Auwahi **Wind**

August 31, 2019

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Via Email

SUBJECT: Auwahi Wind Farm Project Habitat Conservation Plan FY 2019 (Year 7) Annual Report

Dear Dr. Sether and Mr. Metzler:

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-0 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, 2018 through June 30, 2019.

The report identifies each HCP requirement and ITP/ITL condition completed, ongoing requirements and conditions, compliance status, and basis for determining compliance. Also, in compliance with HCP monitoring requirements, we have included a post-construction mortality monitoring update. We have also provided updated FY 2019 reports on the mitigation for the Hawaiian petrel, Hawaiian hoary bat, Hawaiian goose, Blackburn's sphinx moth, and research for the Hawaiian hoary bat.

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

Sincerely,

George Akau

George Akau

Project Biologist/Auwahi Wind Farm

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Auwahi Wind Farm Habitat Conservation Plan FY 2019 Annual Report

Incidental Take Permit TE64153A-0/ Incidental Take License ITL-17

Submitted To:

AEP Renewables

Auwahi Wind

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Acronyms and Abbreviations

DKIST	Daniel K. Inouye Solar Telescope
DLNR	Hawaiʻi Department of land and Natural Resources
DOFAW	DLNR Division of Forestry and Wildlife
EA	Environmental Assessment
EIS	Environmental Impact Statement
EoA	Evidence of Absence
ESRC	Endangered Species Recovery Committee
FMP	Fire Management Plan
FY	Fiscal Year
HCP	Habitat Conservation Plan
ITL	incidental take license
ITP	incidental take permit
LHWRP	Leeward Haleakalā Watershed Restoration Project
MBTA	Migratory Bird Treaty Act
m/s	Meters per second
MOU	memorandum of understanding
NPS	National Park Service
PCMM	post-construction mortality monitoring
PMA	Petrel Management Area
Project	Auwahi Wind Farm Project
Tetra Tech	Tetra Tech, Inc.
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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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 Auwahi Wind Farm Project (Project) in east Maui, Hawaiʻi (Tetra Tech 2012a). The 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 Hawaiʻi 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 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.

This report provides a summary of monitoring and mitigation activities that have occurred during Fiscal Year (FY) 2019 (from July 1, 2018 to June 30, 2019). 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/ITL. The status of Auwahi Wind's permit conditions in FY 2019 are summarized in Table 1. Detailed reports providing updates on Hawaiian petrel mitigation, Hawaiian hoary bat research being conducted by the U.S. Geological Survey (USGS), and the completion of Blackburn's sphinx moth mitigation efforts by Leeward Haleakalā Watershed Restoration Partnership are included as attachments to this report. Completion of the Hawaiian goose mitigation was documented in the FY 2013 HCP annual report (Tetra Tech 2013).

Table 1. Summary of Compliance Status FY 2019

Requirement/Permit Condition	Document Source/Condition	Required Timeframe	Compliance Status	Actions Completed/Basis for Compliance
PCMM at the Project				
Project biologist	HCP, Section 4.2.1 and 7.1.1	To be on-staff during Project operations	In compliance; ongoing	Project biologist has been on staff since project began operations in December 2012.
PCMM	HCP, Section 7.1.1 & PCMM Plan	Intensive monitoring will occur years 1, 2, 7, 12, 17, and 22 (total of 6 years, includes carcass removal and searcher efficiency trials)	In compliance; ongoing	Monitoring commenced in December 2012 and is ongoing. PCMM results for FY 2019 are provided in Section 2 of this report.
Wildlife education and incidental reporting program	HCP, Section 7.11	Prior to and throughout operations	In compliance; ongoing	A wildlife education and incidental reporting program was initiated during construction and is ongoing. Seven fatalities were reported via this program in FY 2019. Wildlife education and reporting protocol training was provided to 107 contractors in FY 2019.
Notify DLNR and the USFWS whenever a species protected by the Migratory Bird Treaty Act (MBTA) or a listed species is found dead or injured, or if there are observations of seabirds attracted to construction lighting	ITP Conditions L(i)	Via telephone within 24 hours and in a written report within five calendar days	In compliance; ongoing	DLNR and USFWS were notified within 24 hours of four listed species and seven MBTA fatalities at the Project and one listed, MBTA species found at the mitigation site in FY 2019. Reports were submitted within 3 days. Table 4 lists all fatalities found at the Project.
Report to DLNR of any mortalities, injuries, or disease related to the Covered Species	ITP Condition L(iv)	Within 3 days		

