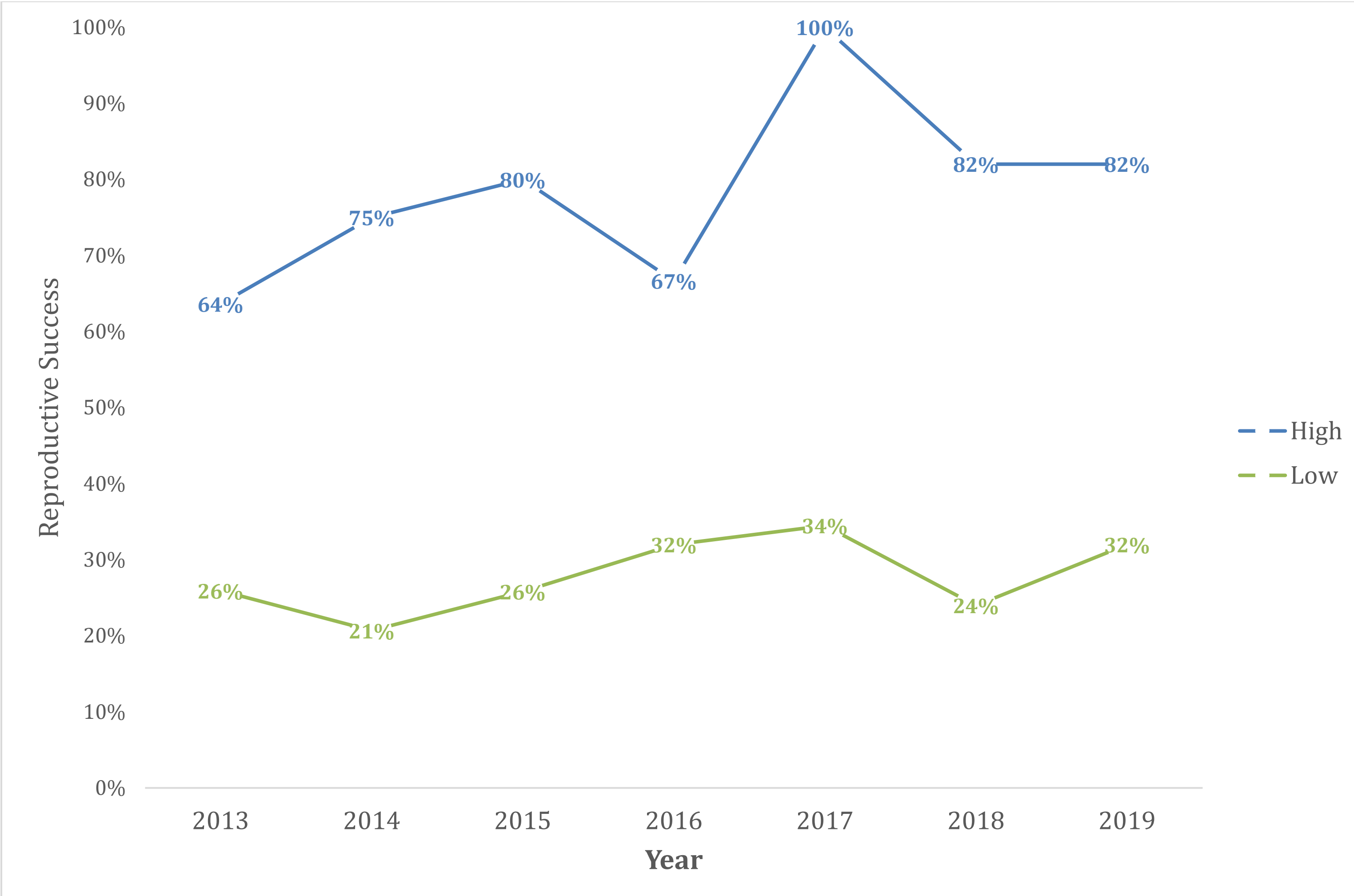


Figure 4. Reproductive Success within Kahikinui PMA, 2013 – 2019. High assumes only those burrows with reproductive sign had breeding adults; and low assumes all consistently active burrows had breeding adults.

Figure 5. Kahikinui PMA Rodent/Mongoose Tracking Tunnel Results, 2019

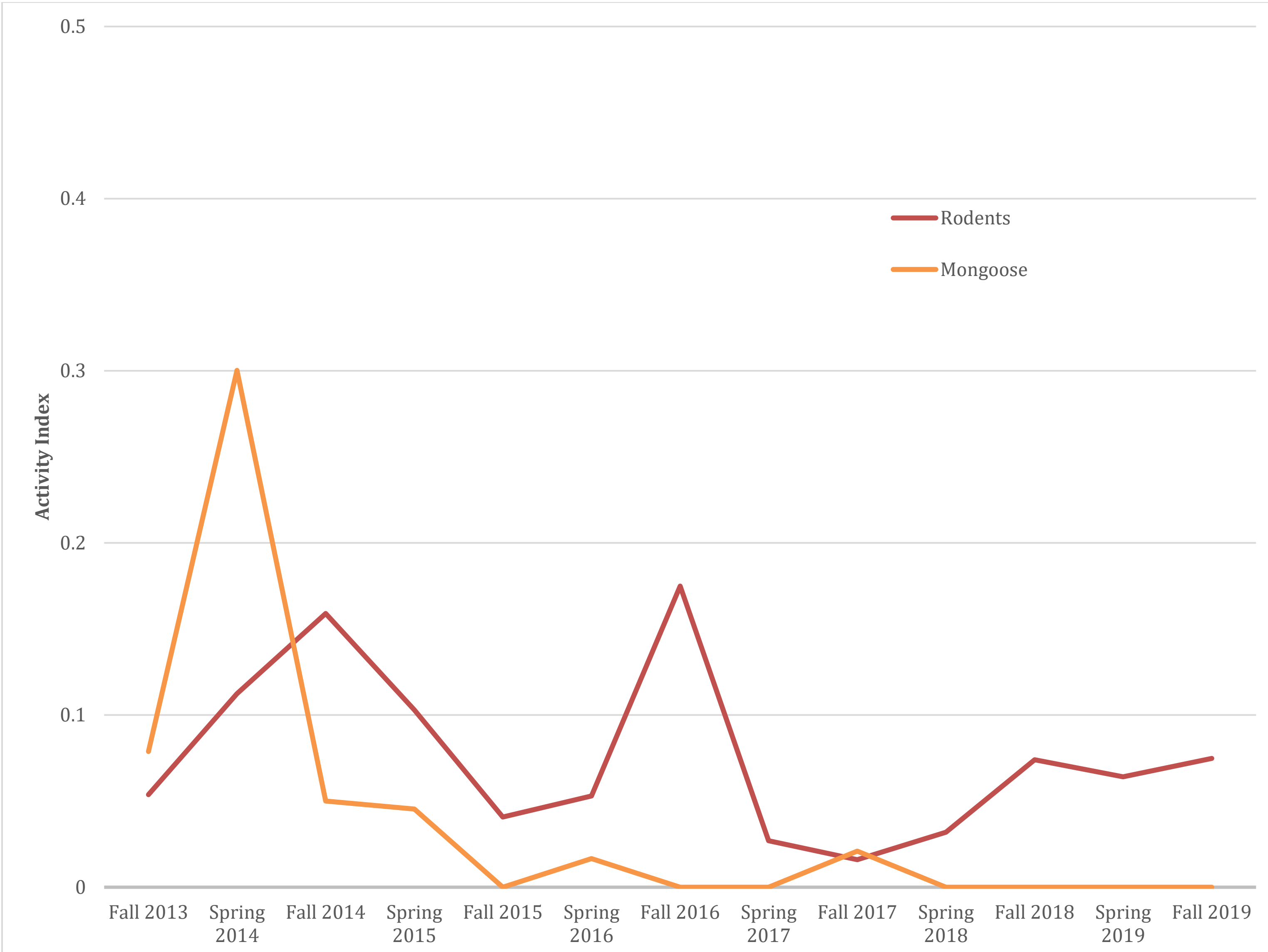


Figure 6. Summary of Rodent and Mongoose Tracking Tunnel Results, 2013 – 2019

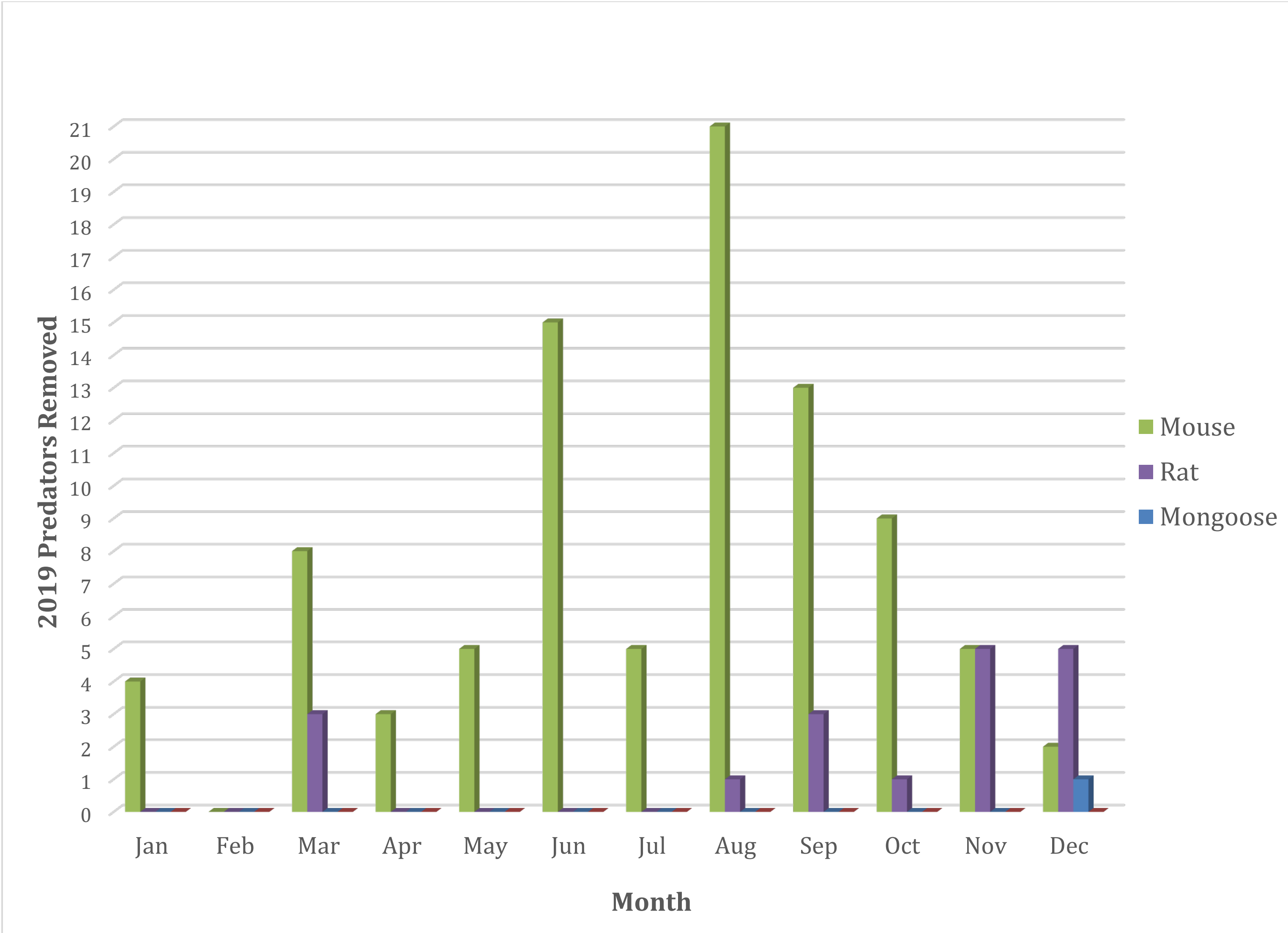


Figure 7. Monthly Summary of Predator Trapping Results, January – December 2019

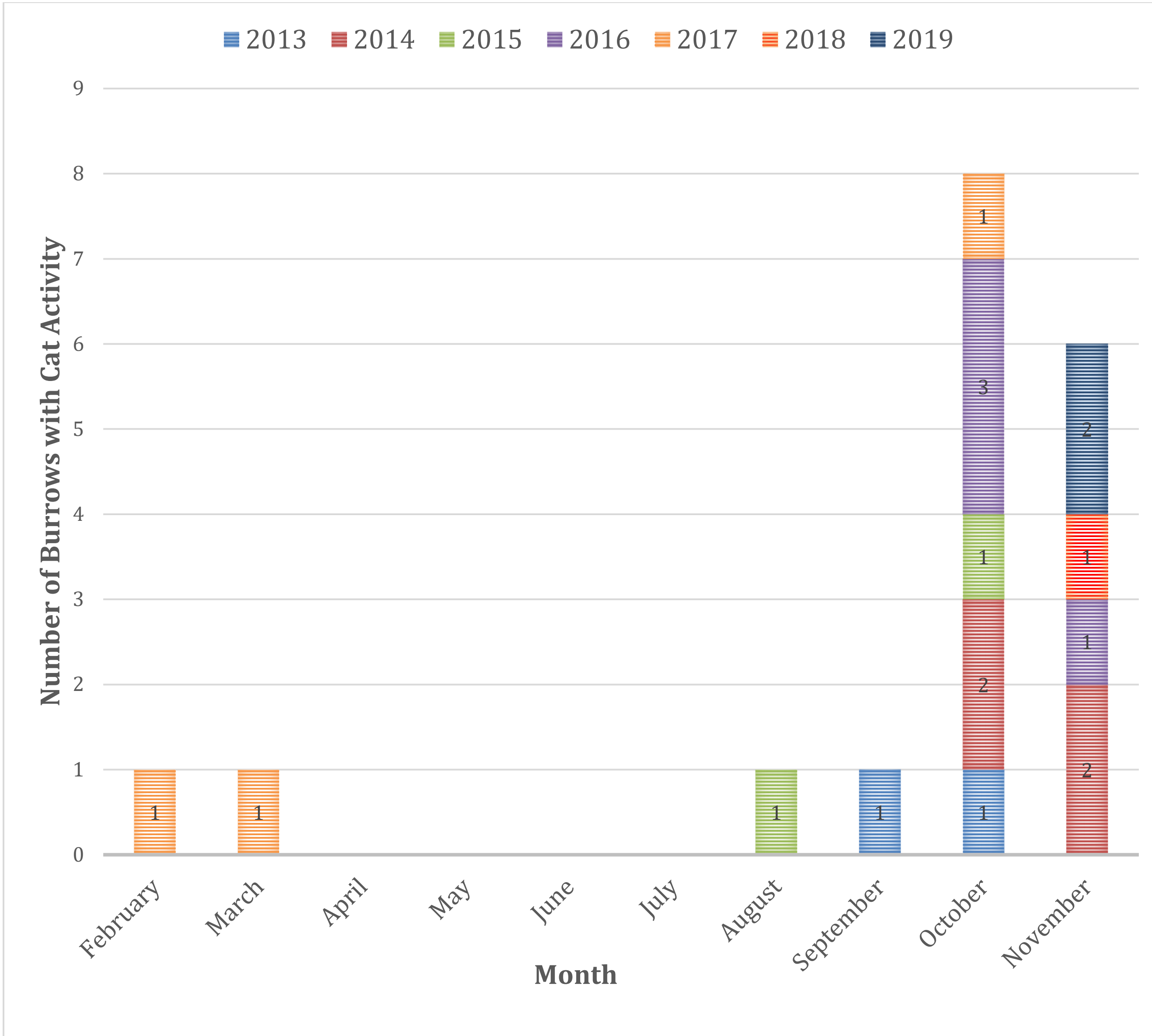


Figure 8. **Seasonal Occurrence of Cats Detected at Burrows by Game Cameras, 2013-2019**

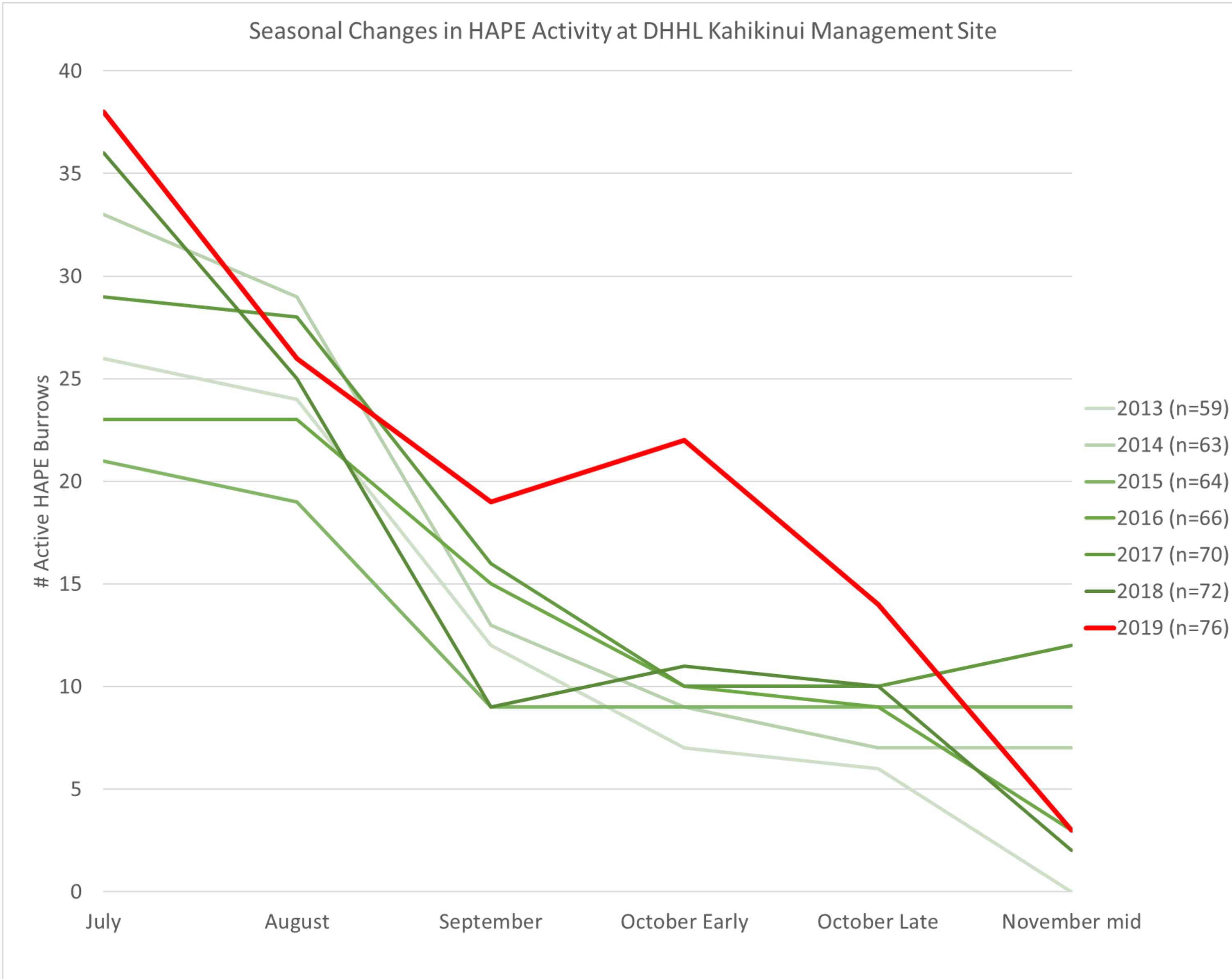


Figure 9. Monthly Summary of Hawaiian Petrel Burrow Activity, July – November 2019

Figure 10. Goats Trampling Burrows Within the Kahikinui PMA. Goat on Horizon Photo Taken On April 3, 2019 While Conducting Hawaiian Petrel Burrow and Predator Trap Checks.

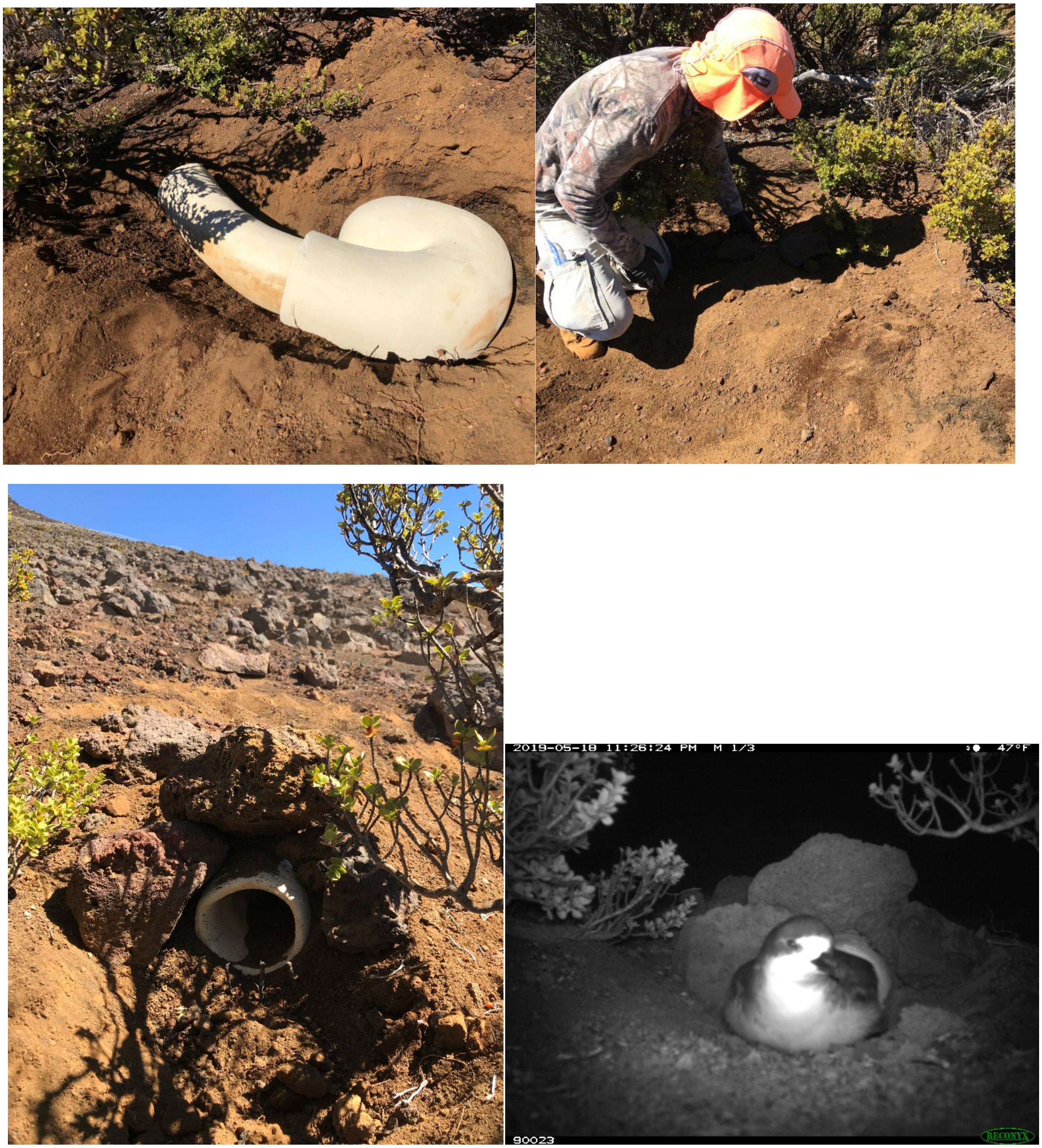


Figure 11. Artificial Clay Burrow Installations and Petrel Use

Figure 11. Artificial Clay Burrow Installations and Petrel Use (continued)

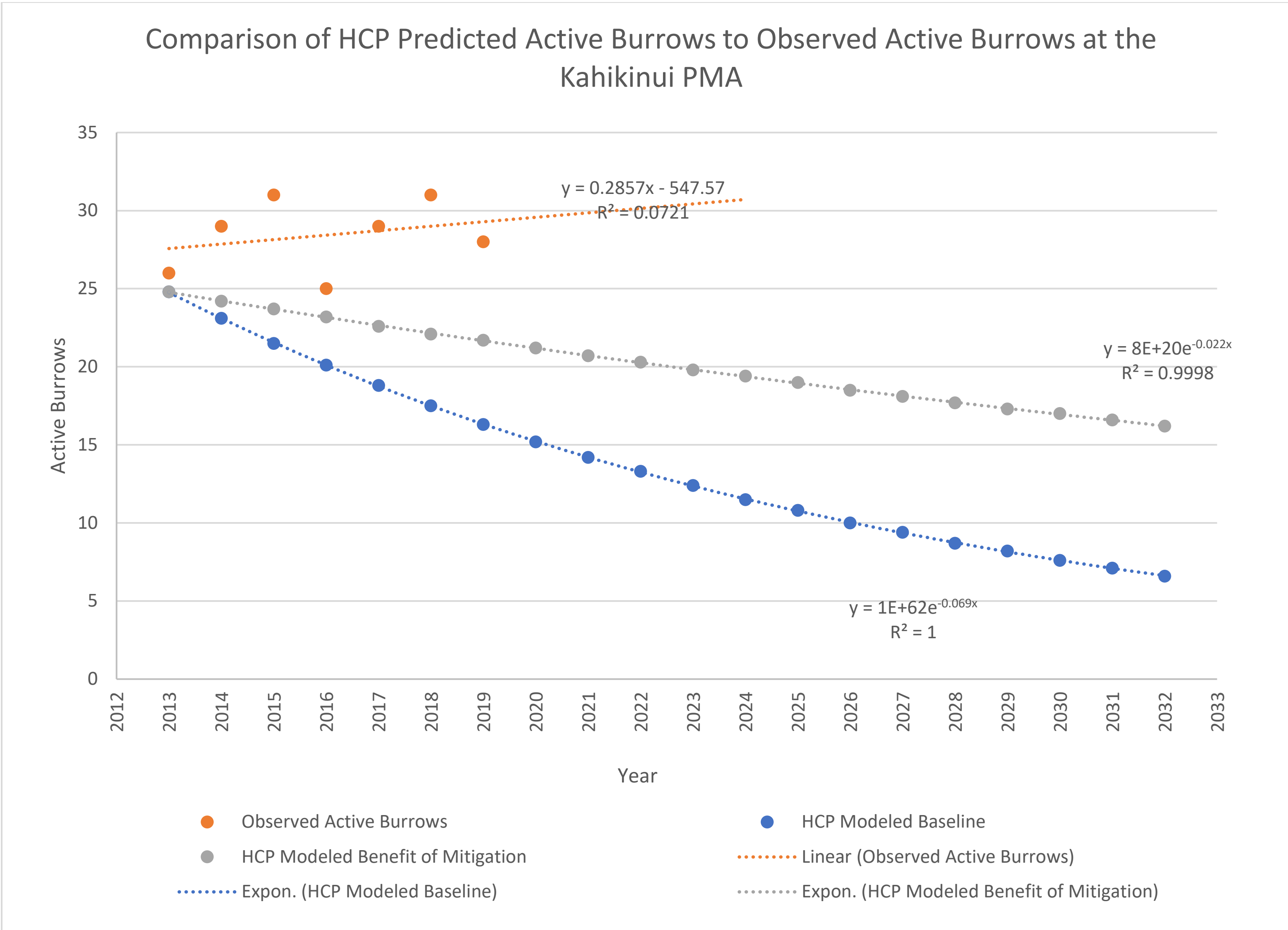


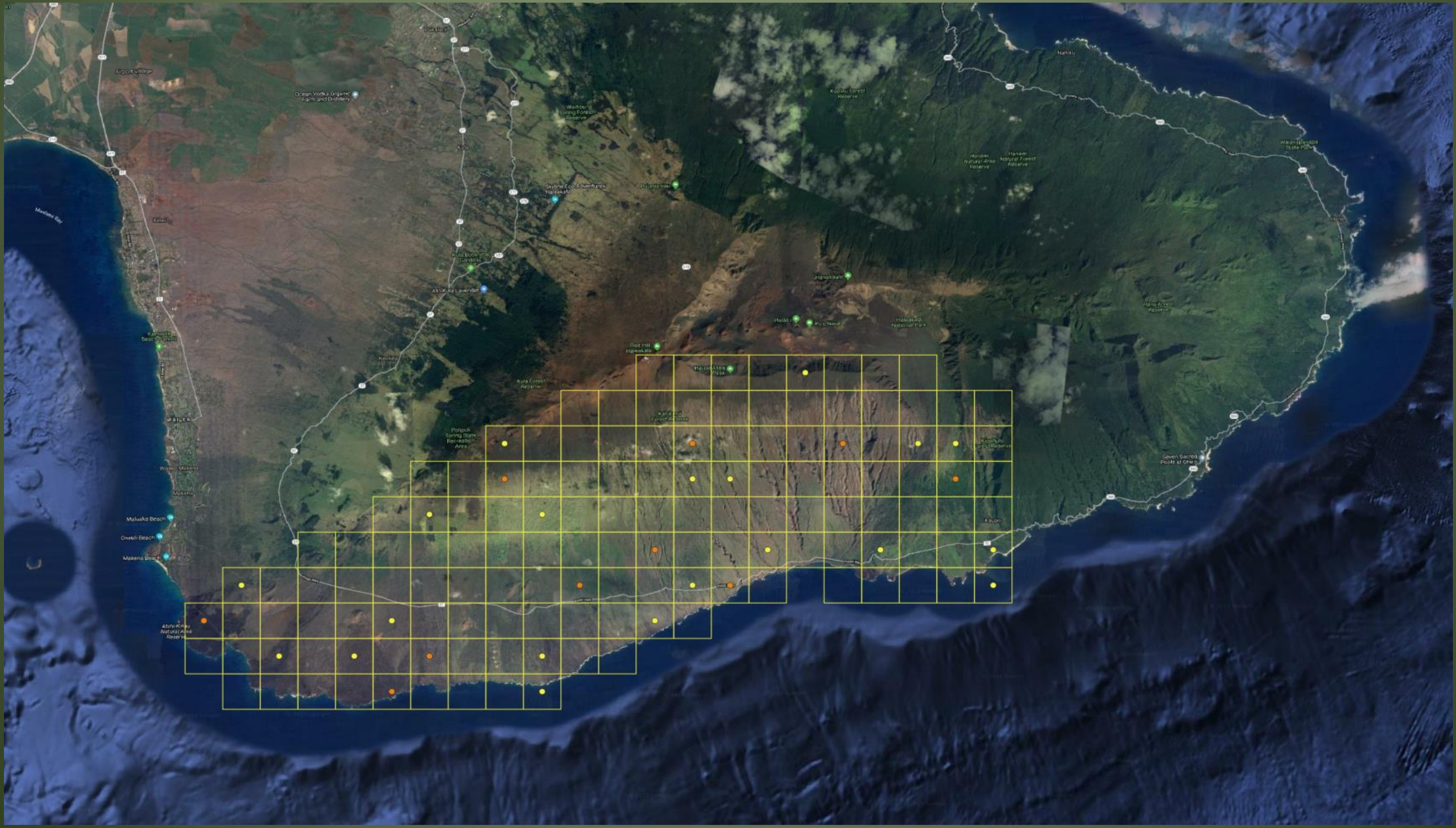
Figure 12. Comparison of HCP Modeled Changes in Active Burrows to Observed Changes in Active Burrows Resulting from Predator Control

Attachment 4

Leeward Haleakalā Hoary Bat Revised Update

LEEWARD HALEAKALA STUDY AREA

- Same methods as the Oahu study
- 2.3 km^2 grid over entire island, then clipped to the study area
- 20 cells selected from sample of 141 within the study area



LEEWARD HALEAKALA OCCUPANCY STUDY

- 20 SM4Bat acoustic detectors
- Same set-up as Oahu study
- Deployed in July 2019
- Checked every 2 months

LEEWARD HALEAKALA OCCUPANCY STUDY

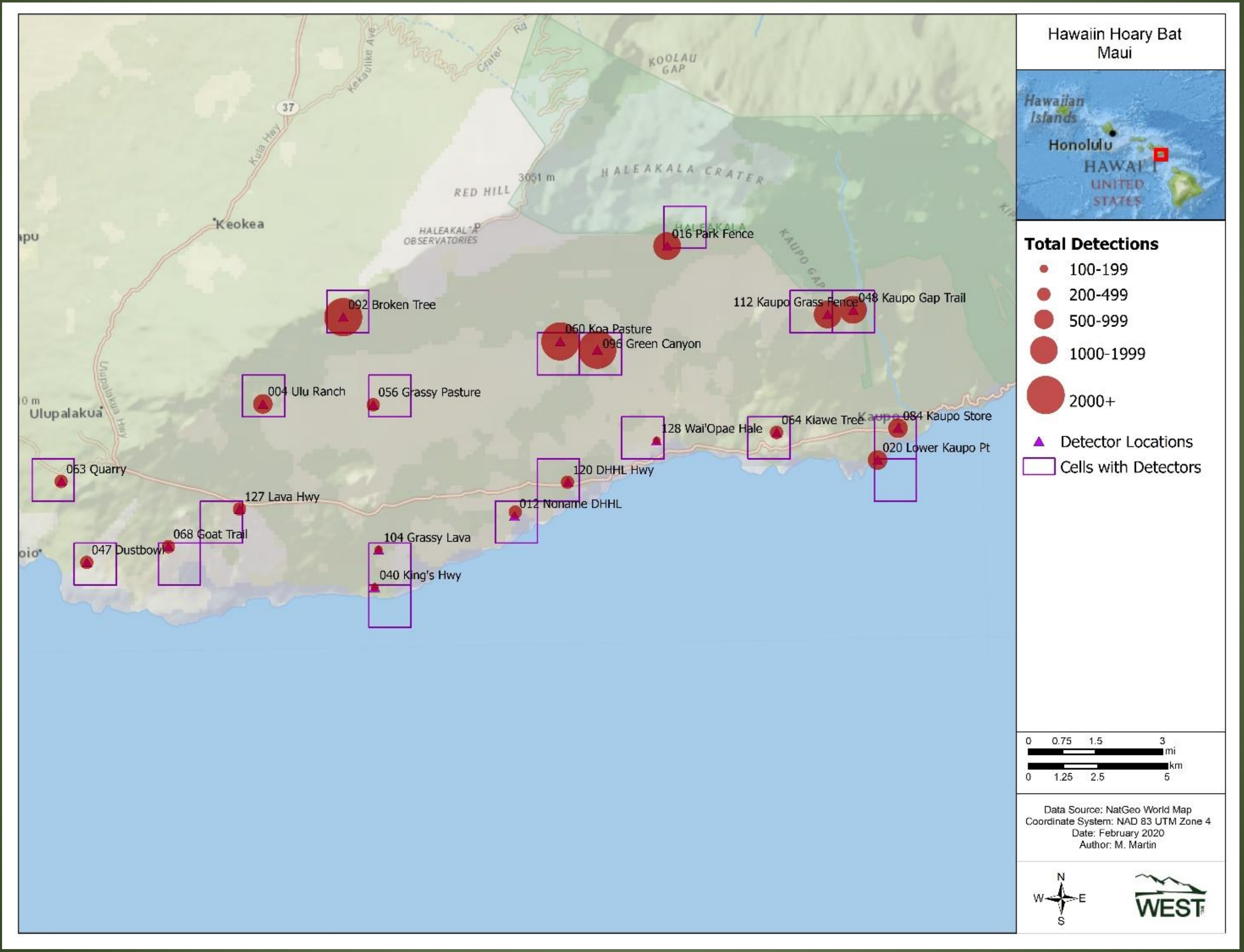
LEEWARD HALEAKALA
July 18 – December 20

- 20 detectors
- 66-157 detector nights
- ~17,429 detections
- 115 – 3,267 detections per site (**median = 455**)
- 0.71 – 27.85 calls/detector night (lactation and post-lactation)
- Feeding buzzes at all locations
- Proportion of nights with detections = 0.19 – 0.96

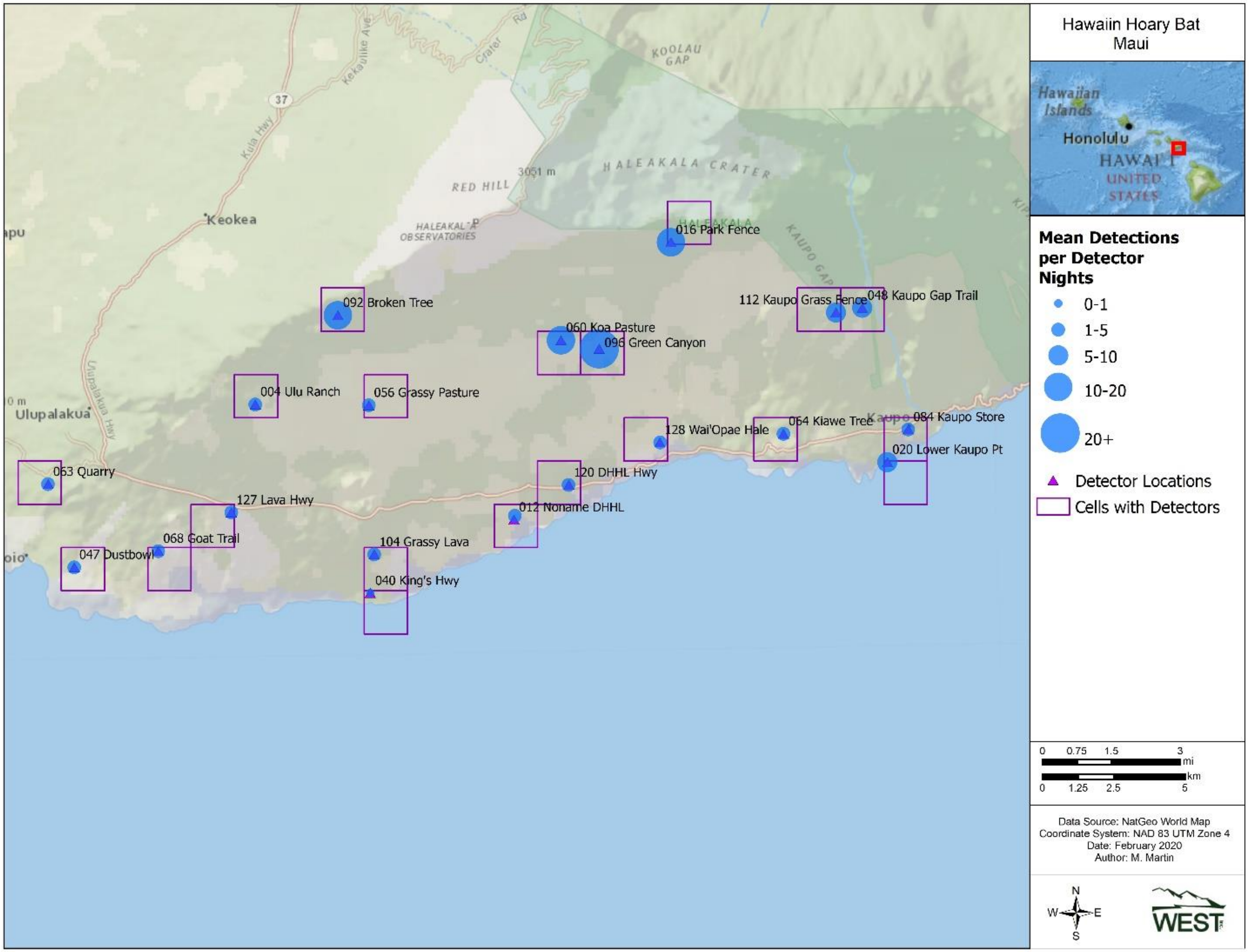
OAHU – ISLAND WIDE
June 2017 – October 2019

- 87 detectors
- 106 - 800 detector nights
- ~12,200 detections
- 0 – 2,551 detections per site (**median = 11**)
- 0 – 21 calls/detector night (lactation and post-lactation
- Feeding buzzes at 39 of 87 locations
- Proportion of nights with detections = 0 – 0.84

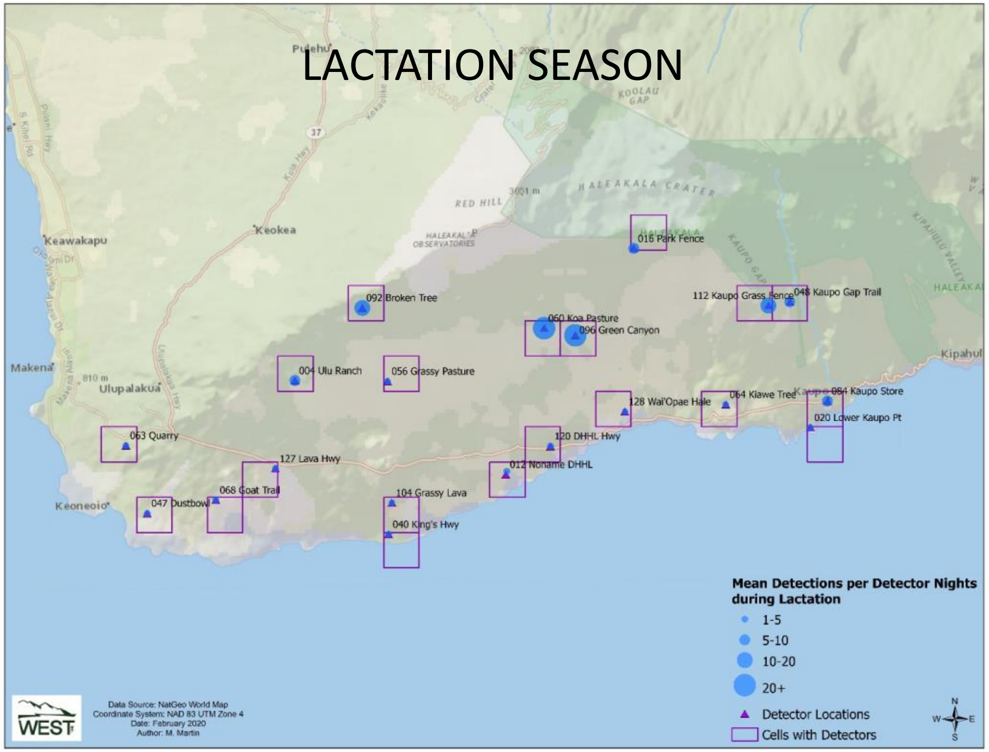
LEEWARD HALEAKALA – TOTAL DETECTIONS JULY 19 – DEC 20, 2019

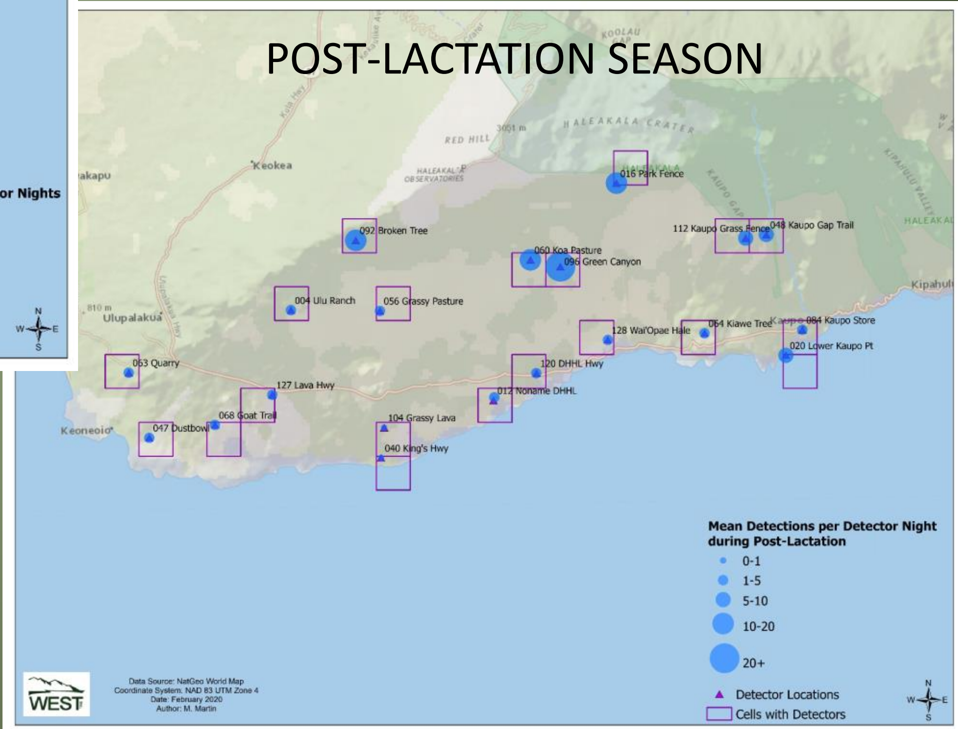


LEEWARD HALEAKALA – MEAN DETECTIONS / NIGHT
JULY 19 – DEC 20, 2019

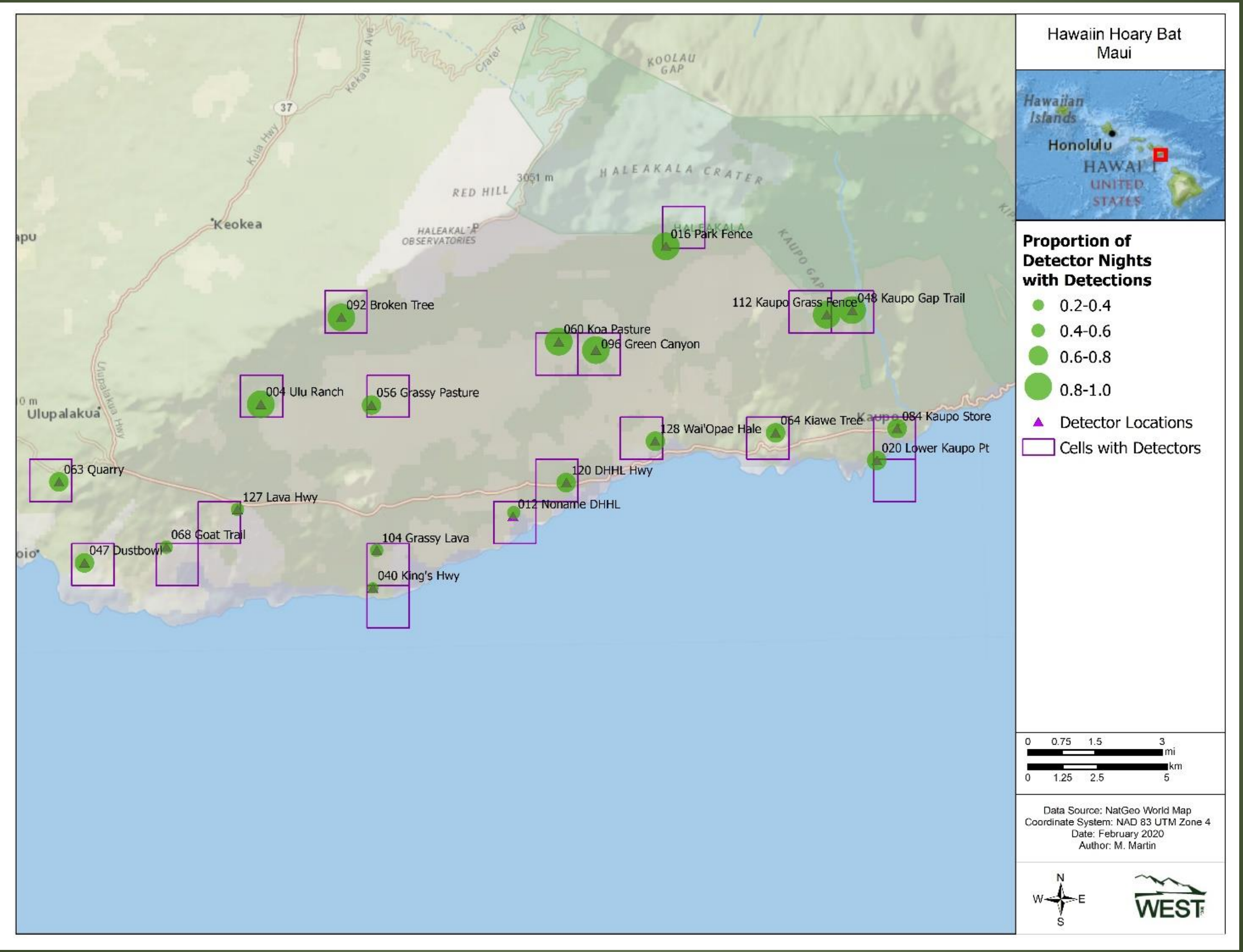


LEEWARD HALEAKALA – MEAN DETECTIONS / NIGHT

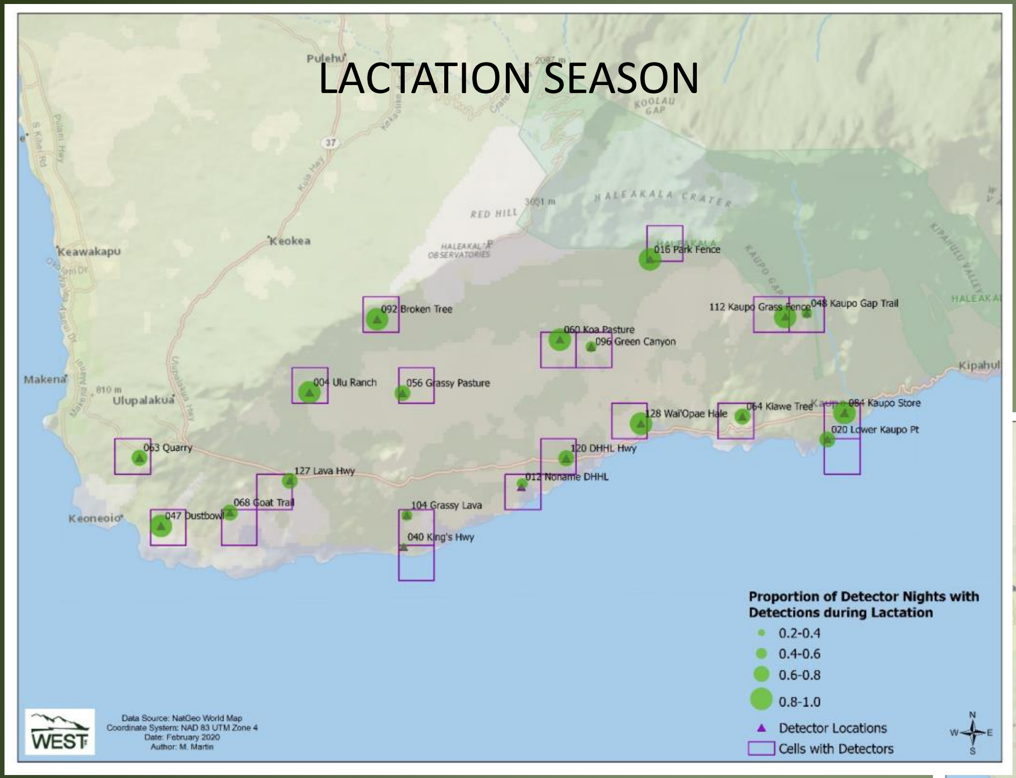


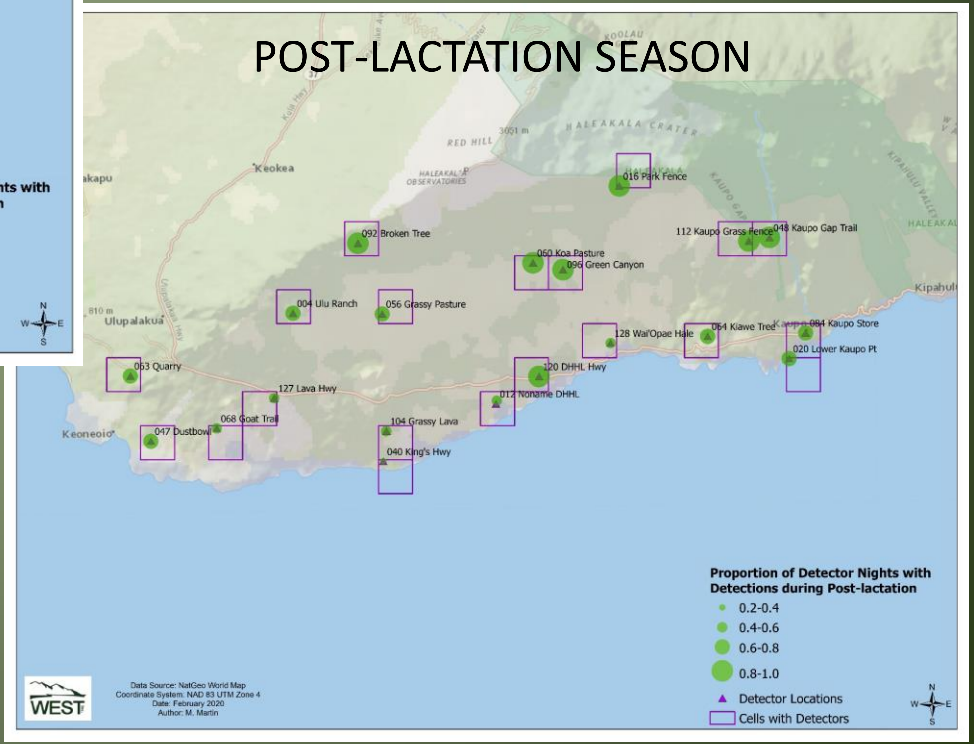


LEEWARD HALEAKALA – PROPORTION NIGHTS WITH DETECTIONS JULY 19 – DEC 20, 2019



LEEWARD HALEAKALA – PROPORTION NIGHTS WITH DETECTIONS





LEEWARD HALEAKALA – INITIAL INSIGHTS

- Bat activity widespread across the leeward Haleakala study area
- Bat activity greater and more frequent in mid-upper elevations and eastern side of study area during lactation and post-lactation periods
- Evidence of foraging activity at all sample locations
- Bat activity much greater than on Oahu

Attachment 5

Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) Behavior at Wind Turbines on Maui

Technical Report HCSU-093

HAWAIIAN HOARY BAT (*LASIURUS CINEREUS SEMOTUS*) BEHAVIOR AT WIND TURBINES ON MAUI

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May 2020

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ABSTRACT

This study examined the activity of the endemic Hawaiian hoary bat (*Lasiurus cinereus semotus*) at wind turbines operated by Auwahi Wind Energy, LLC, on southern Maui Island, from August to November 2018. The research was conducted to assess the potential effect of wind speed and turbine operation on bat presence and behavior and compared information obtained from both acoustic monitoring and thermal videography.

During the four months of nightly surveillance at four wind turbines, we observed 384 visual (videographic) and 244 acoustic detection events involving bats. Bats were infrequently detected, averaging 0.08 events per hour for both visual and acoustic samples. Detections occurred throughout the monitoring period, but bat presence was only evident for a fraction (acoustic: 30%; visual: 44%) of the turbine-nights sampled. Bats were present throughout the night, but detections exhibited a unimodal peak centered on the first third of the night, with events largely absent in the latter half of the night and no apparent seasonal trend towards earlier or later occurrence within nights. However, a decline in the visual detection rate was noted over the four-month period (a similar assessment was not available from acoustic samples due to missing data for much of the later months). Visual bat detections were not significantly correlated over nights (i.e., temporally), but were positively associated among turbines (i.e., spatially).

Visual detections were generally brief (median = 9.0 sec), infrequent (median time between events = 49.0 min), and involved single passes (57%) largely comprised of a single bat (94%). The amount of time during which bats were visually observed amounted to only 0.05% of total videographic monitoring (2.5 hours of 5,066 total hours). Although not directly comparable to the video results because of differences in the volume of airspace sampled and nature of observation, acoustic detection events were similarly brief (median = 6.0 sec), infrequent (median time between passes = 38.8 min), and also composed only 0.05% of the total period of acoustic monitoring (1.6 hours of 3,036 total hours). Most visual observations (61%) were of individuals flying at some point during the event to within about 15 m of the turbine nacelle (machinery housing atop the monopole). Erratic flight paths were the most prevalent flight type with bats often repeatedly approaching and circling the nacelle. Terminal-phase ("feeding buzz") calls were only noted in 3% of all acoustic events.

Bats were most frequently detected visually at relatively low wind speeds (median = 3.4 m/sec); however, 10% of events occurred at wind speeds over 8.5 m/sec. Nightly bat detection rates for the four-month period of monitoring were negatively correlated with total daily precipitation. Generalized linear mixed model analysis confirmed that detection rates were negatively associated with wind speed and precipitation and indicated a positive relation with intermittent wind speed and its consequent effect on turbine blade rotation (i.e., frequent intervals of starting and stopping).

The co-occurrence of bat detection obtained from videographic and acoustic monitoring methods was generally low, and in instances when individuals were visually observed, bats were detected acoustically during only 12% (within a 10-minute window), 22% (within a 2-hour window), and 56% (at some point during the entire night) of such events. Most visual detections (65% within a 2-hour window) lacking an acoustic detection involved bats observed flying within about 15 m of the turbine nacelle on which acoustic detector microphones were situated.

INTRODUCTION

The prevalence and causes of bird collisions with wind turbines have been studied and documented since the 1980s (e.g., Byrne 1983, Howell and Didonato 1991). Investigation into the scope of bat fatalities at wind energy facilities is a more recent development (e.g., Fiedler 2004, Johnson 2005, Kunz *et al.* 2007, Arnett *et al.* 2008). These studies have generally monitored bat acoustic activity at turbines to provide insight into the association of bat occurrence, turbine operation, and geographic and weather variables (e.g., Baerwald and Barclay 2009, Weller and Baldwin 2012, Foo *et al.* 2017).

Bats, however, are cryptic nocturnal mammals that can be difficult to sample during flight and at relevant heights. Recent research has found bats in flight may often forgo echolocation or vocalize in a way that is not detectable with common acoustic monitoring methods (Gorresen *et al.* 2017, Corcoran and Weller 2018). Silent flight behavior has implications for studies of bat behavior and management aimed at minimizing or avoiding fatalities associated with wind energy.

As an alternative to acoustic sampling, visual-based methods such as thermal imaging offer certain advantages due to its capacity to sample relatively large volumes of airspace over long periods and reveal aspects of bat behavior not readily obtained solely from acoustic data. To date, however, only a small number of studies have used thermal imaging to conduct long-term monitoring of bat behavior at wind turbines. These studies have shown bats engaged in investigative behavior of turbine blades, nacelles (machinery housing atop the monopole), and monopoles; repeated approaches after near strikes with moving blades; social interactions by multiple bats; and a concentration of flight activity on the leeward (downwind) side of turbines (Horn *et al.* 2008, Cryan *et al.* 2014, Gorresen *et al.* 2015b). Visual-based systems can produce higher detection probabilities than acoustic-only sampling (Gorresen *et al.* 2018) with the potential to improve assessments of bat activity and behavior at turbines (e.g., Korner-Nievergelt *et al.* 2013). However, although not relevant to Hawaiʻi (which harbors a single species of bat), video recordings are generally not informative for species identification.

Monitoring that combines both acoustic and visual-based systems may also have additional benefits in linking specific behaviors generally only evident when analyzed as paired data sources (e.g., response to deterrents [Gorresen *et al.* 2015a]; flight and vocalization indicative of foraging [Gorresen *et al.* 2018]; obstacle avoidance [Corcoran and Weller 2018]). Sampling with combined acoustic-visual systems may also help address questions related to the frequency of bat vocalization at turbines, a key consideration for management aimed at minimizing collision risk by curtailing turbine operation following the detection of vocalization (e.g., Hayes *et al.* 2019).

In light of the above, we initiated a study with support of Auwahi Wind Energy, LLC, that applied both acoustic and visual-based monitoring systems with the objective of examining bat behavior at wind turbines and its relation with wind speed, a principal variable in determining bat activity and collision risk at turbines (Korner-Nievergelt *et al.* 2013, Wellig *et al.* 2018). The Hawaiian hoary bat (*Lasiurus cinereus semotus*, Vespertilionidae) served as the focal species in this study because it is an endangered endemic susceptible to fatality by collision with moving wind turbine blades (Gorresen *et al.* 2015b) and the subject of management aimed at mitigating these effects (Mykleseth 2017, Tetra Tech 2018). The North American subspecies, *L. c. cinereus*, accounts for approximately 40% of all bat fatalities at turbines in continental North

America (Arnett and Baerwald 2013). Also known as the ʻŌpeʻapeʻa, the Hawaiian hoary bat is the only extant native terrestrial mammal and sole bat species in Hawaii State and occurs on all of the major islands (Tomich 1986). Given previous observations of cryptic vocalization by Hawaiian hoary bats in semi-natural environments (Gorresen *et al.* 2017), we also examined the correspondence between acoustic and visual-based detection rates of bats at wind turbines.

METHODS

Study Area

The study area was located on the wind energy facility operated by Auwahi Wind Energy, LLC, on southern Maui Island, Hawaii. Wind turbines at the facility consist of eight 3-megawatt WTGs (Siemens SWT-3.0-101, Hamburg, Germany), each with a hub height of 80 m, a rotor diameter of 101 m, a maximum height of 131 m, and a rotor-swept area of 8,012 m^2 (www.thewindpower.net/turbine_en_275_siemens_swt-3.0-101.php). Sampling for bat occurrence spanned a four-month period from August 1 to November 30, 2018, at four wind turbine generators (WTG 2, 4, 5, and 7) previously equipped with acoustic detectors managed by Natural Power Consultants, LLC (Saratoga Springs, New York, USA; described below).

Landcover in the area is dominated by dryland vegetation comprised of open grassland, wiliwili (*Erythrina sandwicensis*) groves, and kīawe (*Prosopis juliflora*). The moderately sloping area inclusive of the monitored turbines spans a low elevation range (150–315 m above sea level [asl]) near the coast and is situated over 7 km from tree vegetation that might serve as day-roost habitat (within the region, in areas generally >600 m asl).

Local climatic conditions in the area exhibit relatively constant temperatures, little rainfall, and persistent strong winds throughout much of the year. Sunset to sunrise (nighttime) temperature ranged from 29.1 to 25.9°C on August 1 and from 26.6 to 22.9°C on November 30 (recorded at a weather station located at sea-level 10.5 km west of the study area; www.wunderground.com/dashboard/pws/KHIKIHEI5; accessed December 3, 2018). Cumulative daily precipitation totaled 33.0 cm over the four-month study period (recorded at a weather station located 7.3 km east-northeast from the Auwahi Wind Energy facility [USGS 203721156151601 255.0 Kepuni Gulch Rain Gage; 225 m elevation] waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=203721156151601; accessed December 3, 2018; also available at https://doi.org/10.5066/F7P55KJN). Prevailing winds during this period were generally easterly, and nighttime wind speeds recorded at the nacelle (machinery housing atop the monopole) of sampled turbines averaged 7.1 m/sec (25.6 km/hr), with speeds above 13.0 m/sec recorded about 10% of the time (G. Akau, Auwahi Wind Energy, written comm., 2018). Wind speed and direction were recorded by an ultrasonic anemometer (FT702LT-V22, FT Technologies Ltd., Sunbury on Thames, United Kingdom) and adjusted for placement behind the rotors on a turbine nacelle. Wind speed data for the monitored turbines were provided by Auwahi Wind Energy.

Monitoring Bat Occurrence and Behavior

The rotor-swept area of each turbine was monitored using a surveillance camera equipped with a 19-mm lens (Axis Q1942-E, Axis Communications, Lund, Sweden) that imaged in the thermal infrared spectrum (~9,000–14,000 micrometers) of electromagnetic radiation. The camera sampled at a rate of 30 frames per second with a resolution of 640 by 480 pixels and required no supplemental illumination. The camera was mounted approximately 4 m from the ground on the turbine monopole using a mounting base (RigMount X6 Magnet Camera Mounting Platform, Rigwheels, Minneapolis, Minnesota, USA; Figure 1). The camera was aimed directly up the tower such that the video scene included the monopole, turbine blades, nacelle, and surrounding airspace. Cameras were placed on the leeward (downwind) side of the turbines to image the perspective at which bat activity has been generally shown to be highest in prior studies (Cryan *et al.* 2014, Gorresen *et al.* 2015b).

Figure 1. Placement of camera on turbine monopole (circled, left panel) and camera orientation (right panel).

Video imagery was processed using custom-written code and matrix-based statistical software (Mathworks, Natick, Massachusetts, USA) to automatically detect animals flying through the video scenes. Video was recorded at 30 frames per second, and every 10th video frame was analyzed resulting in the detection of events lasting as little as 0.3 sec. All objects detected by software algorithms were visually reviewed and identified as bat, bird, or insect. Previous field trials showed that bats were detectable with thermal videography at distances of over 100 m.

Bat vocalization was acoustically monitored from atop turbines with acoustic detector systems (Batlogger WE X2, Elekon AG, Luzern, Switzerland) installed and managed by Natural Power Consultants, LLC (Saratoga Springs, New York, USA). Each turbine had one rotor-facing (windward) and one rear-facing (leeward) omnidirectional microphone mounted atop the nacelle and were each tipped down about 9 degrees from vertical. Detectors began recording

1 hour before local sunset until 1 hour after sunrise the next morning. Acoustic detections were recorded without digital compression as full-spectrum wav sound files with the following settings: sampling rate = 312.5 kHz; trigger frequency range of 9–60 kHz within a microphone sensitivity range of 10–150 kHz; decibel gain = 12; period trigger = 95; crest factor = 5; pre- and post-trigger duration = 500–800 ms; max gap time between calls = 200 ms; maximum call file duration = 3 sec; minimum FFT value for trigger = 5; minimum sound level for trigger = 1%. Microphone sensitivity tests were automatically conducted on a daily basis, and results were provided by Natural Power Consultants, LLC. Prevailing wind direction at the facility is usually from the east (80%; G. Akau, Auwahi Wind Energy, written comm., 2018); therefore, acoustic and video observations were expected to jointly sample the same airspace for approximately the same proportion of time.

Delays with acoustic detector installation atop turbines and the progressive decay of microphone sensitivity over the monitoring period limited the number of sample nights available for analyses. Microphone sensitivity was particularly problematic for the microphone aimed towards the rotor; consequently, with the exception of one analysis, only data for the rear-oriented microphone were examined herein. The periods during which acoustic data were determined to be available totaled to 246 nights (turbine 2, August 1–November 3 [63 nights]; turbine 4, September 20–October 6 [17 nights]; turbine 5, August 8–November 30 [115 nights]; turbine 7, August 7–September 26 [51 nights]). Moreover, because microphone sensitivity decayed as a function of time since installation, examination of acoustic detections relative to time of year was not possible because these variables were largely confounded. For these reasons, most descriptive analyses and the statistical modeling of bat occurrence and behavior relative to weather and turbine operation variables focused on thermal video-based detections. The exception was use of all acoustic wav files (i.e., both rotor- and rear-oriented) in an assessment of the correspondence of acoustic and visual (video) detections (the rationale being that this would minimize underestimation of the correspondence of both types of detections). The correspondence between acoustic and visual detection events were examined at three scales: the entire night (averaging approximately 12 hours), a 2-hour period (i.e., an acoustic detection 1 hour before or after a visual detection), and a 10-minute period (i.e., an acoustic detection 5 minutes before or after a visual detection). Bat passes at any point during a visual detection were noted if they occurred at a distance of approximately 15 m or less from the turbine nacelle, a range within which the probability of acoustic detection is high, particularly for low-frequency echolocation calls (Adams *et al.* 2012, Gorresen *et al*. 2017), and used to conservatively assess the proportion of visual detections lacking a corresponding acoustic detection.

Hawaiian hoary bat vocalizations were examined using Kaleidoscope Pro software (version 5.1.9, Wildlife Acoustics, Concord, Maine, USA). All echolocation pulses, feeding buzzes, and files with multiple bats were verified by audio and visual inspection, and all noise files were visually reviewed to ensure that bat calls were not missed. Terminal-phase calls ("feeding buzzes" emitted just prior to an attempted insect catch) were qualitatively distinguished from search and approach-phase calls by a rapid increase in the call rate. Ancillary information on the frequency of acoustic detection of bats from ground-based detectors in the region are described in Pinzari *et al.* (2019a), and for which acoustic data are available at https://doi.org/10.5066/P9U0KRMY (Pinzari *et al.* 2019b).

Videographic recordings were analyzed to identify individual "detection events", defined as a single pass or two or more detections occurring less than a minute apart, such that if bats went out of video field-of-view they were not counted as independent events if they reappeared within 1 minute (consistent with previous work by Cryan *et al.* 2014 and Gorresen *et al.* 2018). Likewise, acoustic detections were also grouped as the same detection event when two or more passes occurred less than 1 minute apart. The resulting data for both video and acoustic sampling included total counts of detection events per night. In addition, to account for partially sampled nights or nights for which video was not available from one or more turbines, the nightly rate of bat detection (number of events per hour, adjusted for duration of night and sampling effort) was calculated both for individual turbines and all four turbines combined. Flight behavior was qualitatively designated as straight, curved, or erratic based on whether the flight path was linear or included one or more curves or loops during the video detection event. In cases where two or more bats were concurrently visible, behavior was recorded as agonistic when individuals flew within a few meters of each other and interacted with sharp turns and chases.

Variables Associated with Bat Detection

We examined the association of bat occurrence and behavior with several variables related to weather conditions and turbine operation. We hypothesized that nightly counts of detection events would be negatively related to wind speed and precipitation, as these conditions may restrict flight activity or foraging success (Erickson and West 2002). Conversely, we expected detections to be positively influenced by wind speed variability because high values of this variable reflect the recurrence of low wind periods during which bats may be more active or more likely to approach turbines. Moreover, the number of turbine blade rotation "start-ups" (i.e., from zero or low to high rates of rotation) has been found to be positively related to bat fatalities (Schirmacher *et al.* 2018), an outcome possibly linked to increased bat occurrence or activity at low wind speeds. The frequency of start-ups is generally associated with the incidence of wind speeds below that which triggers turbine shut-down and low-wind speed curtailment (LWSC; a management protocol for minimizing the likelihood of bat fatalities and incidental take). Consequently, high wind speed variability and frequent turbine start-ups are both variables expected to be positively related to nightly counts of detection events. Curtailment is accomplished by "feathering" turbine blades; that is, pitching blades parallel to the wind, resulting in very slow movement of the rotor and blades. During the period of study, turbine LWSC at Auwahi Wind Energy implemented a "cut-in speed" (i.e., wind speed at which the turbine begins to rotate and generate power) of 6.9 m/sec from August to October and 5 m/sec in November.

Wind speed (m/sec) recorded at the nacelle of each turbine at 10-minute intervals and limited to night-time periods were used to calculate nightly mean and standard deviation (SD) metrics; referred herein as "wind-mean" and "wind-sd". Turbine blade movement, measured as rotations per minute ("rpm"), was obtained for each turbine over 10-minute intervals from Auwahi Wind Energy. Turbine rpm during individual bat detection events were derived directly from the video recording of each event by calculating the time needed for the rotor to complete a full rotation. The frequency of turbine start-ups ("rpm-starts") was determined by tallying the number of times per night a turbine transitioned from ≤1 rpm to >1 rpm in two or more consecutive 10-minute periods. For context, at 1.0 rpm, blade tips are moving at a speed of 5.3 m/sec (= 19.0 km/hr) for a turbine rotor diameter of 101 m and a circumference of 317 m.

Precipitation was obtained from a weather station located 7.3 km east-northeast from the Auwahi Wind Energy facility (USGS site number 203721156151601, 255.0 Kepuni Gulch Rain Gage). Temperature was not included in analyses due to the low variability observed in nighttime values over the four months of sampling (sunset to sunrise temperature differences averaged about 3.5°C).

Descriptive Analyses and Statistical Modeling

Bat occurrence and behavior were explored and graphically described with a variety of methods (e.g., analysis of variance, simple linear regression, correlation analysis) in the statistical computing environment R (version 3.5.1; R Core Team 2018). The relation of nightly counts of bat detection events to multiple predictor variables were also examined with generalized linear mixed models (GLMMs) using the glmmTMB package (Brooks *et al.* 2019) to account for temporally and spatially correlated observations requiring the incorporation of random effects. In the GLMMs the variables "night" and "turbine" were added as random effect terms to deal with repeated measures at the four turbines. In addition, the models were fit to counts for the following fixed effects: "rpm", "rpm-starts", "precip", "wind-mean", and "wind-sd". The fixed effect terms were scaled and centered on zero (creating z-scores) using the base scale function in R to improve model convergence and allow for direct comparison of the magnitude of fixed effect coefficients. Mean wind speed and turbine rpm were highly correlated ($r = 0.70$ from measures for all four turbines, and $r = 0.92$ when excluding turbine 2, which was not operational for most of the monitoring period). In addition, rpm start-ups and the standard deviation of wind during the night were also moderately correlated ($r = 0.37$). All other variables were correlated pairwise at an $r \leq 0.35$. Therefore, to minimize multicollinearity in regression analyses and limit the number of models tested, models were developed that did not jointly include both of the correlated variables. To account for differences in nightly sampling duration among turbines, we included the log of the total duration of recording per night and turbine as an offset in models, thereby converting counts of detection events to a detection rate.

Preliminary regression analyses demonstrated underdispersion of the residuals in both negative binomial and Poisson models. The consequence of underdispersion is that standard errors (SEs) are generally too conservative (i.e., confidence intervals tend to be too broad and p-values too large) potentially resulting in false-negative conclusions about parameter effects (Brooks *et al.* 2019). To address this, we fit GLMMs with several additional distribution specifications that allow for underdispersion; specifically, generalized Poisson and Conway-Maxwell-Poisson (Brooks *et al.* 2019). The four distribution groups are referred herein as NB, P, GP, and CMP for the negative binomial, Poisson, generalized Poisson, and Conway-Maxwell-Poisson models.

The candidate set of predictor variables totaled to 18 models, including a null model with only the random effect terms "night" and "turbine", the offset, and no fixed effects. We used small-sample-size corrected Akaike information criterion (AICc) via the AICctab function from the bbmle package (Burnham and Anderson 2002, Bolker and R Core Team 2017) to compare all models. Model ranking was performed in two steps: the first identified the top-ranked model from among the 18 candidate models within each of the four distribution groups (NB, P, GP, and CMP), and the second step ranked this subset. Final top-ranked models (i.e., those with a $\Delta AICc < 7$; Burnham *et al.* 2011) were examined with post-fitting diagnostics performed with the DHARMa package (Hartig 2017). A statistical significance criterion of $P < 0.05$ was used in all tests.

RESULTS

Visual (Thermal Video) Bat Detections—Descriptive Analyses

Thermal video was recorded at four turbines over the four-month period between August 1 and November 30, 2018. Technical difficulties resulted in the loss of recording for 65 turbine-nights. The number of nightly recordings over the 122-night period was 111, 119, 107, and 75 for turbines 2, 4, 5, and 7, respectively, for a total of 412 turbine-nights with a full or partial night of recording (median duration = 12.6 hours, including a 15-minute period before sunset and after sunrise). This yielded 5,066 hours of video that resulted in a total of 384 detection events of bats (72%) and bat-like observations (27%; n = 140) with an additional 288 bird observations. Only definitive bat detections were used in analyses of occurrence and behavior (i.e., bat-like detections were not included as these were generally brief and/or of distant targets). Visual bat detection data are available at https://doi.org/10.5066/P937H9LQ (Gorresen 2020) and are summarized in Appendix I and II.

Bats were detected visually in 44% (n = 180) of the turbine-nights sampled. Detections at turbines occurred throughout the night, with the earliest occurring 8 minutes after sunset and the latest 16 minutes before sunrise. Detections exhibited a unimodal distribution and a median of 0.27 for the fraction of night at which the observation occurred, corresponding to a peak of 3.4 hours after sunset (Q1 = 0.18, Q3 = 0.45, mean = 0.33 ± 0.20 SD; standardized as a fraction of night and scaled from 0 at sunset to 1 at sunrise; Figure 2). Detections generally did not begin until about an hour after sunset.

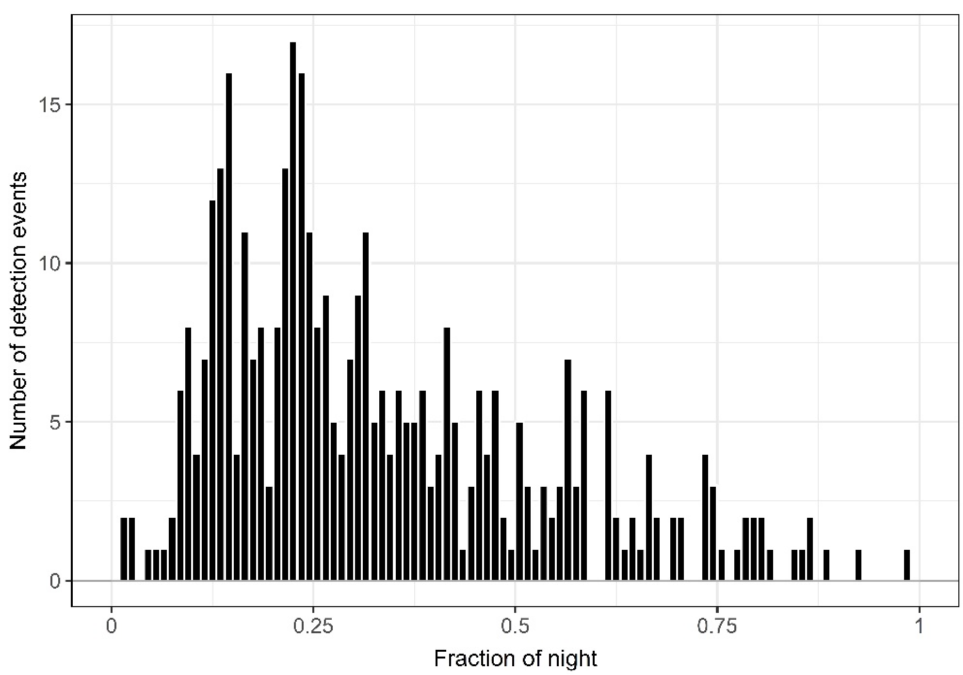

Figure 2. Distribution of visual detections of bats by time of night. To account for seasonal changes in night duration, the time of detection was standardized as a fraction of night and scaled from 0 (sunset) to 1 (sunrise).

Bats were detected throughout the four-month monitoring period (Figure 3), and linear regression demonstrated no evidence of a seasonal shift toward earlier or later activity during the night (slope = -1.17e-09, SE = 3.42e-09, $P = 0.733$). However, the rate of nightly bat detection (number of events per hour; adjusted for duration of night and sampling effort, including partially sampled nights) was highly variable among nights but evinced a seasonal pattern, with the rate decreasing (slope = -0.0005, SE = 0.0002, $P = 0.029$) from a mean of 0.11 events/hour (SE = 0.02) on survey night 1 (August 1) to 0.05 events/hour (SE = 0.02) on survey night 122 (November 30; Figure 4).

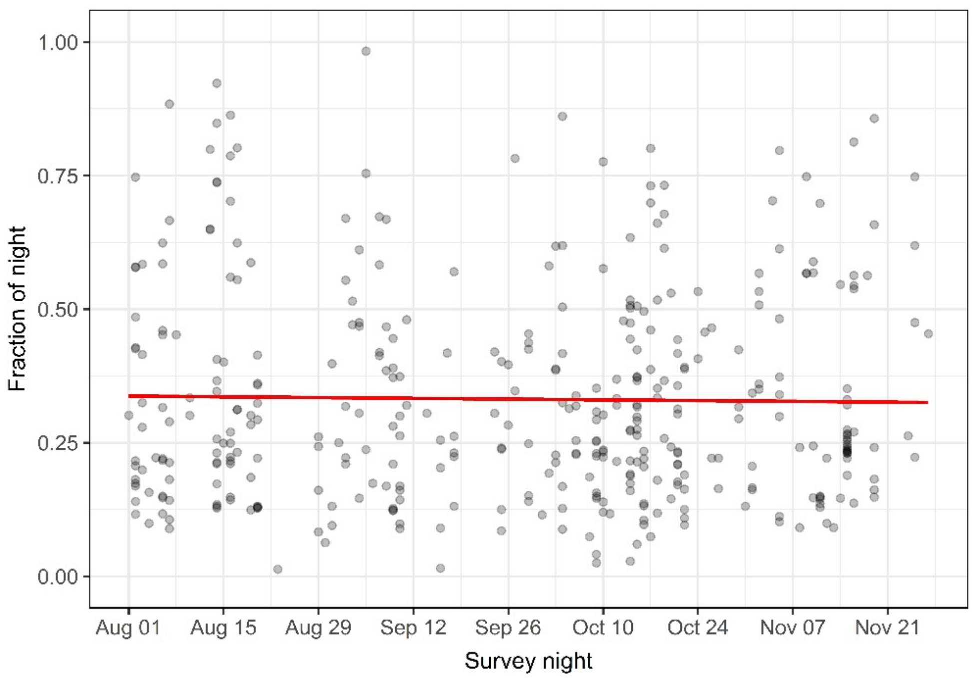

Figure 3. Detections (points) of bats by time of night over the four-month videographic monitoring period. To account for seasonal changes in night duration, the time of detection was standardized as a fraction of night and scaled from 0 (sunset) to 1 (sunrise). Situated below 0.5, the trendline of the mean values (red line) indicates a greater proportion of detections occurred in the first half of the night throughout the monitoring period.

The overall mean nightly detection rate for the entire videographic monitoring period was 0.08 events/hour (SD = 0.10, Q1 = 0.00, median = 0.04, Q3 = 0.13). Bat detection rates for each turbine were similar to the overall mean (Table 1, Figure 5) and not found to be significantly different from one another ($F[3, 402] = 0.885$, $P = 0.449$). Nightly detection rates demonstrated a weak but significant spatial correlation among turbines (all p-values <0.001), with pairwise Kendall's tau values ranging from 0.23 to 0.31 (Figure 6). The detection rate for all turbines combined demonstrated a weak positive relation with the rate on a previous night ($r = 0.18$), but the temporal pattern was not statistically significant to a lag of up to 12 nights (all p-values ≥ 0.05; Figure 7).

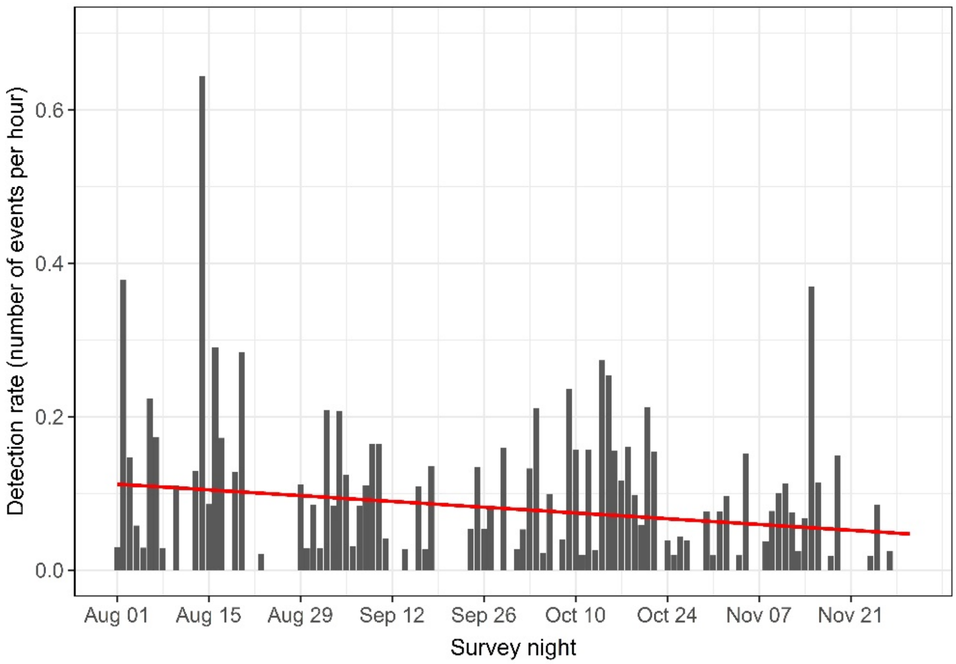

Figure 4. Detection rate of bats (number of events per hour per night) for all four turbines combined over the four-month videographic monitoring period. Detection rate is adjusted by survey effort (i.e., sample duration night interval and number of turbines monitored per night). The red line is a linear model of trend in detection rate over the monitoring period.

Table 1. Overall mean detection rate of bats by turbine (mean and SD). Detection rate was calculated as the nightly total of detection events at a turbine divided by the sample duration per night at the turbine. The combined mean is the overall average of the nightly detection rates for the four turbines over the four-month videographic monitoring period.

Turbine	Nightly mean (events/hour)	SD
2	0.07	0.10
4	0.07	0.13
5	0.09	0.14
7	0.07	0.11
combined mean	0.08	0.12

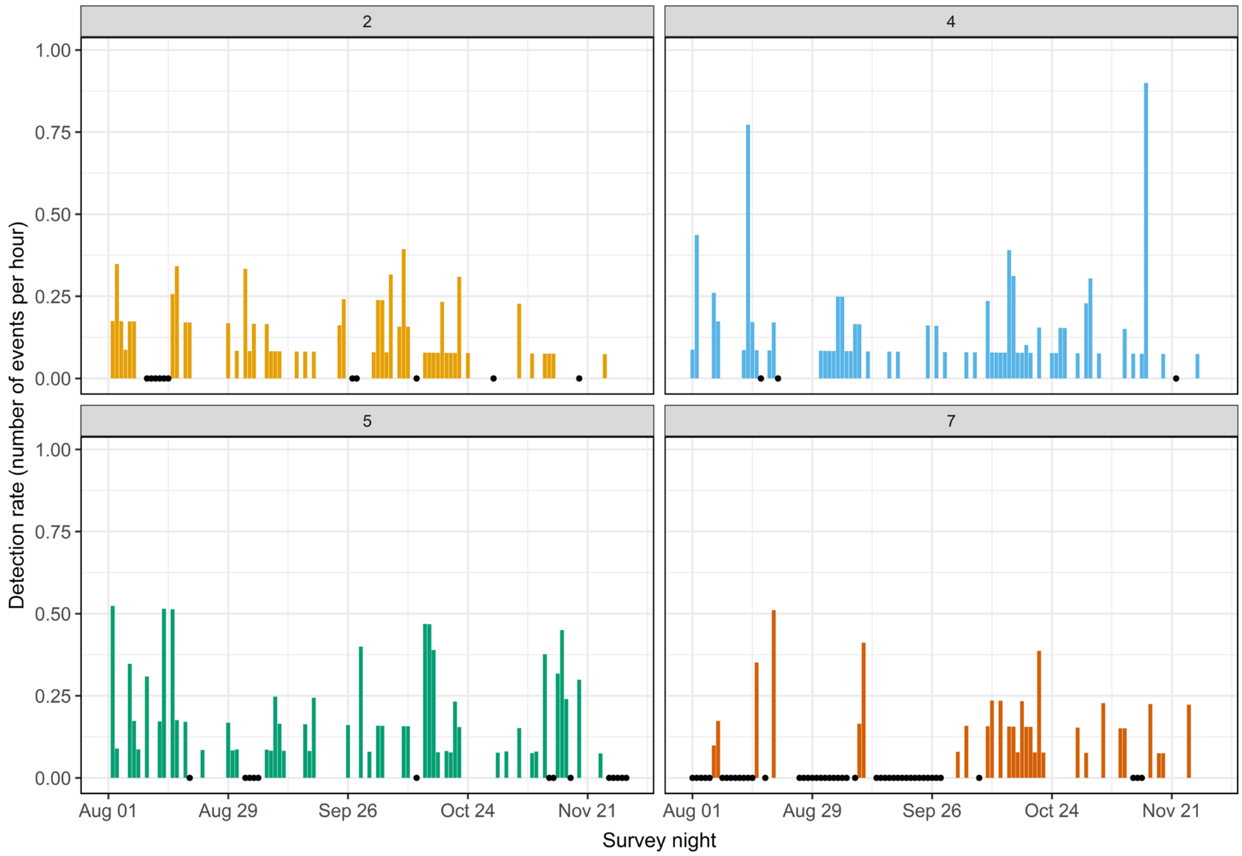

Figure 5. Detection rate of bats (number of events per hour per night) for each of four turbines (2, 4, 5, and 7) over the four-month videographic monitoring period. Detection rates are adjusted by survey effort (i.e., sample duration within night interval). Nights with no samples are indicated with a black point.

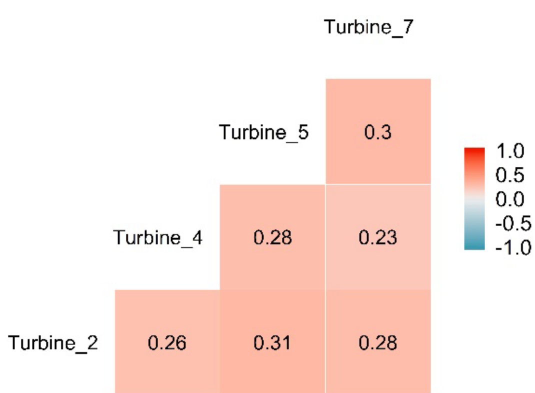

Figure 6. Spatial pairwise correlation of nightly detection rates between turbines. The p-values for all Kendall's rank correlation tau values are <0.001.

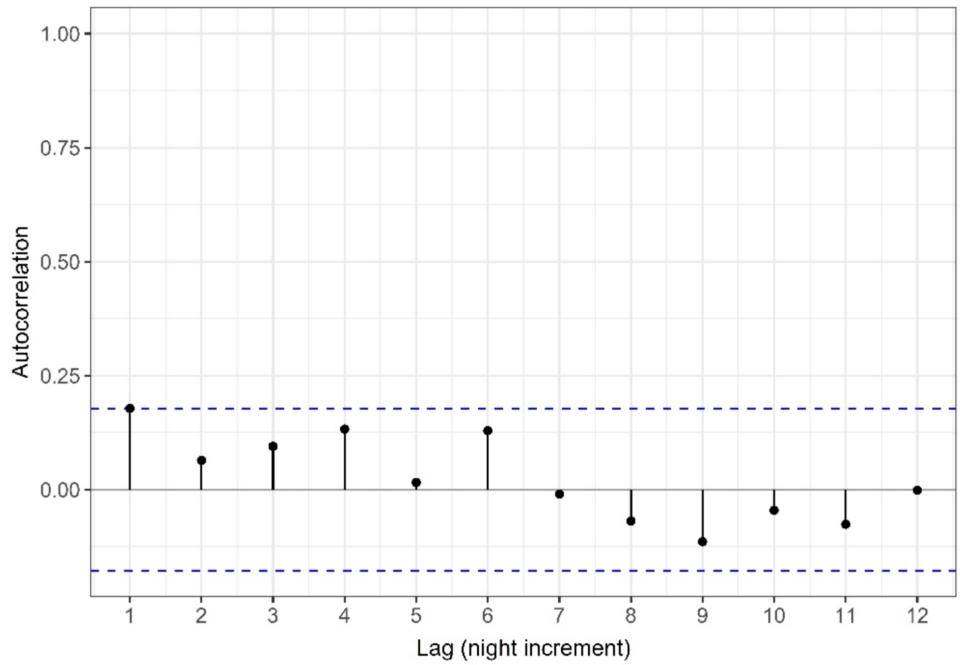

Figure 7. Temporal autocorrelation in the detection rate of bats (number of events per hour per night) for a series of lag increments up to 12 nights for all turbines combined over the four-month videographic monitoring period. Dashed lines indicate the threshold for statistical significance given sample size.

Almost all (n = 362; 94%) bat detections involved single bats within the 1-minute period used to quantify each event. Multiple bats seen concurrently were observed infrequently, with two bats (n = 22) observed during 6% of detection events, and no greater number noted at any time with any certainty. Most (n = 14) observations of two bats involved individuals not directly interacting, and bats were only rarely seen chasing (n = 5) or closely following each other (n = 3). All observations of bats engaged in chasing occurred when the individuals were in proximity (approx. <15 m) to the turbine nacelle.

The duration of individual bat detection events (in part determined by the limited field-of-view) averaged 23.5 sec per event. However, 11% (n = 41) of the events lasted 60 sec or more, with 4% (n = 14) of events lasting ≥120 sec, and one event was sustained for at least 211 sec (min = 0.5, Q1 = 3.8, median = 9.0, Q3 = 28.3, max = 211.2). On a per-turbine basis, the cumulative duration of nightly detection events averaged 50.1 sec (min = 0.6, Q1 = 7.1, median = 20.9, Q3 = 56.9, max = 804.2; Figure 8), with the maximum duration (totaling 13.4 minutes) comprised of a series of 12 distinct events (occurring on November 15 at turbine 4). The duration of detection events appears to moderately decline over time; however, linear regression demonstrated no evidence of a seasonal shift toward shorter or longer duration episodes of bat activity (slope = -0.016, SE = 0.012, $P = 0.187$) during the four-month period of monitoring (Figure 9). Although the individual and cumulative duration of detection events on some nights sometimes lasted several minutes, bats generally did not appear to be spending much time in the rotor-swept zone imaged by video. The duration of all detection events totaled to 150 minutes (9,015 sec) and made up only 0.05% of the total period of videographic

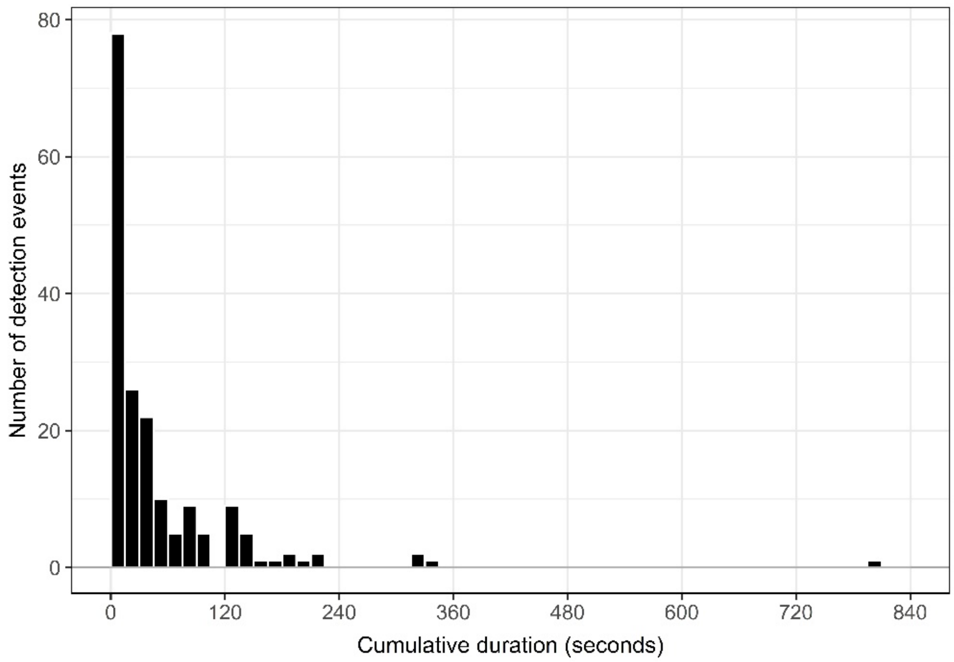

Figure 8. Distribution of the cumulative duration (seconds) of detection events on a nightly and per-turbine basis over the four-month monitoring period.

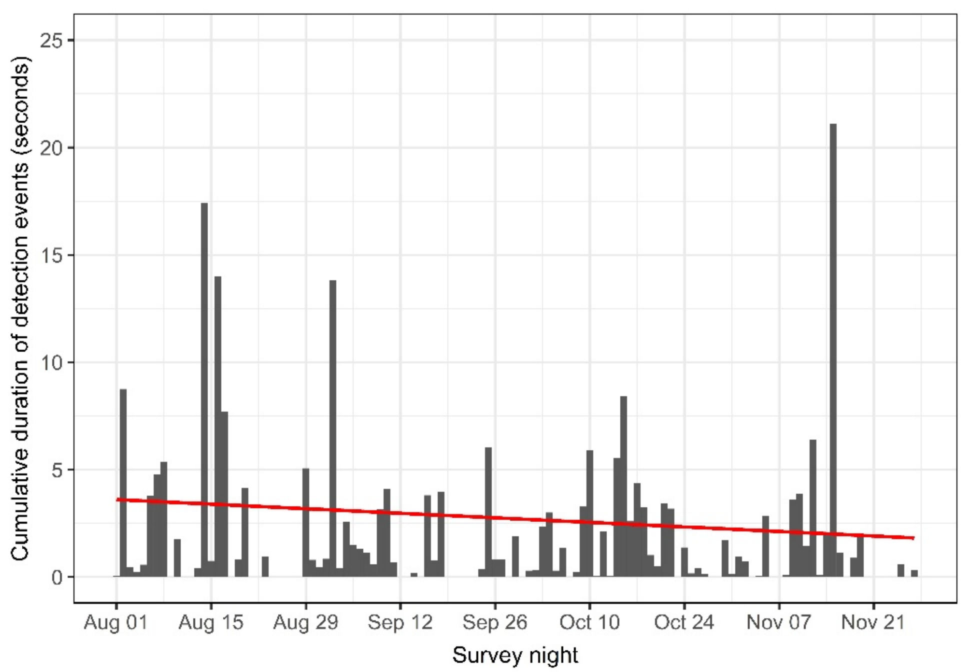

Figure 9. Cumulative duration (seconds) of detection events of bats on a nightly and per-turbine basis over the four-month monitoring period. The red line is a linear model of trend in event duration over the monitoring period.

monitoring (2.5 hours of 5,066 total hours). The time difference between consecutive detection events within a night averaged 80.4 minutes (min = 1.1, Q1 = 12.8, median = 49.0, Q3 = 101.2, max = 481.5; Figure 10). Most detection events consisted of a bat making a single pass through the field of view (57%; n = 220). Repeated passes (which together compose individual detection events when occurring <1 minute apart) were seen less frequently (2–4 passes [34%; n = 122], 5–10 passes [10%; n = 38], and 11–15 passes [1%; n = 4]).

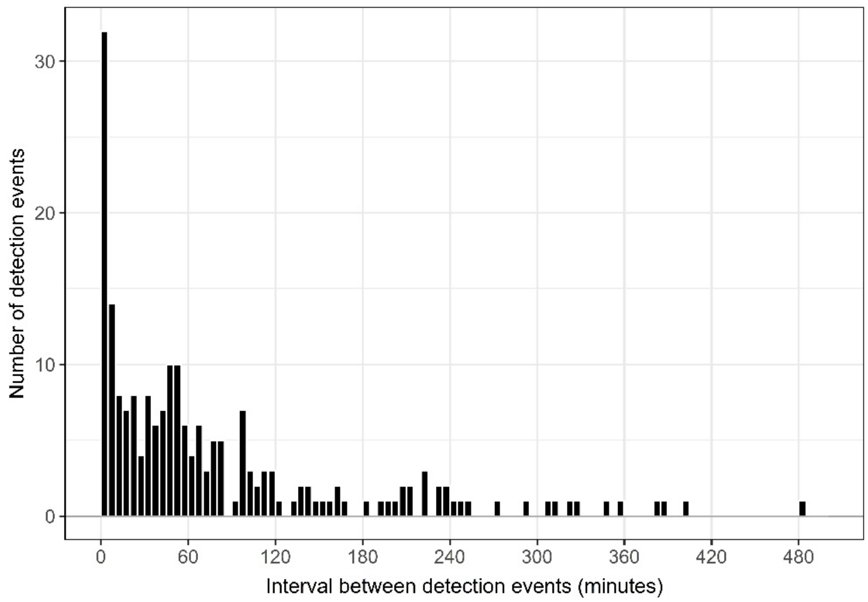

Figure 10. Distribution of the time interval (minutes) between consecutive detections of bats within a night combined for all turbines over the four-month monitoring period.

The largest proportion of bat detections involved erratic flight (80%; n = 306) suggestive of active foraging behavior in the immediate area of the turbine (i.e., within the video field-of-view; Table 2; Figure 11). Curved flight trajectories that may have involved either an approach towards or avoidance of the turbine were seen in 14% (n = 55) of events. Observations of straight flight paths indicative of a "fly-by" and little time spent near a turbine were observed in 6% (n = 23) of detections. Some of the observed curved and straight trajectories may simply consist of the less erratic parts of flight by bats otherwise engaged in foraging.

Table 2. Number and proportion of detection events by flight path type relative to bat proximity to nacelle (near = <15 m, far = ≥15 m).

Flight type	Near	Far
straight	13 (3%)	10 (3%)
curved	30 (8%)	25 (7%)
erratic	190 (49%)	116 (30%)
Total	233 (61%)	151 (39%)

Figure 11. Thermal video frame of a Hawaiian hoary bat at nacelle height (80 m) and within approximately 15 m of the nacelle (green dashed line), a distance within which vocalizing bats are likely to be recorded by acoustic detectors.

Most bat detection events (61%; n = 233) involved individuals that flew to within an estimated 15 m of the turbine nacelle. Comparatively, this 15-m radius area around the nacelle composed about a third of the video camera field-of-view; therefore, bats detected on video seemed to have closely approached the nacelle and upper monopole more often than not. Erratic flight paths were the most prevalent flight type observed, with bats repeatedly approaching and circling the nacelle in most cases. However, a Fisher's exact test did not demonstrate a significant relation ($P = 0.513$) between the number of events by flight path type as a function of bat proximity to turbine nacelle. Observations of displacement of bats or near-strikes by spinning turbine blades were seen in only two instances (0.5%). Direct strikes of bats by turbine blades were not observed.

Bats were most frequently detected at relatively low wind speeds (as measured at the turbine nacelle at 10-minute intervals; Figure 12). Wind speeds up to 3.4, 5.4, and 8.5 m/sec corresponded to 50%, 70%, and 90% of cumulative bat detection events, respectively, and

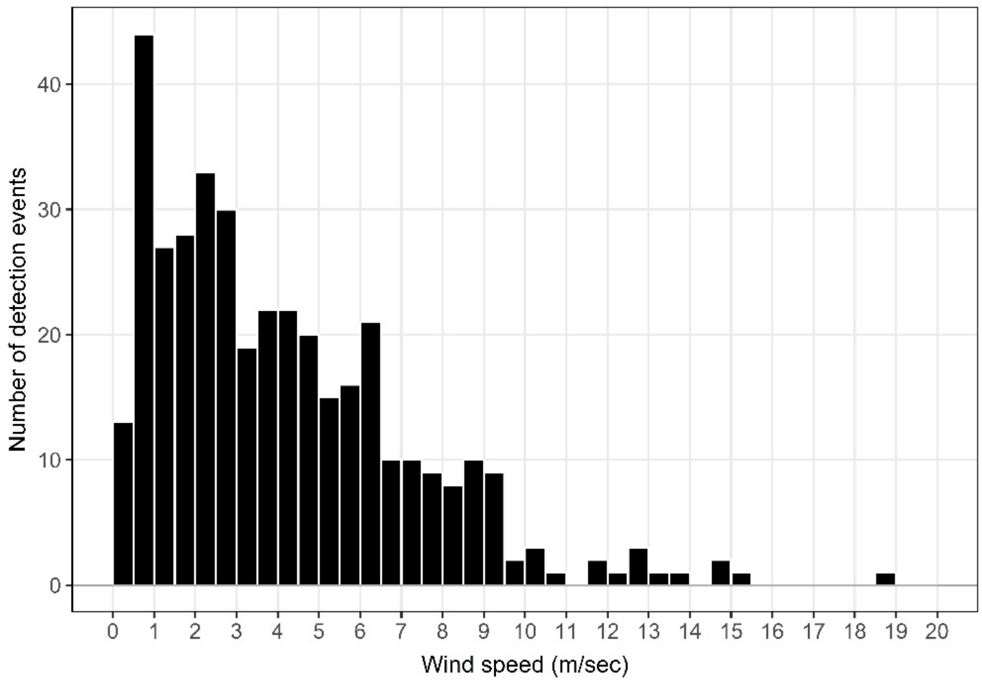

Figure 12. Distribution of bat detection events relative to wind speed (m/sec) measured at the turbine nacelle at 10-minute intervals over the four-month monitoring period.

10% of total detection events occurred at wind speeds between 8.5 m/sec and the maximum observed value of 18.9 m/sec (Table 3). A two-sample Kolmogorov–Smirnov (KS) test comparing wind speed during bat detection events to "ambient" nighttime conditions (both recorded at turbine nacelles) confirmed that the cumulative distributions were significantly different (KS test statistic D = 0.352, $P < 0.0001$; Figure 13). The KS test statistic D, defined as the maximum value of the absolute difference between the two cumulative distribution functions, was located at a wind speed value of 6.6 m/sec, corresponding to approximately 81% of cumulative bat detection events.

Table 3. Distribution of wind speed (m/sec) during bat detection events relative to randomly selected "ambient" nighttime conditions.

Samples	Mean	Median	70%	75%	80%	85%	90%	95%	100%
bat detection events	4.1	3.4	5.4	6.0	6.4	7.4	8.5	9.4	18.9
ambient nighttime	7.1	7.0	9.8	10.5	11.1	12.2	13.0	14.8	22.0

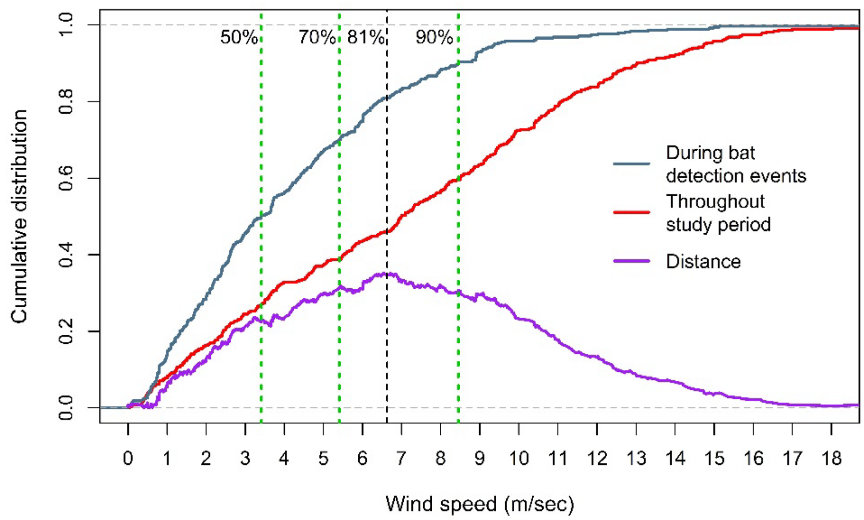

Figure 13. Cumulative distribution of wind speed (m/sec) during bat detection events relative to randomly selected "ambient" nighttime conditions recorded throughout the four-month monitoring period. A two-sample Kolmogorov–Smirnov (KS) test confirmed that the cumulative distributions were significantly different (KS test statistic D = 0.352, $P < 0.0001$). The KS test statistic D, defined as the maximum value of the absolute difference between the two cumulative distributions ("distance"), was located at a wind speed value of 6.6 m/sec, corresponding to approximately 81% of cumulative bat detection events (vertical dashed black line). Wind speeds for a range of cumulative distribution intervals (50%, 70%, and 90%) are shown with vertical dashed green lines.

There were relatively few bat detection events during periods when the turbine blades were in motion (Table 4, Figure 14). Bat observations during which there was no turbine rotation composed 81.5% (n = 313) of total events. A further 10.2% (n = 39) of events were observed at turbine rotor speeds of 0.1 to 0.5 rpm, with the remaining 8.3% (n = 32) at rpm values >0.5. However, of the 32 events that occurred when the turbine was moving >0.5 rpm, 8 events ensued when wind speeds were below the curtailment "cut-in" threshold (i.e., the wind speed at which the turbine begins to rotate and generate power; ≤6.9 m/sec for the period of August to October and ≤5.0 m/sec in November).

Table 4. Turbine rotations per minute (rpm) during bat detection events (number per rpm category) and proportion (percent).

Rpm	Number of events	Proportion
0	313	81.5%
>0–0.5	39	10.2%
>0.5–1.0	2	0.5%
>1.0–5.0	1	0.3%
>5.0–10.0	10	2.6%
>10.0–16.3 (max.)	19	4.9%

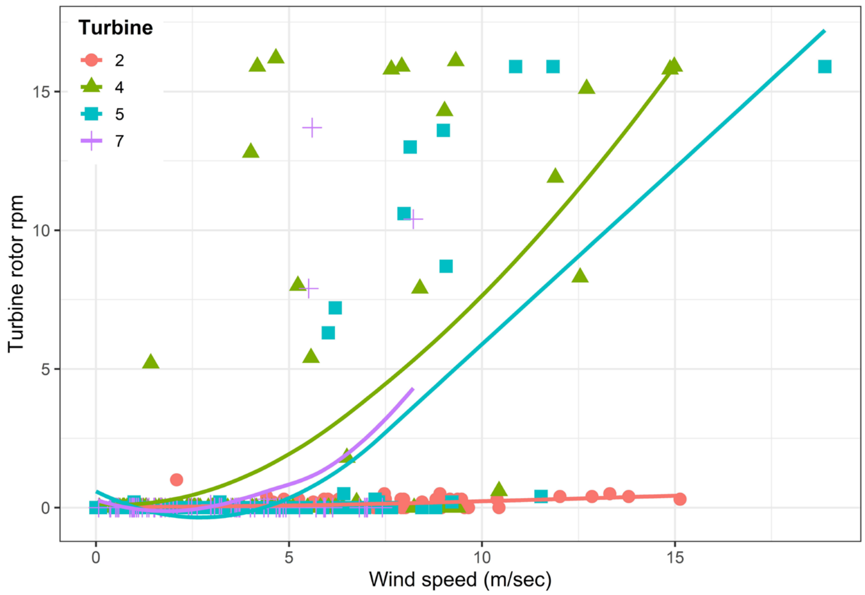

Figure 14. Turbine rotor rotations per minute (rpm) relative to wind speed (m/sec) during bat detection events over the four-month monitoring period. Locally estimated scatterplot smoothing (loess) curves are fit separately for turbines. Wind speed values are specific to the nearest 10-minute interval record. Turbine 2 was not operational, and rpm remained at or near zero until November 20 (10 nights before the end of monitoring).

Nightly bat detection rates for the four-month period of monitoring were negatively correlated with total daily precipitation (Kendall's rank correlation tau = -0.24, $P = 0.0009$). In addition, there were six periods lasting one or more nights with relatively high total daily precipitation (>1 cm) that corresponded with no bat detections or low detection rates (less than the nightly mean of 0.08 events per hour; Appendix I). These periods were associated with the passage of Hurricane Hector (August 9), Hurricane Lane (August 23–26), Tropical Storm Olivia (September 12–13), and strong low pressure systems (September 24–27, October 6–7, October 12) (National Weather Service Monthly Precipitation Summary, www.weather.gov/hfo/hydro_summary, accessed June 6, 2019).

Visual (Thermal Video) Bat Detections—Generalized Linear Mixed Model Analysis

The top-ranked GLMMs consistently included distribution types GP and CMP, indicating that underdispersion was effectively addressed in the final model selection. The weights of the top four models summed to 0.91, with only an additional weight of 0.06 gained from the fifth- and sixth-ranked models combined (Table 5). These models largely demonstrated similar combinations of variables (Table 6; summarized in Appendix II). All top models included either "wind-mean" or "rpm", and each of the models also included either "rpm-starts" or "wind-sd" (neither pairs were included jointly because of their high correlation). Diagnostics demonstrated that the final regression models met assumptions of uniformity and did not exhibit zero inflation (Appendix III), with underdispersion addressed in GP and CMP models. Data used in models are available at https://doi.org/10.5066/P937H9LQ (Gorresen 2020).

Table 5. Generalized linear mixed models ranked by model fit. "Type" refers to model distribution type: generalized Poisson (GP) or Conway-Maxwell-Poisson (CMP). "log *L*" refers to the estimate of the log-likelihood and "DF" refers to model degrees of freedom.

Model	Type	Predictor variables			log *L*	AICc	Δlog *L*	ΔAICc	DF	Weight
1	CMP	rpm	wind-sd	precip	-470.5	955.4	38.8	0.0	7	0.43
2	CMP	rpm	wind-sd		-472.2	956.6	37.2	1.2	6	0.23
3	GP	wind-mean	rpm-starts		-472.7	957.7	36.6	2.3	6	0.14
4	GP	wind-mean	rpm-starts	precip	-471.9	958.1	37.5	2.7	7	0.11
5	GP	wind-mean	wind-sd		-473.8	959.9	35.5	4.5	6	0.04
6	GP	wind-mean	wind-sd	precip	-473.5	961.3	35.8	6.0	7	0.02
7	GP	rpm	precip		-475.2	962.6	34.2	7.2	6	0.01
8	GP	rpm	rpm-starts	precip	-475.2	964.6	34.2	9.2	7	<0.01
9	GP	rpm			-477.9	965.9	31.5	10.6	5	<0.01
10	GP	rpm	rpm-starts		-477.8	967.7	31.6	12.3	6	<0.01
11	GP	wind-mean	precip		-480.0	972.2	29.4	16.8	6	<0.01
12	GP	wind-mean			-481.3	972.7	28.1	17.4	5	<0.01
13	GP	precip			-502.8	1015.7	6.6	60.4	5	<0.01
14	GP	rpm-starts	precip		-502.0	1016.3	7.3	60.9	6	<0.01
15	GP	wind-sd	precip		-502.7	1017.6	6.7	62.2	6	<0.01
16	GP	null			-509.4	1026.8	0.0	71.5	4	<0.01
17	GP	rpm-starts			-508.6	1027.4	0.8	72.0	5	<0.01
18	GP	wind-sd			-509.4	1028.9	0.0	73.5	5	<0.01

Table 6. Standardized model estimates and associated measures from the six top-ranked GLMMs (combined weight = 0.97) predicting the effect of weather and turbine operation variables on the number of nightly bat detections events. Number of observations for all models = 412.

Model	Parameter	Estimate		SE	z value	p-value	Variance
1	Random effect						
	night (Intercept)						0.38
	turbine						0.21
	Conditional model						
	(Intercept)	-3.22	±	0.26	-12.47	<0.0001	
	rpm	-1.13	±	0.14	-8.26	<0.0001	
	wind-sd	0.31	±	0.09	3.29	0.0010	
	precip	-0.27	±	0.17	-1.62	0.1055	
2	Random effect						
	night (Intercept)						0.38
	turbine						0.23
	Conditional model						
	(Intercept)	-3.19	±	0.27	-11.91	<0.0001	
	rpm	-1.18	±	0.13	-8.80	<0.0001	
	wind-sd	0.33	±	0.09	3.60	0.0003	
3	Random effect						
	night (Intercept)						0.42
	turbine						0.02
	Conditional model						
	(Intercept)	-3.17	±	0.14	-22.15	<0.0001	
	wind-mean	-1.08	±	0.13	-8.05	<0.0001	
	rpm-starts	0.40	±	0.09	4.23	<0.0001	
4	Random effect						
	night (Intercept)						0.41
	turbine						0.02
	Conditional model						
	(Intercept)	-3.19	±	0.14	-22.04	<0.0001	
	wind-mean	-1.04	±	0.14	-7.49	<0.0001	
	rpm-starts	0.39	±	0.09	4.12	<0.0001	
	precip	-0.21	±	0.18	-1.16	0.2450	
5	Random effect						
	night (Intercept)						0.42
	turbine						0.00
	Conditional model						
	(Intercept)	-3.15	±	0.13	-24.20	<0.0001	
	wind-mean	-1.09	±	0.14	-7.94	<0.0001	
	wind-sd	0.39	±	0.10	3.95	<0.0001	
6	Random effect						
	night (Intercept)						0.42
	turbine						0.00
	Conditional model						
	(Intercept)	-3.16	±	0.13	-23.97	<0.0001	
	wind-mean	-1.06	±	0.14	-7.335	<0.0001	
	wind-sd	0.37	±	0.10	3.675	0.0002	
	precip	-0.14	±	0.18	-0.743	0.4575	

Acoustic Bat Detections—Descriptive Analyses

Acoustic monitoring at the four turbines yielded 247 turbine-nights of viable recording, comprising 3,036 hours of sampling (including a 15-minute period before sunset and after sunrise; turbine 2 [767.0 hrs], turbine 4 [212.2 hrs], turbine 5 [1,446.7 hrs], turbine 7 [610 hrs]). During this period a total of 1,873 wav sound files with confirmed bat detections were acquired from the rear-facing (leeward) microphone. Detections pooled into groups that occurred within 1 minute of each other totaled to 244 discrete events. Bats were detected acoustically in 31% (n = 75) of the turbine-nights sampled. Acoustic bat detection data are available at https://doi.org/10.5066/P937H9LQ (Gorresen 2020) and are summarized in Appendix I and II.

Acoustic detections of bats at turbines occurred throughout the night, with the earliest detection occurring 25 minutes after sunset and the latest 18 minutes before sunrise. Detections exhibited a unimodal distribution and a median fraction of night time of detection equal to 0.28, corresponding to a peak about 3.3 hours after sunset (Q1 = 0.19, Q3 = 0.40, mean = 0.32 ± 0.18 SD; standardized as a fraction of night and scaled from 0 at sunset to 1 at sunrise; Figure 15). A Welch two-sample t-test (Delacre *et al.* 2017) of the bat observations produced by video and acoustic monitoring found no significant difference in the mean time of detection events between the two sampling methods ($t = 1.0592$, $df = 558.37$, $P = 0.290$).

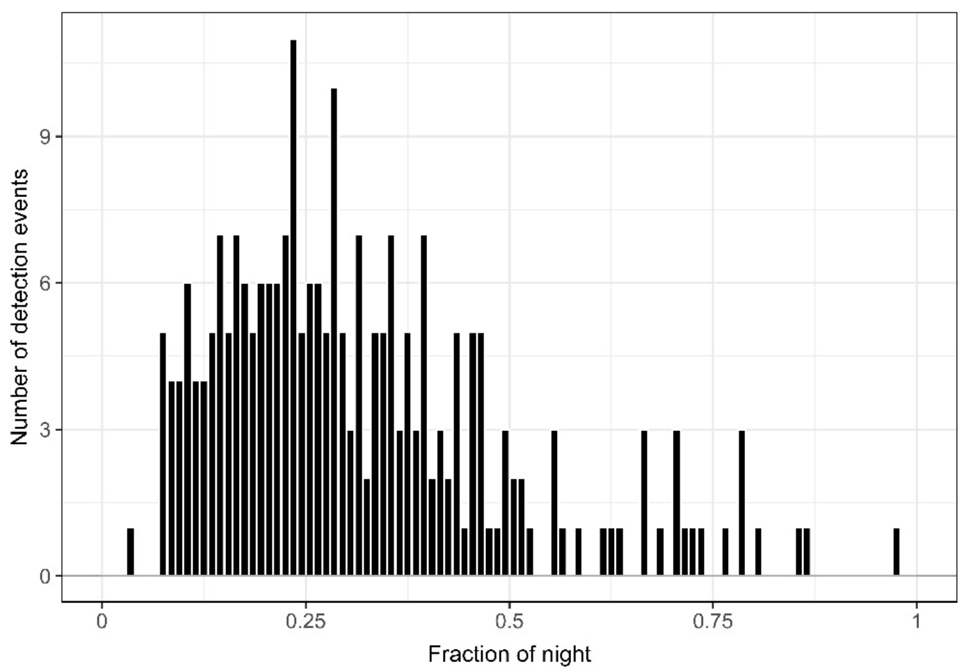

Figure 15. Distribution of acoustic detections of bats by time of night over the four-month monitoring period. To account for seasonal changes in night duration, the time of detection was standardized as a fraction of night and scaled from 0 (sunset) to 1 (sunrise).

The overall mean acoustic detection rate for which data were available was 0.08 events/hour (SD = 0.18; Q1 = 0.00, median = 0.00, Q3 = 0.08). Because the acoustic samples were largely concentrated on the earlier part of the four-month monitoring period (Figure 16), a direct comparison for all turbines combined with the rate obtained from videographic sampling was not possible. However, acoustic samples for turbine 5 were comparable in the span of the monitoring period that matched video samples, and a Welch two-sample t-test found no significant difference in the mean detection rate between the two sampling methods ($t = 1.7011$, $df = 167.11$, $P = 0.0978$). Extensive periods with missing acoustic data and uncertainty in the decay rate of microphone sensitivity did not permit a quantitative comparison of detection rates among turbines relative to time of year.

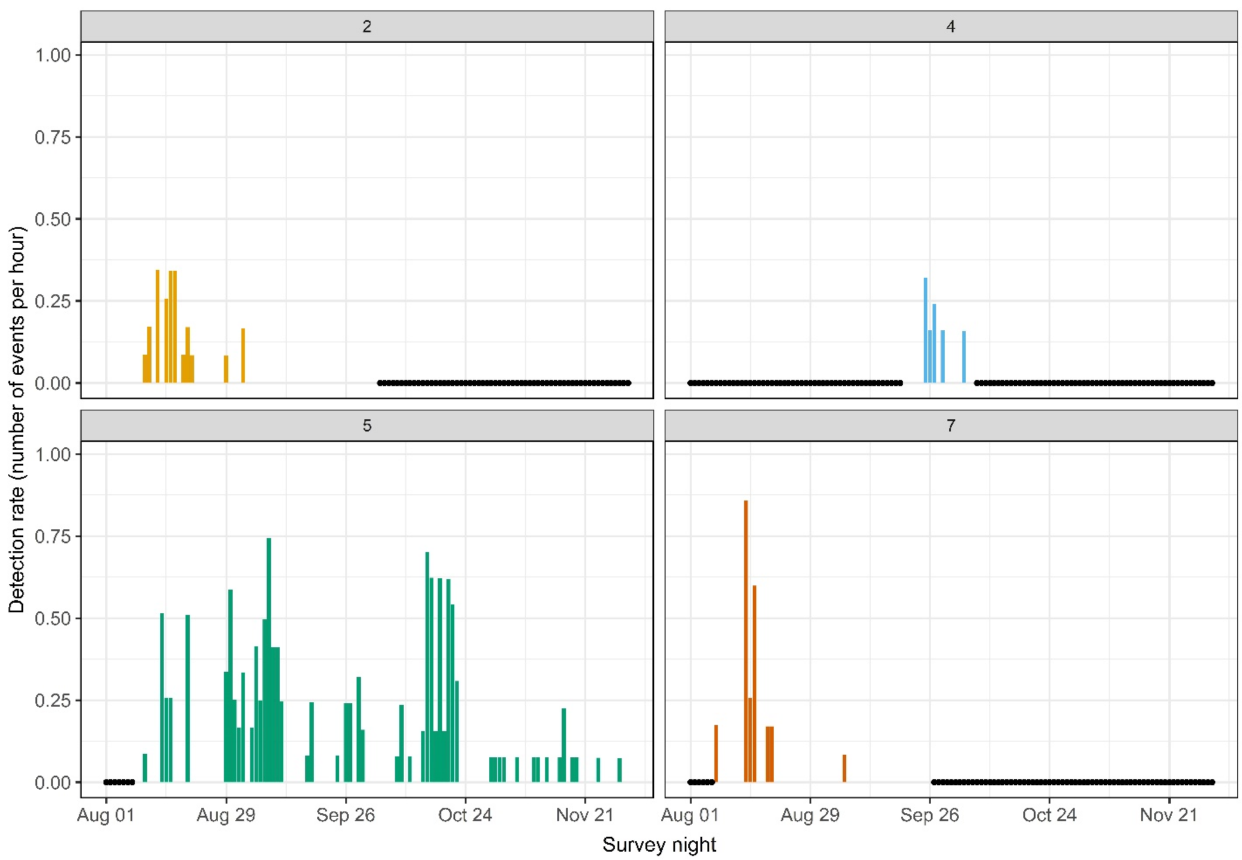

Figure 16. Detection rate of bats (number of events per hour per night) for each of four turbines (2, 4, 5, and 7) over the four-month acoustic monitoring period. Detection rates are adjusted by survey effort (i.e., sample duration within night interval). Nights with no samples are indicated with a black point.

The duration of individual acoustic bat detection events (in part determined by the range acoustic detectors are capable of sampling) averaged 23.2 sec per event. However, 7% (n = 17) of the events lasted 60 sec or more, of which 2% (n = 5) of events lasted ≥120 sec, and one event was sustained for 13.4 minutes (min = 3.0, Q1 = 3.0, median = 6.0, Q3 = 21.0, max

= 803.0 sec). On a per-turbine basis, the nightly cumulative duration of events averaged 76.0 sec (min = 3.0, Q1 = 6.0, median = 36.0, Q3 = 71.0, max = 1,232.0; Figure 17), with the maximum duration (totaling to 20.5 minutes) comprised of 14 individual events (occurring on September 25 at turbine 5). Although the cumulative duration of events appears to more than halve during the four-month period of monitoring, high variance precluded the detection by linear regression of a seasonal change in the duration of bat activity (slope = -0.0446, SE = 0.0329, P = 0.1805; Figure 18). As with the results inferred from visual (thermal video) monitoring, acoustic sampling indicated that bats generally do not appear to be spending much time in the rotor-swept zone. The duration of all detection events totaled to 94 minutes (5,650 sec) over the survey and made up only 0.05% of the total period of acoustic monitoring (1.6 hours of 3,036 total hours). Acoustic detections were infrequent and the time difference between consecutive events within a night averaged 65.4 minutes (min = 1.4, Q1 = 14.4, median = 38.8, Q3 = 74.7, max = 530.6; Figure 19). Most nightly detection events (57%; n = 44) at a turbine were comprised of 10 or fewer "bat passes" (i.e., distinct wav files). More numerous passes were recorded less frequently: >10 to 100 passes (40%; n = 31); >100 passes (3%; n = 2; Figure 20). Terminal-phase (feeding buzz) type calls were only noted in 3% (n = 7) of all events.

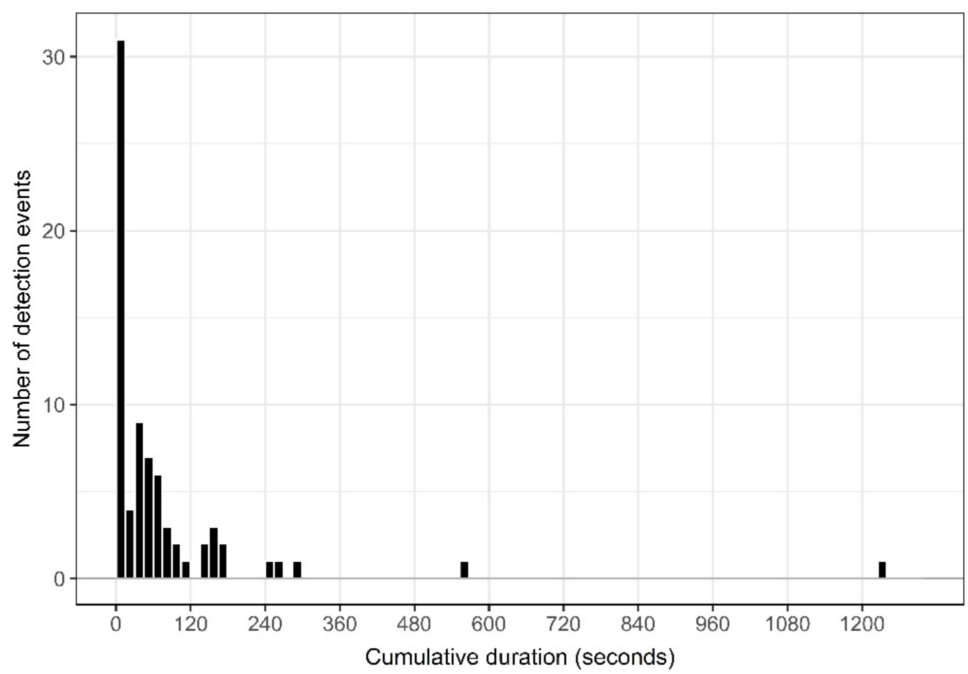

Figure 17. Distribution of the cumulative duration (seconds) of acoustic detection events on a nightly and per-turbine basis over the four-month monitoring period.

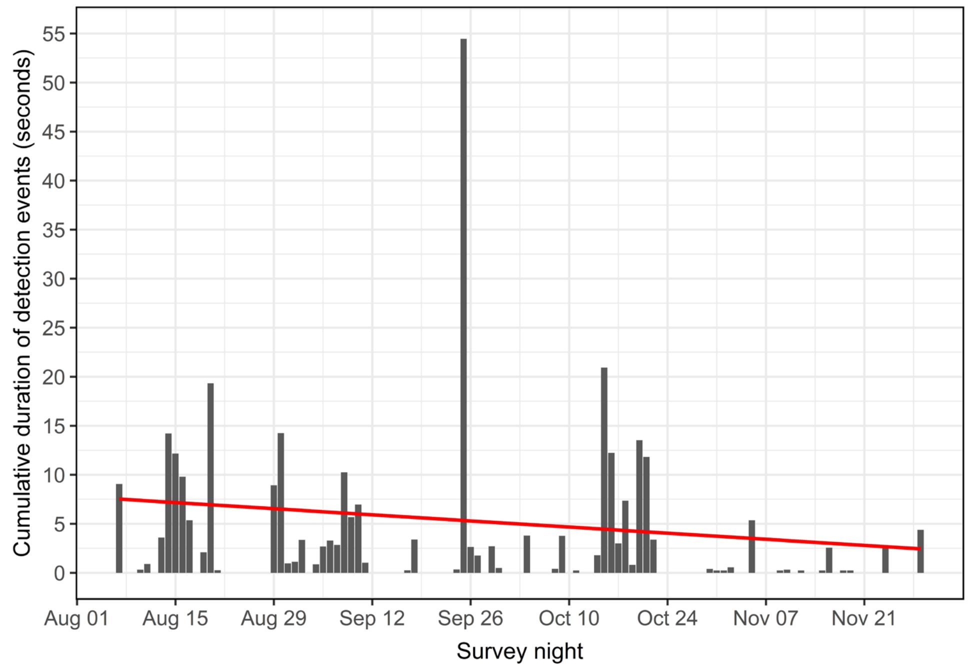

Figure 18. Cumulative duration (seconds) of acoustic detection events (adjusted for total nightly sampling duration for all turbines) over the four-month monitoring period. The red line is a linear model of trend in event duration.

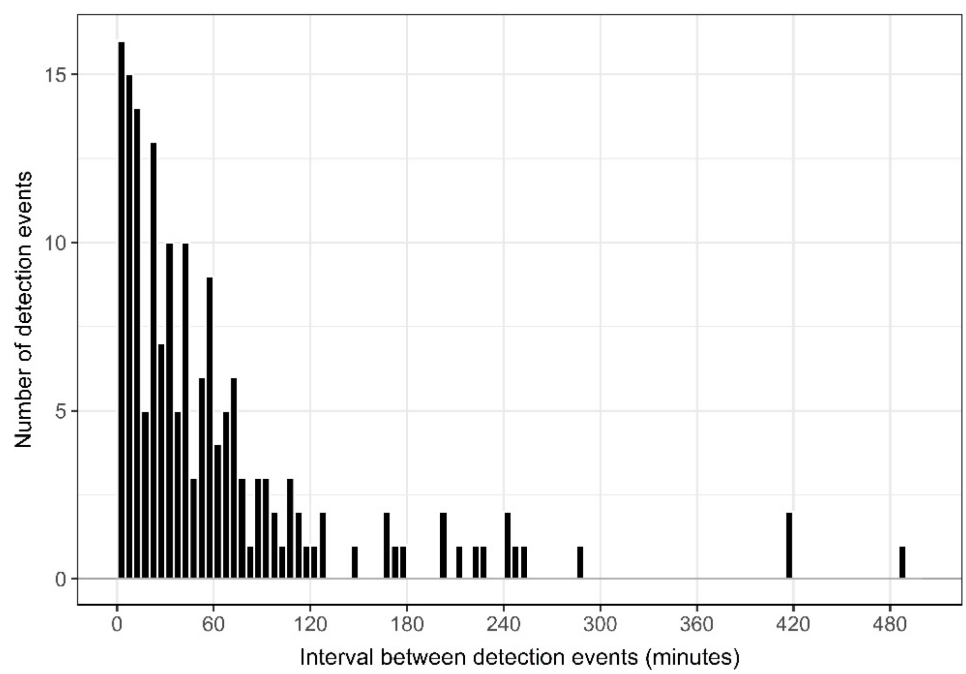

Figure 19. Distribution of the time interval (minutes) between consecutive acoustic detections of bats within a night over the four-month monitoring period.

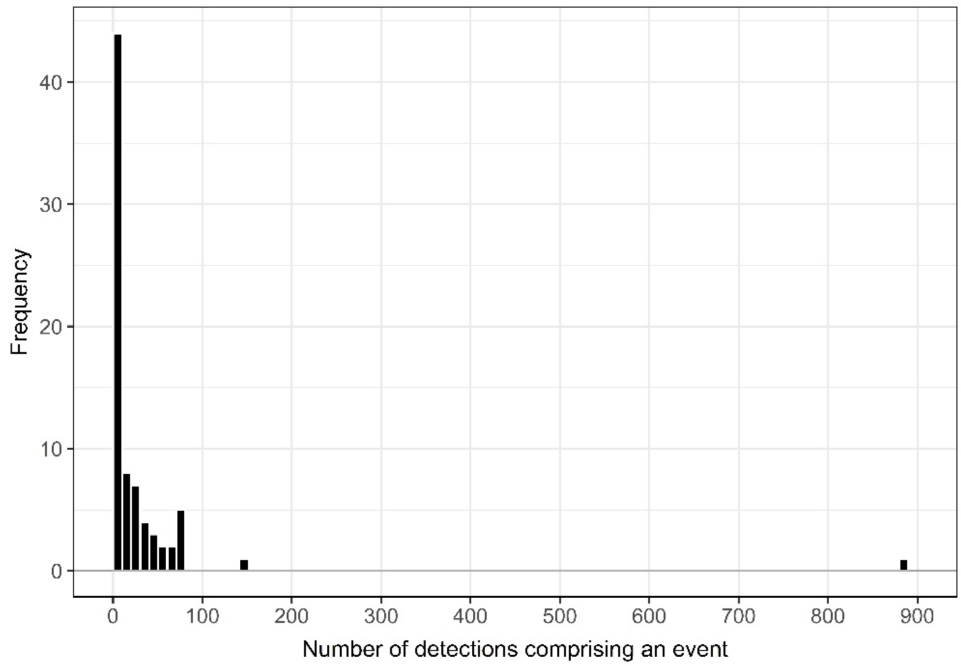

Figure 20. Distribution of the number of discrete detections (wav sound files measuring "bat passes") that comprised events over the four-month monitoring period.

The correspondence between acoustic and visual detection events at a turbine were examined at three scales: the entire night (averaging approximately 12 hours); a 2-hour period (i.e., an acoustic detection 1 hour before or after a visual detection); and a 10-minute period (i.e., an acoustic detection 5 minutes before or after a visual detection). A total of 187 turbine-nights was concurrently sampled both acoustically and visually. Of this subset, acoustic detections (regardless of whether it was also detected visually) composed 33% (n = 62) of the concurrently sampled turbine-nights (Table 7). Acoustic samples confirmed bat presence on 56% (= 45/81) of the turbine-nights for which bats were also detected visually with thermal cameras at some point during the night. Bats were not detected by either method during 48% (n = 89) of the concurrent sample.

Table 7. Proportion of concurrently sampled turbine-nights (n = 187) with bat detections.

Sample method	Nights bats detected
Both visual & acoustic	45 (24%)
Visual only	36 (19%)
Acoustic only	17 (9%)
Neither method	89 (48%)
Visual only plus both visual & acoustic	81 (43%)
Acoustic only plus both visual & acoustic	62 (33%)

At a finer temporal scale, there were a total of 294 visual detection events during the concurrently sampled period, of which 22% (n = 65) of acoustic detections occurred within a 2-hour window of a visual detection, and of these, a subset of 12% (n = 36) occurred within a 10-minute window. Conversely, a total of 229 visual detection events did not have an acoustic match within a 2-hour window, even though 65% (n = 149) of these involved a bat making a close approach to the nacelle (i.e., within approximately 15 m).

DISCUSSION

Our findings reveal new information about the potential effects of wind speed and turbine operation on the presence and behavior of Hawaiian hoary bats occurring on the coast of southwest Maui. We used complementary observation technologies (sound recordings and video imaging) over four months to document distinct seasonal and nightly patterns in the occurrence and activity rates of hoary bats at the Auwahi Wind Energy facility. Overall, the picture emerging from these results is that individual hoary bats from other parts of the island sporadically visit the wind facility, usually before midnight, dwell in the airspace near each turbine for a few seconds (probably searching for insect prey), and then move out of the area without returning for several nights. Bat activity patterns across the local landscape were likely affected by the presence of wind turbines, weather conditions, and possibly operational changes implemented as mitigation efforts. These findings offer unique perspective toward broadening our understanding of the behavioral reasons why bats might regularly approach wind turbines, gauging the efficacy of different monitoring and research technologies, and point to new possibilities for fatality reduction.

We observed bat activity at the Auwahi wind turbines from early August through late November of 2019. Although this timespan represents an intensive field and analysis effort, it only covered one-third of an annual cycle during a single year, so our conclusions are based on conditions that happened to occur at the study site during this period. Lacking additional longer-term, site-specific information, the following discussion assumes that the patterns we report are representative of typical bat visitation, weather conditions, and turbine operation at the site.

Although we detected a slight downward trend in bat visitation to the wind turbines from August through November of 2019, bat activity was consistently low and sporadic. This downward seasonal trend differs from more distinct patterns of hoary bat activity observed at wind facilities studied using comparable methods on nearby islands (Gorresen *et al.* 2015b) and on the U.S. mainland (Cryan *et al.* 2014). At a wind facility on the island of O‘ahu, bat visitation to turbines increased during a six-month study period spanning from mid-May through mid-November of 2013, peaking in November (Gorresen *et al.* 2015b). We are not aware of other comparable data sets relevant to Hawaiian hoary bats. On the U.S. mainland and Canada, hoary bat fatality and video activity at wind turbines generally begins increasing in mid-June, tends to peak in September, then decreases by October and November (Arnett and Baerwald 2013, Cryan *et al.* 2014).

The question of whether bat activity and presumably collision risk in Hawai‘i is seasonally consistent or peaks during certain times of year remains unanswered. The hypothesis that seasonal peaks in hoary bat fatalities at turbines on the mainland have more to do with migration than other factors (Cryan and Barclay 2009), and thus the non-migratory Hawaiian hoary bat would be less susceptible, is yet untested. The possibility remains that factors other than migration, such as feeding or mating strategies that trigger bat investigation of tall landscape structures, primarily drive the seasonal peaks of bat fatalities observed elsewhere (Cryan and Barclay 2009, Cryan *et al.* 2014). Considering our results and available information, seasonal peaks in bat activity and fatality rates at wind turbines may occur in Hawai'i too, yet to our knowledge relevant year-long observations of occurrence combined with fatality monitoring have not been made at a sufficient number of wind energy facilities within the range of the Hawaiian hoary bat to discern whether or not a distinct and consistent seasonal peak occurs. Clearly establishing the existence and temporal consistency of seasonal peaks in bat activity at wind turbines has clear implications toward design and implementation of operational fatality reduction strategies.

We observed both similarities and differences in the nightly activity patterns of bats at the Auwahi Wind Energy facility compared to those uncovered using similar methods at turbines on O'ahu and the U.S. mainland. The bat detection rate at the Auwahi Wind Energy facility, measuring in the hundredths of bat detections per hour over the approximately 5,000 hours of video observation, was much lower than that observed during a comparable video-based study on O'ahu. The detection rate at the Auwahi Wind Energy facility was about an order of magnitude lower than was observed at turbines in an upland forest site on O'ahu, where bat detections numbered in the tenths (0.88) per hour over almost 4,000 hours of video, and which also included additional months with low bat activity (mid-May through July; Gorresen *et al.* 2015b). Similar to patterns observed on the U.S. mainland, hoary bat activity around the turbines at the Auwahi Wind Energy facility mostly occurred during the first half of the night, although bats were sometimes active in the hours before dawn (Cryan *et al.* 2014). This nightly activity pattern of a single activity peak more than an hour after sunset yet before midnight differs from that documented over six months at the upland forest turbines on O'ahu in 2013, where detections showed not only an earlier primary peak immediately after sunset, but also a smaller secondary peak in the hours just before dawn (Gorresen *et al.* 2015b).

Possible explanations for the single, lower, and slightly later nightly activity peak of Hawaiian hoary bats at the Auwahi Wind Energy facility include individuals having to commute to the site after emerging from roosts at sunset in nearby habitats (likely forests), and environmental conditions that potentially draw bats to turbines from the broader landscape being more likely to occur at that time. On O'ahu, the peaks of highest bat detections coincided with sunset and sunrise, indicating that bats were likely to visit turbines immediately after emerging from or returning to roosts in the surrounding forest. The lack of such crepuscular activity peaks at the Auwahi Wind Energy facility lead us to believe that bats visiting the turbines there do not roost during the daytime at or near the site, but instead reach the turbines by flying from more distant locations—probably tree roosts in denser forest stands, the closest of which are about 7 km away. The pattern also indicates bats do not regularly visit the Auwahi Wind Energy facility turbines in the hours before sunrise. The possibility of early nighttime environmental conditions that might draw bats to turbines are discussed below.

In addition to generally observing fewer visits by bats, a delayed post-sunset activity peak, and the lack of a pre-dawn activity peak, another notable pattern in the nightly activity of bats at the Auwahi Wind Energy facility was their sporadic occurrence at the wind facility from night to night. Our results indicate that when bats visit the wind facility, they tend to dwell around the turbines for slightly longer on a per-visit basis than was observed in upland forest at the wind facility on O'ahu. The duration of individual bat detection events at the Auwahi Wind Energy facility averaged 23.5 sec and were about six times longer than the duration of detections recorded at the O'ahu forest site, which averaged 4.0 sec per event (Gorresen *et al.* 2015b). However, the cumulative amount of time bats spent around a turbine on a nightly basis was remarkably similar between the two studies, with cumulative times totaling about 40 and 50 sec per turbine per night at the site on O'ahu and at the Auwahi Wind Energy facility, respectively (Gorresen *et al.* 2015b). These findings show that although Hawaiian hoary bats visit the Auwahi Wind Energy facility less frequently, their longer nightly visits could result in individuals spending an equivalent amount of time per night around turbines as at the forested site on O'ahu. However, patterns in the spacing of bat detections at the Auwahi Wind Energy facility within and among nights indicates potential differences in the way bats perceive and interact with wind turbines there compared to other sites.

Two notable patterns we observed at the Auwahi Wind Energy facility were the correlation of bat detections among turbines and the relatively long and unpredictable time periods between consecutive detection events, both within and among nights. Within a given night, visiting bats tended to dwell at the site and were likely to visit many of the turbines before leaving. When they did leave the site, an average of 1 hour 20 minutes elapsed before another bat was detected. On a night-to-night basis, bat occurrence was sporadic and unpredictable. That is, a Hawaiian hoary bat using the wind facility on a given night may not be strongly predictive of a bat occurring there again on subsequent nights or be strongly influenced by cyclic or other night-to-night patterns caused by short-term factors or predictable environmental conditions (at least within the 12-night analysis window we examined). The relatively infrequent, unpredictable, and lingering observations of Hawaiian hoary bats detected at the Auwahi Wind Energy facility could be attributable to certain wide-ranging individuals sporadically but repeatedly commuting to the site from distant roosting areas, multiple wide-ranging individuals haphazardly encountering the turbines during more randomly directed landscape movements, or some combination of these scenarios. Activity patterns of Hawaiian hoary bats observed in forested habitats on O'ahu led to speculation that those individual bats were familiar with turbines interspersed among their roosting and foraging grounds, and the resources (e.g., prey, mates, etc.) available at those structures (Gorresen *et al.* 2015b). It remains to be determined whether bats visiting turbines at the Auwahi Wind Energy facility are naïve to the resources sought at the turbines or if they become familiar and less risk-prone as experienced individuals.

The relatively longer periods of observation per bat visit at the Auwahi Wind Energy facility gave us better opportunities than in previous studies to determine why those hoary bats might have been flying in the airspace near the turbines. The duration of all detection events in this study totaled only 2.5 hours and made up only 0.05% of the entire period of video monitoring. This cumulative total was less than in the study at turbines in upland forest on O'ahu, where bat video observations totaled about 3.8 hours and represented 0.1% of video analyzed (Gorresen *et al.* 2015b). As discussed above, despite less frequent detections at the Auwahi Wind Energy facility, the longer duration of events there resulted in the cumulative period of bat detections per turbine per night being similar between the two studies. However, bats at the Auwahi Wind Energy facility were observed for proportionally longer periods per detection event, giving us more opportunities to accurately discern behaviors during these typically brief encounters.

Eight out of ten of the observations of Hawaiian hoary bats around wind turbines at the Auwahi Wind Energy facility involved erratic flight indicative of bats engaged in foraging behavior. Only a small proportion of events involved straight, directed flight past the turbines, suggestive of bats quickly transiting the rotor-swept airspace. The proportion of events involving foraging-like flight at the Auwahi Wind Energy facility was approximately double that documented during the study on O‘ahu, where turbines were situated in upland forest, and bat activity correlated to insect activity (Gorresen *et al.* 2015b). A 2017 videographic survey of upland habitats on O‘ahu (including the wind facility mentioned previously) also showed that most bat detection events involved single passes involving straight and directed flight, suggestive of samples obtained from bats moving within frequently traversed home ranges (Gorresen *et al.* 2018). The bats at the Auwahi Wind Energy facility may have been concentrating their flight and associated search for food disproportionately more on the wind turbines than on surrounding habitats, whereas those observed on O‘ahu may have been primarily moving through the habitats with ample feeding opportunities surrounding the turbines and thus spending proportionally less time focusing on the turbines. Overall, our observations indicate bats travel from distant roost sites to the remote but potentially focal foraging area around the Auwahi Wind Energy facility turbines, search promising habitat features (including the turbines themselves) for insect prey, then leave and only infrequently return during the same or subsequent nights. In contrast, the proportionally lower incidence of foraging-like behavior observed around turbines in forested uplands of O‘ahu might have been attributable to those turbines being situated amidst more favorable alternative foraging prospects.

Regardless of why bats entered the airspace around wind turbines at the Auwahi Wind Energy facility, more than half of the detection events involved individuals flying within an estimated 15 m of the turbine nacelle. This regular and consistently observed close-approach behavior, combined with relatively few observations of bats being displaced by moving blades and no observation of strikes, indicates that the presence of Hawaiian hoary bats in the rotor-swept zone of a turbine may not be directly proportional to their risk of being injured, particularly when presence is considered independent of wind speed. Systematic ground-based carcass searches resulted in no documented bat fatalities at the four turbines during the four-month monitoring period (Tetra Tech 2019).

The activity of bats is generally believed to decrease with increasing wind speed (Weller and Baldwin 2012, Korner-Nievergelt *et al.* 2013), as strong winds can influence the abundance and activity of insects (Erkert 1982). The results from the Auwahi Wind Energy facility are mostly consistent with these trends, although nearly one-fifth of our bat observations were made when wind speeds were greater than the mitigation cut-in speed of 6.9 m/sec. When we modeled the influence of environmental conditions on the probability of hoary bats occurring at the Auwahi Wind Energy facility, results revealed that bat occurrence was negatively related to wind speed, averaged over 10-minute intervals, and possibly declined after or during rain events (although available precipitation data made it difficult to clearly test for the influence of rain at the nightly temporal scale we used for the analysis). Despite the apparent relation of bat detection rates with wind speed and precipitation (both negative), the relation was not predictable—considerable variation was present in the modeled response of bats to weather. We found that low detection rates could occur when conditions appeared favorable, such as when there was no wind and wind speeds were low. Conversely, high detection rates may occur during relatively unfavorable conditions. For example, the largest observed detection rate we documented (nearly a bat per hour) occurred on the night of 15 November when turbine blade rotation averaged 7.1 rpm, wind speed averaged 5.7 m/sec, and wind speed variability, blade rotation intermittency, and light precipitation were also similar to the average conditions observed during the entire four-month study period. Such an event does not seem predictable given available information, but this does not mean that predictable associations among bat occurrence, environmental conditions, and turbine operation do not exist.

Our study objective was to learn more about how bat behaviors at wind turbines relate to wind speed and turbine operation—key elements of effective mitigation strategies for minimizing fatalities of Hawaiian hoary bats. In assessing possible reasons for bat occurrence near the turbines at the Auwahi Wind Energy facility during high wind conditions, we evaluated our data in the context of behaviors we observed on video and the unique turbine operational conditions observable due to the relatively high curtailment cut-in wind speed of 6.9 m/sec. One of the patterns that clearly emerged from the data was that bats were more likely to be detected at turbines when the blades were not moving or were moving slowly, although perhaps not proportional to what would be expected due to wind speed alone in part because of curtailment. However, it is noteworthy that the bat detection rate at the non-operational turbine (WTG2) was similar to the overall mean and not found to be significantly different from the other three operational turbines. This may indicate that fast turbine blade movement is not a causal factor related to the attraction of bats and their presence at turbines. Nevertheless, variability in wind speed and turbine blade rotation intermittency were both positively related to bat detection probability in our analysis. Nearly one-fifth of the observations of bats at the Auwahi Wind Energy facility turbines occurred during conditions when wind speeds exceeded the 6.9 m/sec threshold, indicating that responding to wind-speed alone may not maximize opportunities to produce energy and avoid bat fatalities. When discussing similar results from a video study of bat activity at wind turbines on the U.S. mainland, Cryan *et al.* (2014) speculated "…observations that tree bats show a tendency to closely investigate inert turbines and sometimes linger for minutes to perhaps hours (in the cases of clustered observations) highlight the plausibility of a scenario in which bats are drawn toward turbines in low winds, but sometimes remain long enough to be put at risk when wind picks up and blades reach higher speeds. Therefore, the frequency of intermittent, blade-spinning wind gusts within such low-wind periods might be an important predictor of fatality risk; fatalities may occur more often when turbine blades are transitioning from potentially attractive (stationary or slow) to lethal (fast) speeds."

Such a scenario may be compatible with our observations and analysis from the Auwahi Wind Energy facility. For example, of the proportionally small sample of 34 bat events we observed when turbine blades were moving more than one-half a rotation per minute, eight ensued when wind speeds were below the curtailment threshold. These events may have occurred because of computational lags over the 10-minute period within which the rolling average wind-speed calculated included occasional interludes during which winds dropped below the cut-in threshold but did not yet trigger curtailment. Combining these observations with earlier discussion that bats visiting the Auwahi Wind Energy facility might periodically and intensely search the turbines for feeding opportunities, a plausible hypothesis emerges: Hawaiian hoary bats might occur at the Auwahi Wind Energy facility during variable wind periods because windy periods concentrate insects on the lee of emergent features (e.g., trees), and when winds slacken bats might take the opportunity to focus foraging on the ephemeral concentrations of prey. In other words, relative to calm wind conditions, bats may opportunistically exploit certain landscape features during lulls on otherwise windy nights. A prerequisite for opportunistic use of tall structures such as wind turbines is that they be visually conspicuous and attract bats. This is largely supported by research demonstrating that, relative to surrounding landscapes, the activity of tree bats at tall structures increases as individuals encounter these features during migration in late summer and autumn (Jameson and Willis 2014).

Our study was not able to make optimal use of combined sampling methods because of the poor quality of acoustic data. Fortunately, video cameras functioned more consistently and produced more useful data for drawing inferences about bat presence and behaviors at the turbines than acoustic detectors. Known limitations of the acoustic detection process and potentially cryptic vocalization behavior of hoary bats were concerns going into this study, as well as likely only a modest overlap of the airspace sampled by the two methods (bats could be out of the video field of view, and video can also image farther than an acoustic detector can sample). In general, we confirmed that the range of acoustic detectors was different, less consistent across conditions, and generally lower than thermal surveillance cameras in this study. Although it is clear that Hawaiian hoary bats are acoustically active when present at Auwahi Wind Energy facility, it also appears that the species exhibits, to some extent, the cryptic vocalization noted in other settings (Gorresen *et al.* 2017, Corcoran and Weller 2018). Although both video and acoustic sampling had similar detection rates for the entire four-month monitoring period (albeit not directly comparable because acoustic sampling was weighted towards the earlier months during which nightly bat detections were more prevalent), there was a clear mismatch in the incidence and proportion of samples with bat detections. For the subset of concurrently sampled turbine-nights, acoustic detectors confirmed bat presence in about three-quarters of the turbine-nights for which bats were also detected by thermal cameras. Acoustic bat detectability further declined at finer-resolution time periods of sampling, such as hourly and 10-minute intervals at which video monitoring determined bat occurrence. The frequent lack of detections within a reasonable window for informing acoustically triggered turbine curtailment may have implications for the effectiveness of this method in reducing fatalities, at least in the setting examined in this study. The nature and variability of vocalization by bats at tall structures such as turbines, as well as the operational limits of the detection system, warrants further investigation using both acoustic and videographic methods.

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APPENDIX I

Table 1. Total nightly bat visual (video) and acoustic detection events and respective detection rates (combined and adjusted for sampling effort for all four turbines). Additional supporting information (including detection events by turbine) are available as a U.S. Geological Survey data release at https://doi.org/10.5066/P937H9LQ. Total daily precipitation (cm) obtained from weather station USGS 203721156151601 (Kepuni Gulch Rain Gage, Maui, Hawaii, located 7.3 km ENE from Auwahi Wind Energy, LLC, at 226 m above local mean sea level) is available at: https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=203721156151601; also available at https://doi.org/10.5066/F7P55KJN.

Date	Total visual detection events	Visual detection rate	Total acoustic detection events	Acoustic detection rate	Daily precipitation (cm)
8/1/2018	1	0.029	0	0.000	0.00
8/2/2018	13	0.378	0	0.000	0.00
8/3/2018	5	0.146	0	0.000	0.00
8/4/2018	2	0.058	0	0.000	0.00
8/5/2018	1	0.029	0	0.000	0.00
8/6/2018	10	0.224	0	0.000	0.00
8/7/2018	8	0.173	2	0.087	0.00
8/8/2018	1	0.029	0	0.000	0.00
8/9/2018	0	0.000	0	0.000	1.73
8/10/2018	2	0.111	2	0.058	0.00
8/11/2018	0	0.000	2	0.058	0.46
8/12/2018	0	0.000	0	0.000	0.00
8/13/2018	3	0.129	4	0.115	0.00
8/14/2018	15	0.644	16	0.458	0.00
8/15/2018	2	0.086	9	0.257	0.00
8/16/2018	11	0.290	14	0.400	0.00
8/17/2018	6	0.172	4	0.114	0.20
8/18/2018	0	0.000	0	0.000	0.00
8/19/2018	5	0.128	3	0.085	0.00
8/20/2018	10	0.283	10	0.284	0.00
8/21/2018	0	0.000	1	0.028	0.00
8/22/2018	0	0.000	0	0.000	0.81
8/23/2018	1	0.021	0	0.000	1.30

Date	Total visual detection events	Visual detection rate	Total acoustic detection events	Acoustic detection rate	Daily precipitation (cm)
8/24/2018	0	0.000	0	0.000	4.17
8/25/2018	0	0.000	0	0.000	2.29
8/26/2018	0	0.000	0	0.000	2.21
8/27/2018	0	0.000	0	0.000	0.13
8/28/2018	0	0.000	0	0.000	0.03
8/29/2018	4	0.112	5	0.140	0.00
8/30/2018	1	0.028	7	0.196	0.00
8/31/2018	3	0.085	3	0.084	0.00
9/1/2018	1	0.028	2	0.056	0.00
9/2/2018	5	0.208	6	0.167	0.00
9/3/2018	2	0.083	0	0.000	0.00
9/4/2018	5	0.208	2	0.055	0.00
9/5/2018	3	0.124	5	0.138	0.00
9/6/2018	1	0.031	4	0.111	0.00
9/7/2018	4	0.084	6	0.166	0.00
9/8/2018	4	0.110	9	0.248	0.00
9/9/2018	8	0.165	5	0.138	0.00
9/10/2018	8	0.165	5	0.137	0.00
9/11/2018	2	0.041	3	0.082	0.00
9/12/2018	0	0.000	0	0.000	4.47
9/13/2018	0	0.000	0	0.000	0.79
9/14/2018	1	0.028	0	0.000	0.00
9/15/2018	0	0.000	0	0.000	0.00
9/16/2018	4	0.109	0	0.000	0.00
9/17/2018	1	0.027	1	0.027	0.00
9/18/2018	5	0.135	3	0.081	0.00
9/19/2018	0	0.000	0	0.000	0.00
9/20/2018	0	0.000	0	0.000	0.00
9/21/2018	0	0.000	0	0.000	0.00
9/22/2018	0	0.000	0	0.000	0.00
9/23/2018	0	0.000	0	0.000	0.30
9/24/2018	2	0.054	1	0.020	0.97
9/25/2018	5	0.134	18	0.362	0.05

Date	Total visual detection events	Visual detection rate	Total acoustic detection events	Acoustic detection rate	Daily precipitation (cm)
9/26/2018	2	0.054	5	0.100	0.00
9/27/2018	2	0.080	6	0.160	0.46
9/28/2018	0	0.000	0	0.000	0.03
9/29/2018	6	0.160	6	0.160	0.05
9/30/2018	0	0.000	2	0.053	0.00
10/1/2018	1	0.027	0	0.000	0.00
10/2/2018	2	0.053	0	0.000	0.00
10/3/2018	5	0.132	0	0.000	0.00
10/4/2018	8	0.211	2	0.079	0.00
10/5/2018	1	0.023	0	0.000	0.89
10/6/2018	5	0.099	0	0.000	1.88
10/7/2018	0	0.000	0	0.000	5.79
10/8/2018	2	0.039	1	0.079	0.20
10/9/2018	12	0.236	3	0.236	0.00
10/10/2018	8	0.157	0	0.000	0.00
10/11/2018	1	0.020	1	0.079	0.00
10/12/2018	4	0.157	0	0.000	1.83
10/13/2018	1	0.026	0	0.000	0.08
10/14/2018	14	0.273	2	0.156	0.00
10/15/2018	13	0.253	9	0.703	0.00
10/16/2018	8	0.156	8	0.624	0.00
10/17/2018	6	0.117	2	0.156	0.00
10/18/2018	6	0.161	8	0.622	0.00
10/19/2018	5	0.098	2	0.155	0.00
10/20/2018	3	0.058	8	0.620	0.00
10/21/2018	11	0.213	7	0.542	0.00
10/22/2018	7	0.154	4	0.309	0.00
10/23/2018	0	0.000	0	0.000	0.00
10/24/2018	2	0.038	0	0.000	0.00
10/25/2018	1	0.019	0	0.000	0.00
10/26/2018	2	0.044	0	0.000	0.00
10/27/2018	2	0.038	0	0.000	0.03
10/28/2018	0	0.000	0	0.000	0.00

Date	Total visual detection events	Visual detection rate	Total acoustic detection events	Acoustic detection rate	Daily precipitation (cm)
10/29/2018	0	0.000	0	0.000	0.13
10/30/2018	3	0.076	1	0.076	0.10
10/31/2018	1	0.019	1	0.076	0.03
11/1/2018	4	0.076	1	0.076	0.00
11/2/2018	5	0.096	1	0.076	0.00
11/3/2018	0	0.000	0	0.000	0.20
11/4/2018	1	0.019	0	0.000	0.20
11/5/2018	8	0.152	1	0.076	0.00
11/6/2018	0	0.000	0	0.000	0.00
11/7/2018	0	0.000	0	0.000	0.00
11/8/2018	2	0.038	0	0.000	0.00
11/9/2018	3	0.077	1	0.075	0.00
11/10/2018	4	0.100	1	0.075	0.00
11/11/2018	6	0.113	0	0.000	0.00
11/12/2018	2	0.075	1	0.075	0.00
11/13/2018	1	0.025	0	0.000	0.00
11/14/2018	2	0.067	0	0.000	0.03
11/15/2018	18	0.369	1	0.075	0.23
11/16/2018	6	0.114	3	0.225	0.00
11/17/2018	0	0.000	0	0.000	0.00
11/18/2018	1	0.019	1	0.075	0.00
11/19/2018	6	0.149	1	0.075	0.00
11/20/2018	0	0.000	0	0.000	0.00
11/21/2018	0	0.000	0	0.000	0.00
11/22/2018	0	0.000	0	0.000	0.76
11/23/2018	0	0.000	0	0.000	0.00
11/24/2018	1	0.019	1	0.074	0.00
11/25/2018	4	0.085	0	0.000	0.00
11/26/2018	0	0.000	0	0.000	0.00
11/27/2018	1	0.025	0	0.000	0.00
11/28/2018	0	0.000	0	0.000	0.00
11/29/2018	0	0.000	1	0.074	0.18
11/30/2018	0	0.000	0	0.000	0.00

APPENDIX II

Table 1. Summary of the number of nightly visual (video) and acoustic bat detection events per turbine, detection rate (number of detection events per hour, calculated as the nightly total of events divided by sample duration at a turbine), and the nightly metrics of weather and turbine operation variables, including precipitation ("precip"; total in cm for a 24-hour midnight-to-midnight period centered on the day of the record), mean wind speed ("wind-mean"; calculated as the mean of 10-minute interval recordings), variability in wind speed ("wind-sd"; calculated as the standard deviation of 10-minute interval recordings), turbine blade movement ("rpm"; rotations per minute), and turbine starts ("rpm-starts"; calculated as the total of such events following one or more 10-minute intervals at which the blade was motionless). Values include minimum, 1st quartile, median, mean, 3rd quartile, and maximum. All weather and turbine operation variables used in regression analysis were standardized and centered on the variable mean (i.e., subtracting variable values by its grand mean and dividing by its standard deviation). See methods for description of data sources. Additional supporting information are available as a U.S. Geological Survey data release at https://doi.org/10.5066/P937H9LQ.

Values	Visual detection events	Visual detection rate	Acoustic detection events	Acoustic detection rate	Precip	Wind-mean	Wind-sd	Rpm	Rpm-starts
Min:	0.000	0.000	0.000	0.000	0.000	0.985	0.745	0.000	0.000
1Q:	0.000	0.000	0.000	0.000	0.000	3.865	1.570	0.160	1.000
Median:	0.000	0.000	0.000	0.000	0.000	7.098	2.125	4.293	2.000
Mean:	0.934	0.077	0.988	0.081	0.271	7.336	2.178	6.394	3.879
3Q:	1.000	0.087	1.000	0.077	0.030	10.252	2.676	13.020	5.000
Max:	12.000	0.899	14.000	1.125	5.790	21.021	4.886	16.210	21.000

APPENDIX III

Figures 1–6. Post-model-fitting diagnostics performed with the DHARMa package (Hartig 2017). Diagnostics demonstrated that the six top-ranked regression models (listed in Tables 5 and 6) met assumptions of uniformity (left panels) and did not exhibit zero inflation (right panels).

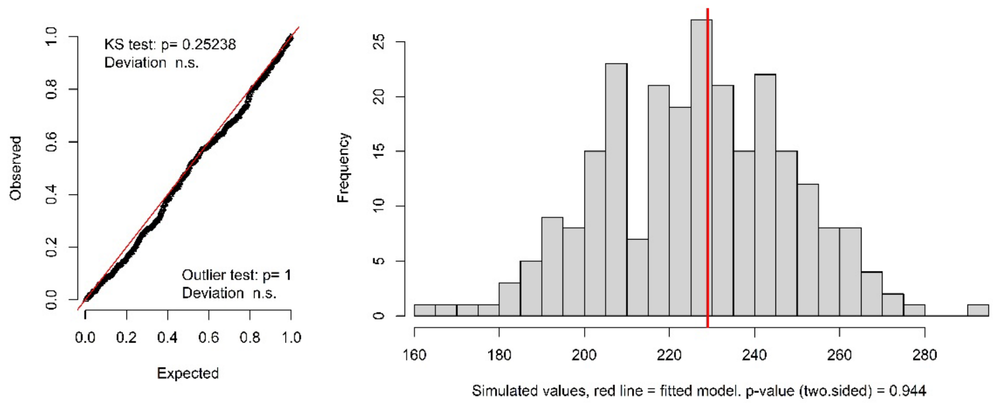

Figure 1. Model 1 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

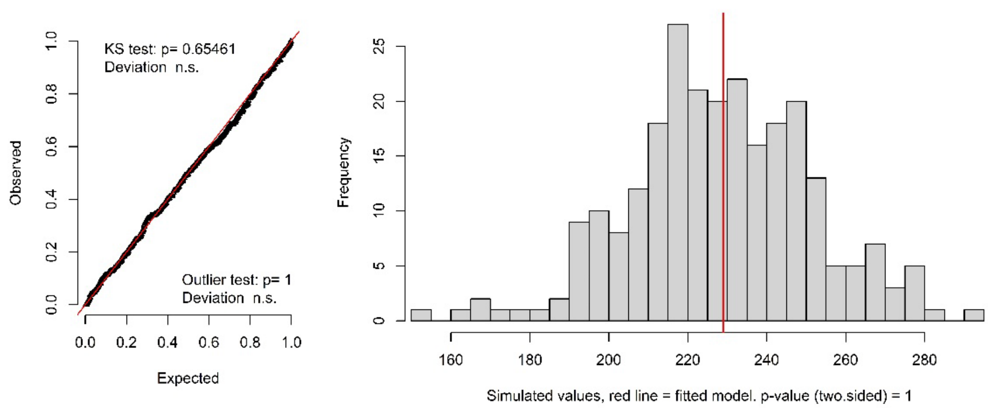

Figure 2. Model 2 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

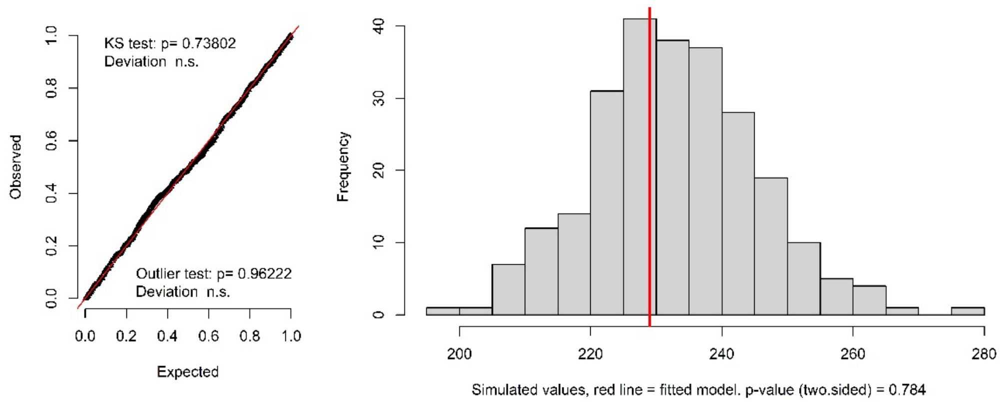

Figure 3. Model 3 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

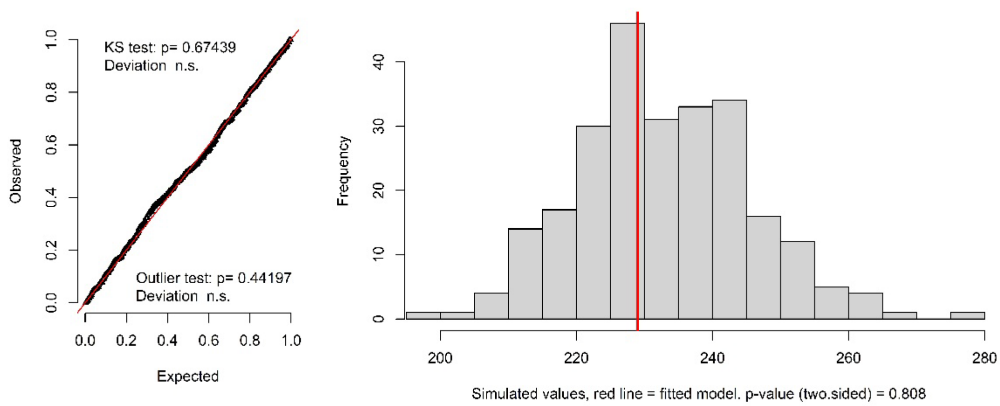

Figure 4. Model 4 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

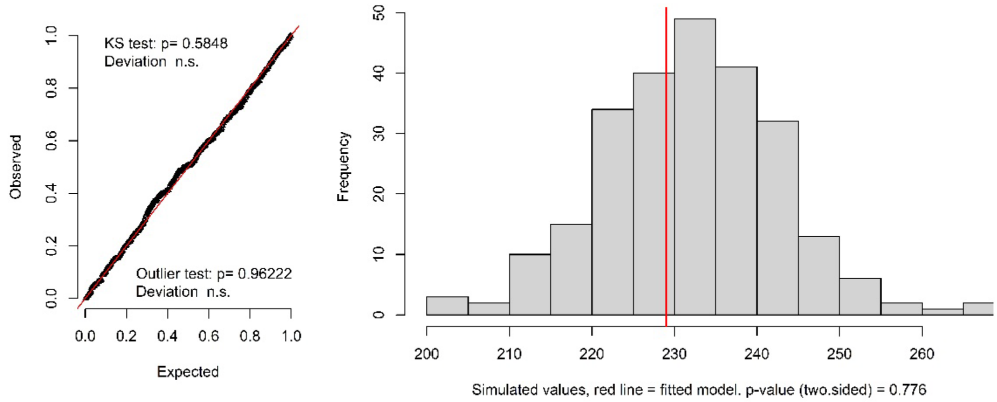

Figure 5. Model 5 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

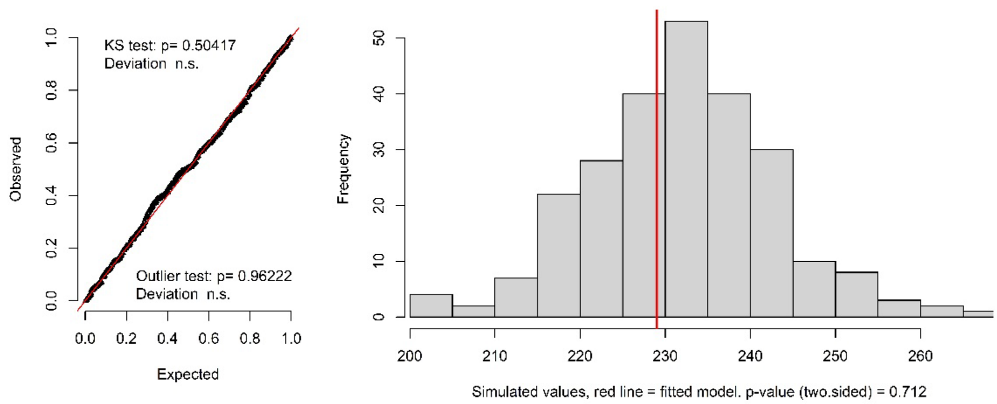

Figure 6. Model 6 of six top-ranked regression models. Left panel shows model met assumptions of uniformity, and right panel displays model did not exhibit zero inflation.

Attachment 6

Comments on Draft Updated Hawaiian Hoary Bat Guidance (January 2020 Version)

Auwahi **Wind**

20100 Piilani Hwy
Kula, HI 96790

February 21, 2020

Lauren Taylor

Protected Species Habitat Conservation Planning Coordinator

Department of Land and Natural Resources

Division of Forestry and Wildlife

1151 Punchbowl Street, Room 325

Honolulu, HI 96813

Re: Comments on Draft Updated Hawaiian Hoary Bat Guidance (January 2020 Version)

Dear Ms. Taylor:

At the Endangered Species Recovery Committee (ESRC) meeting on January 15, 2020, the ESRC announced the delivery of the Draft Hawaiian Hoary Bat Guidance for Renewable Wind Energy Proponents (dated January 2020; Draft Updated Guidance). This is the first proposed revision of the original ESRC Hawaiian Hoary Bat Guidance Document issued in December 2015. The ESRC has requested comments on the Draft Updated Guidance prior to its Hawaiian Hoary Bat Workshop, scheduled for March 5-6, 2020. Auwahi Wind and American Electric Power Renewables read through the draft and is submitting this literature review in response to the ESRC request.

Auwahi Wind is owned and operated by American Electric Power Renewables that acquired the project from Sempra Renewables in 2019. Auwahi Wind is located on Ulupalakua Ranch, Maui, and began operations in 2012. Auwahi Wind developed a Habitat Conservation Plan (HCP) and was issued an incidental take permit (ITP) and incidental take license (ITL) from US Fish and Wildlife service and the Hawai'i Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW), for the project including coverage for the Hawaiian hoary bat (*Lasiurus cinereus semotus*). Starting in 2014, Auwahi Wind worked with USFWS, DOFAW, and ESRC to receive approval of an HCP amendment in 2019. Auwahi Wind has over eight years of experience since ITP/ITL issuance implementing the HCP responsibilities for minimization, downed wildlife monitoring, and Hawaiian hoary bat mitigation and conducted innovative research to better understand the species.

The Draft Updated Guidance is an opportunity to summarize the best available science to guide Hawaiian hoary bat conservation and recovery through applicable HCP development and implementation. The Draft Updated Guidance does not include all current best available information. Therefore, Auwahi Wind, American Electric Power Renewables, and Tetra Tech worked together to aggregate additional topics and available literature that will help identify the gaps in the Draft Updated Guidance. Attached is a summary of the additional topics and associated literature which enhance the depth and breadth of what is currently known about Hawaiian hoary bat ecology and their interactions with turbines; thus identifying management and recovery actions to provide benefits to Hawaiian hoary bats across the Hawaiian Islands.

Sincerely,

George Akau

Project Biologist

Auwahi Wind

American Electric Power Renewables

Literature Compilation

For the

Hawaiian Hoary Bat Guidance for Renewable Wind Energy Proponents

Updated January 2020

Endangered Species Recovery Committee and

State of Hawaiʻi Department of Land and Natural Resources

Division of Forestry and Wildlife

February 2020

Overview

Tetra Tech, Inc. (Tetra Tech) conducted a literature review of the draft Hawaiian Hoary Bat Guidance for Renewable Wind Energy Proponents Updated January 2020 (Draft Guidance) prepared by Endangered Species Recovery Committee (ESRC) and Division of Forestry and Wildlife (DOFAW) to identify additional citations that should be considered for future revisions of the Draft Guidance. This literature compilation identifies the best available science related to wind farm operation and habitat conservation planning for the Hawaiian hoary bat (*Lasirus cinereus semotus*) in 2020 and includes a suite of topics and relevant uncited literature to support key guidance topic areas. This information can support the ESRC's efforts to include a comprehensive analysis of the available literature in the Draft Guidance. Studies included below are those relevant to each major topic in the Draft Guidance.

The literature compilation is generally based on the structure of the Draft Guidance. Relevant headings provided in the Draft Guidance are included and additional recommended citations for inclusion in the Draft Guidance are listed alphabetically.

The Draft Guidance should be clear on what are the key findings from cited literature. In addition to considering these citations, the Draft Guidance would benefit from noting if findings are peer reviewed, supported by multiple sources, or conversely if they are preliminary, or conflict with other findings.

1. Background

A. Ecology and Status of The Hawaiian Hoary Bat

The ecology of the Hawaiian hoary bat has been the subject of many studies. The studies of the Hawaiian hoary bat have produced a depth and breadth of knowledge that can inform many aspects of Habitat Conservation Plan (HCP) development. The U.S. Fish and Wildlife (USFWS) Programmatic Environmental Impact Statement (USFWS 2019), specifically Appendix G includes a review of information on Hawaiian hoary bat ecology. Where information is absent or limited, documentation of the limitation or absence is also valuable.

Additionally, research has demonstrated that the behaviors, diet preferences, and habitat selection and other aspects of Hawaiian hoary bat biology closely match mainland hoary bat (*Lasirus cinereus*) ecology. The similarity between Hawaiian hoary bats and mainland hoary bats demonstrates the importance of incorporating literature from mainland hoary bats to supplement the knowledge of the Hawaiian hoary bat. General bat biology is also applicable, and patterns of behavior or association seen across all species or comparable species provide additional insight for Hawaiian hoary bats. If aspects of

Hawaiian hoary bat ecology are documented to differ from mainland hoary bat or general bat ecology the difference should be noted.

<u>The information on the Hawaiian hoary bat should include a discussion of the following topics:</u>

- Monitoring methods
  - Metrics of activity
  - Detection definition
  - Limitations
- Distribution
  - Documented occurrence on each island
  - Maps of known observation relative to sampling effort and date
  - Elevation range
- Diet
  - Prey
    - Species
    - Size
    - Selection relative to abundance
    - Range of species identified
    - Seasonal changes
  - Foraging strategies
    - Water
      - Drinking
      - As a foraging substrate
    - Edge habitat
    - Open habitat
  - Requirements
- Physiology
  - Body size
  - Differences from mainland hoary bats and implications
  - Wing morphology and implications
  - Echolocation
    - Frequency
    - Amplitude
    - Range
- Patterns of activity
  - Seasonal activity
    - Call abundance
    - Elevation changes
  - Hour of night
  - Interspecies competition
  - Intraspecies competition
  - Bat activity correlation (positive and negative) with habitat types or other covariates by behavior

        - Breeding
        - Roosting
            - Day
            - Night
        - Foraging
        - Drinking
        - Social
    - Spatial patterns of activity
    - Response to habitat management
- Demographic information
    - Average and maximum lifespan
    - Male to female ratio observed
    - Breeding
        - Seasonality
        - Changes to diet and habitat
        - Number of offspring
        - Age at first breeding
        - Frequency of breeding
        - Proportion of breeding population
- Genetics
    - Origin
    - Closest species
    - Species status
    - Most recent colonization
- Legal
    - Species status under HRS 195D
    - Listing determination criteria
    - Critical habitat
    - Downlisting criteria
    - Delisting criteria

Recommended Additional Literature Citations:

Baird, A.B., Braun, J.K., Mares, M.A., Morales, J.C., Patton, J.C., Tran, C.Q. 2015. Molecular systematic revision of tree bats (Lasiurini): doubling the native mammals of the Hawaiian Islands. Journal of Mammology 96(5):1-20.

Baird A.B., J.K. Braun, M.D. Engstrom, A.C. Holbert, M.G. Huerta, B.K. Lim, et al. 2017. Nuclear and mtDNA phylogenetic analyses clarify the evolutionary history of two species of native Hawaiian bats and the taxonomy of Lasiurini (Mammalia: Chiroptera). PLoS ONE 12(10): e0186085.

Baker. R. J., J. C. Patton, H. H. Genoways, and J. W. Bickham. 1988. Genic studies of Lasiurus (Chiroptera: Vespertilionidae). Occasional Papers the Museum Texas Tech University Number 117.

Banko, P. C., R. W. Peck, S. G. Yelenik, E. H. Paxton, F. J. Bonaccorso, K. Montoya-Aiona, and D. Foote. 2014. Dynamics and ecological consequences of the 2013−2014 koa moth outbreak at Hakalau Forest National Wildlife Refuge. Technical Report HCSU-058, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, Hawai'i, 89 pp

Barclay, R. M. R. 1989. The effect of reproductive condition on the foraging behavior of female hoary bats, Lasiurus cinereus. Behavioral Ecology and Sociobiology. 24: 31-37.

Barclay, R., Dolan, M., Dyck, A., 1991. The Digestive Efficiency of Insectivorous Bats. Canadian Journal of Zoology, Vol 69, no 7. P 1853-1856.

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B. Bats and Wind Energy

Bat fatalities have been found at many wind farms on the mainland. Multiple studies report observed bat species fatality composition includes a significant portion of mainland hoary bats. Most studies of mainland bat fatalities note the significance of migration, or only implement minimization in the migratory period. The greatest relevance for mainland studies of impacts applies to minimization measures which are discussed in Section 3.

C. Hawaiian Hoary Bats and Wind Energy

Hawaiian hoary bats have been covered by HCPs in Hawaiʻi since 2006 and associated acoustic and fatality monitoring data has been documented in annual reports. When combined over 40 years of monitoring has occurred at wind farms in Hawaiʻi providing an opportunity to summarize trends.

<u>The information on Hawaiʻi Wind Energy should include a discussion of the following topics:</u>

- Observed take
  - Seasonality
    - Relation to reproductive cycles
    - Relation to bat activity (acoustic and thermal)
  - Age
  - Gender ratio
  - Documented predictors of fatalities in Hawaiʻi
  - Impacts of observed take
- Take rates
  - Observed take rates at existing wind farms
  - Trends in take rates
  - Authorized take rates
- Minimization measures implemented and documented effectiveness in Hawaiʻi
  - Low wind speed curtailment (LWSC)
  - Acoustic Deterrents
- Acoustic monitoring results for existing projects
  - Trends in activity
  - Influence on minimization measures

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2. Assessment of Take and Impacts for HCPs

A. Take Calculations

USFWS and DOFAW have provided guidance documents for biological monitoring of wind farms which outline methods for assessing take. Within the established downed wildlife monitoring framework there are project specific optimizations for selected search methods and bias correction. Although search methods or bias trials may vary, the evaluation of impacts is equivalent through the use of standardized statistical tools.

<u>The information on the take calculations should include a discussion of the following topics:</u>

- Definitions
  - HRS 195 Definitions
  - Statistical definitions
- Existing guidance
- Fatality estimation (How unobserved take is estimated)
  - Relationship between observed take, detection probability, and unobserved take
  - Selecting a model
    - Evidence of Absence (EoA)
    - Generalized Estimator (GenEst)
    - Huso
    - Schoenfeld
    - Others
- Detection probability
  - Level of effort
    - Area searched
    - Search schedule
      - Seasonal variation
      - Changes to search parameters by year
    - Search interval
    - Search methods
    - Searcher Efficiency
    - Carcass Persistence
  - Uncertainty
  - Relationship to take estimate
- Density Weighted Proportion (DWP) of fall distribution
  - Hull and Muir
  - Empirical models
  - Other
- Credible level
  - Agency recommended credible level with calculations
  - Citation from Dalthorp et al. 2017 regarding credible levels
  - Assessment of impacts considering the credible level selected
- Translating a probability distribution to a point estimate

- Indirect take
    - Definition of indirect take
    - Biological basis for recommended calculations
    - Calculation

B. Fatality Monitoring

Fatality monitoring incorporates onsite monitoring for covered species and estimates of detection probability. Fatality monitoring is interrelated with fatality estimation and the topics could be addressed together.

- Requirements of HRS 195D
- Area searched
- Search interval
- Search methods
- Searcher Efficiency
- Carcass Persistence

Recommended Literature Citations:

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3. Hawaiian Hoary Bat Take Avoidance and Minimization

Avoidance and minimization measures to reduce bat fatalities have focused on two mechanisms: LWSC and bat deterrents. Both methods have been the subject of scientific tests of effectiveness for reduction in bat fatality rates. Neither LWSC nor deterrents have proven to equate to complete avoidance. Both methods have been implemented at wind farms in Hawaiʻi.

<u>The information on minimization measures should include a discussion of the following topics:</u>

- Definitions
- Influence of time on bat activity and the relevance to minimization measures
    - Documentation of the time of night of bat activity
    - Documentation of the seasonality of bat activity
- LWSC
    - Biological basis for LWSC from bat activity literature
        - Relationship between bat activity and wind speed
            - Averaging period
            - Measurement of wind speed
            - Wind speed variability
        - Proportion of activity explained and not explained by wind speed
        - Interaction between bat activity and other environmental variables
            - Insect activity
            - Precipitation
            - Humidity
            - Barometric pressure
            - Moon illumination
    - Demonstrated Effectiveness
        - Mainland
        - Hawaiʻi
    - Variation in effectiveness
    - Expected benefit by cut-in speed
    - Smart curtailment
        - Model inputs
        - Applicability or limitations in Hawaiʻi
    - Energy losses by cut-in speed
- Bat Deterrents
    - Biological basis for bat deterrent systems
        - Acoustic
        - Visual
        - Texture
    - Demonstrated Effectiveness
        - Mainland

        - Hawaiʻi
    - Variation in effectiveness
- Estimating project impacts
    - Correlation between baseline activity and fatality rates
    - Changes to bat behavior correlated with wind turbines
    - Hawaiian hoary bat distribution
        - Habitat correlations for the Hawaiian hoary bat
        - Island distributions
        - Relative abundance
    - Correlation between fatality rates and wind project design with citations
        - Number of turbines
        - Layout
        - Turbine structure
        - Nacelle height
        - Rotor swept area
        - Impacts to other covered species
- Adaptive Management
    - Triggers
    - Actions
    - Incorporation of uncertainty
    - Incorporation of new information

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4. Mitigation

Studies of the Hawaiian hoary bat document statistically significant habitat correlations, which should be prioritized when considering Hawaiian hoary bat mitigation. Existing Hawaiian hoary bat HCP holders have performed required mitigation, which is documented in annual reports and can inform future mitigation. As with Hawaiian hoary bat ecology, mainland hoary bat ecology and general bat biology provide valuable scientific literature to inform Hawaiian hoary bat mitigation.

<u>The information on Hawaiian hoary bat mitigation should include a discussion of the following topics:</u>

- Definitions
- Reference data from Hawaiian hoary bat ecology
  - Distribution
  - Diet
  - Patterns of activity
  - Demographic information
- Mitigation actions
  - Goals and objectives for mitigation
  - Status of existing mitigation projects
  - Timeline for mitigation actions
  - Success criteria
    - Direct measurement of individuals
    - Measurement of population trends
    - Proxy measurements (habitat, insects, or others)
    - Thresholds for success
- Monitoring methods
  - Level of effort relative to success criteria
  - Monitoring tools
    - Acoustic
    - Thermal
    - Insect
    - Habitat
    - Other
- Mitigation Offset
  - Requirements of HRS 195D
  - Comparison to baseline conditions and the absence of mitigation actions
  - Quantitative assessment of the benefit of the mitigation actions for the Hawaiian hoary bat and the likelihood of recovery for the species
    - Lands
      - Selection of mitigation location(s)
      - Size
      - Habitat
      - Legal protection
      - Connectivity relative to bat movement

- Duration
  - Lifespan of Hawaiian hoary bats
    - Average
    - Maximum
  - Hawaiian hoary bat reproduction
    - Average number of juveniles produced per bat per year
    - Growth model for subsequent reproduction
- Management
  - Legal protections added
  - Prevention of habitat loss or degradation
  - Change in habitat
  - Change in foraging or drinking resources
  - Change in breeding resources
- Research
  - Relationship to Hawaiian hoary bat recovery
  - Approved research and results
  - Requested research
  - Reduced uncertainty derived from management
  - Consistency with federal policy

- Adaptive Management
  - Triggers
  - Actions
  - Incorporation of uncertainty
  - Incorporation of new information

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Attachment 7

FY 2021 Annual Work Plan and Timeline

<table>
<tr><th rowspan="2"></th><th rowspan="2"></th><th colspan="6">2020</th><th colspan="6">2021</th></tr>
<tr><th>July</th><th>August</th><th>September</th><th>October</th><th>November</th><th>December</th><th>January</th><th>February</th><th>March</th><th>April</th><th>May</th><th>June</th></tr>
<tr><td rowspan="4">PCMM</td><td>Fatality Searches</td><td colspan="12">Weekly Canine Searches</td></tr>
<tr><td>Searcher Efficiency Trials</td><td colspan="12">Monthly Trials</td></tr>
<tr><td>Carcass Persistence Trials</td><td colspan="12">Monthly Trials</td></tr>
<tr><td>Predator control</td><td colspan="12">Weekly Checks</td></tr>
<tr><td rowspan="4">HAPE</td><td>HAPE Monitoring</td><td colspan="5">Bi-Weekly Burrow Monitoring</td><td colspan="3"></td><td colspan="4">Monthly Burrow Monitoring</td></tr>
<tr><td>Predator Control</td><td colspan="5">Bi-Weekly Trap Checks</td><td colspan="3">Trap Maintenance</td><td colspan="4">Bi-Weekly Trap Checks</td></tr>
<tr><td>Predator Assessment</td><td>Burrow Game Camera Review</td><td>Predator Activity Assessment</td><td colspan="3">Burrow Game Camera Review</td><td colspan="2"></td><td>Predator Activity Assessment</td><td colspan="4">Burrow Game Camera Review</td></tr>
<tr><td>Predator Control trap monitoring using Reconyx Game Cameras</td><td colspan="5">Remote trap monitoring</td><td colspan="3">Maintenance and repositioning</td><td colspan="4">Remote trap monitoring</td></tr>
<tr><td rowspan="9">Bat</td><td>Tier 1 - Ungulate Control</td><td colspan="12">Quarterly Fence Inspection</td></tr>
<tr><td>Tier 1 - Vegetation Monitoring and Invasive Species Control</td><td colspan="5">Target Weed Control</td><td colspan="3">Annual Vegetation Monitoring</td><td colspan="4">Target Weed Control</td></tr>
<tr><td>Tier 4 - Conservation Easement</td><td></td><td>DOFAW/USFWS Approval</td><td colspan="10"></td></tr>
<tr><td>Tier 4 - Fence Construction</td><td colspan="2">Survey Fence Lines</td><td colspan="10">Fence Construction</td></tr>
<tr><td>Tier 4 - Reforestation</td><td colspan="4">Plant Propagation (Native Nursery)</td><td colspan="8">Outplanting in Completed Fences</td></tr>
<tr><td>Tier 4 - Pond Construction</td><td colspan="5">Survey pond areas</td><td colspan="2">Pond Construction</td><td colspan="5">Quarterly Checks</td></tr>
<tr><td>Tier 4 - Water Trough Modifications</td><td colspan="12">Quarterly Checks</td></tr>
<tr><td>Tier 4 - Bat Acoustic Monitoring</td><td colspan="12">Quarterly Checks</td></tr>
<tr><td>Tier 4 - Insect Monitoring</td><td colspan="12">Monthly Checks</td></tr>
<tr><td>Reporting</td><td>ITP & ITL Conditions</td><td></td><td>Annual HCP Report Submitted</td><td colspan="4"></td><td>Incidental Take Summary Tables Submitted</td><td>Semiannual Progress Report Submitted</td><td colspan="4"></td></tr>
</table>

Attachment 8

FY 2020 Expenditures for HCP Implementation

	Tier, Ongoing, or One-time	Event	Proposed Costs	Total Costs Incurred to Date (up to July 2020)	Costs Incurred FY 13 (July 1, 2012 - June 30, 2013)	Costs Incurred FY 14 (July 1, 2013 -June 30, 2014)	Costs Incurred FY 15 (July 1, 2014 -June 30, 2015)	Costs Incurred FY 16 (July 1, 2015 -June 30, 2016)	Costs Incurred FY 17 (July 1, 2016 -June 30, 2017)	Costs Incurred FY 18 (July 1, 2017 - June 30, 2018)	Costs Incurred FY 19 (July 1, 2018 - June 30, 2019)	Costs Incurred FY 20 (July 1, 2019 - June 30, 2020)
General Measures	Ongoing	Wildlife Education and Incidental Reporting Program	$5,000	$30,534	$3,000	$1,500	$167	N/A	N/A	N/A	N/A	N/A
	Ongoing	Downed Wildlife Post-Construction Monitoring and Reporting and Mitigation Monitoring	$1,810,000	$1,641,443	$100,000	$185,145	$152,901	$108,727	$96,700	$140,167	$154,185	$176,497
	Ongoing	*DOFAW Compliance Monitoring (only if needed)	$200,000	$30,773	N/A	N/A	$2,423	N/A	4600	$8,100	$15,600	$7,800
		Subtotal General Measures	*$1,815,000*	*$1,702,750*	*$103,000*	*$186,645*	*$155,324*	*$108,727*	*$101,300*	*$145,967*	*$169,835*	*$184,297*
Hawaiian Hoary Bat	Tier 1	Retrofit fencing and restoration measures at the Waihou Mitigation Project	$522,000	$1,135,478	$314,900	$63,173	$128,410	$149,833	$126,463	$124,852	$137,337	$36,937
	Tier 1	Acoustic Monitoring onsite	$40,000	$63,226	$5,000	$8,691	$14,663	$11,473	N/A	N/A	N/A	N/A
	Tier 2	Telemetry Research	$250,000	$250,000	N/A	$32,726	$8,308	$142,819	$66,146	N/A	N/A	N/A
	Tier 3	USGS Expanded Research	$250,000	$320,000	N/A	$32,726	$8,308	$142,819	$234,360	$81,518	$4,122	N/A
	Tier 4	Ulupalakua Ranch Conservation Easement and Related Work	$4,013,047	$225,098	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$188,161
	Ongoing	Minimization Adaptive Management	N/A	$223,615	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$223,615
		Subtotal Bats	*$5,075,047*	*$2,217,417*	*$319,900*	*$104,591*	*$151,381*	*$304,125*	*$426,969*	*$238,528*	*$141,459*	*$448,713*
Hawaiian Petrel	Tier 1	Burrow Monitoring and Predator Control	$550,000	$791,408	$214,000	$74,572	$107,743	$56,410	$62,731	$116,885	$187,437	$76,083
		Subtotal Petrels	*$550,000*	*$791,408*	*$214,000*	*$74,572*	*$107,743*	*$56,410*	*$62,731*	*$116,885*	*$187,437*	*$76,183*
Nene	One-Time	Research and Management Funding	$25,000	$25,000	$25,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Subtotal Nene	*$25,000*	*$25,000*	*$25,000*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Backburn's Sphinx Moth	One-Time	Restoration of 6 acres of Dryland Forest	$144,000	$144,000	$144,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Subtotal Moth	*$144,000*	*$144,000*	*$144,000*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
		Total HCP-related Expenditures	**$7,359,047**	**$4,188,053**	**$805,900**	**$365,808**	**$414,448**	**$469,263**	**$591,000**	**$436,218**	**$396,223**	**$709,193**