Requirement/Permit Condition	Document Source/Condition	Required Timeframe	Compliance Status	Actions Completed/Basis for Compliance
Table summarizing fatalities documented during PCMM	ITP Condition L(iv)	Semi-annually	In compliance; ongoing	Semi-annual table submitted to USFWS/DOFAW January 31, 2019. Fatalities documented during FY 2019; provided in Section 2 of this report, Table 4.
Semi-annual progress report	ITP Condition L(ii)	Annually in February	In compliance; ongoing	Semi-annual progress report submitted to USFWS/DOFAW February 19, 2019. The next semi-annual progress report will be submitted in February 2020.
Hawaiian Hoary Bat Mitigation				
Conservation easement for the Waihou Mitigation Area (Tier 1 mitigation)	HCP, Section 6.2.1	Within 210 days of ITP/ITL issuance or the initiation of vertical construction of the turbines, whichever comes sooner; easement extension granted by DOFAW	In compliance; completed	Recorded conservation easement with the Hawaiian Islands Land Trust to preserve the Waihou Mitigation Area in perpetuity on December 18, 2012.
Install new ungulate-proof fencing or retrofit cattle fencing around the Waihou Mitigation Area (Tier 1 mitigation)	HCP, Section 6.2.1	Initiate within first year of permit issuance and complete within two years of permit issuance (February 9, 2014)	In compliance; completed	Installation complete September 2013.
Remove ungulates from within Waihou Mitigation Area fence line (Tier 1 mitigation)	HCP, Section 6.2.1	Initiate after ungulate proof fence is completed	In compliance; completed	Ungulates removed in March of 2014. Quarterly fence inspections continued in FY 2019.
Conduct vegetative restoration activities, including removal of invasive species and native reforestation (Tier 1 mitigation)	HCP, Section 6.2.1, Table 6-3	Initiate after ungulate proof fence is completed	In compliance; ongoing	Native species plantings and invasive species removals continued in FY 2019.

Requirement/Permit Condition	Document Source/Condition	Required Timeframe	Compliance Status	Actions Completed/Basis for Compliance
Acoustic monitoring at the wind farm (Tier 1 mitigation)	HCP, Table 6-2	Years 1 and 2 of operation	In compliance; completed	Initiated July 2013, completed in December 2015. Results provided in FY 2016 HCP annual report (Sempra Energy 2016).
Hawaiian hoary bat research plan (Tier 2 mitigation)	HCP, Section 6.2.2	Draft research plan submitted to USFWS/DOFAW within 1 year of issuance of ITP; finalize within 2 years of ITP issuance and before the start of the study.	In compliance; completed	Final plan submitted in cooperation with USGS to USFWS/DOFAW in February 2014. Plan approved by USFWS/DOFAW in March 2014. Plan implemented March 2015. Final report provided in Attachment 3.
Hawaiian hoary bat research continued (Tier 3 mitigation)	HCP, Section 6.2.3	Use research in Tier 2 to evaluate appropriate mitigation – additional area for bat habitat restoration or conduct additional research.	In compliance, completed	Final Tier 2 & 3 field work completed in March 2017. Data analysis and final report completed FY 2019. Final report provided in Attachment 3.
Hawaiian Petrel Mitigation				
Predator control at the Kahikinui Petrel Management Area (Tier 1 mitigation)	HCP, Section 6.3.5; Petrel Management Plan	Auwahi Wind will begin predator control within the first year of operation	In compliance; ongoing	Full implementation of predator control in February 2014. Results from 2018 provided in Attachment 2.
Petrel burrow surveys (Tier 1 mitigation)	HCP, Section 6.3.6, Table 6-6	Burrow monitoring will occur annually for first 3 years; an additional 5 years of monitoring will occur at certain points during the life of the mitigation	In compliance; ongoing	Conducted petrel burrow surveys 2012 – 2019; burrow surveys start in March and continue through November. Results from 2018 provided in Attachment 2.
Blackburn's Sphinx Moth Mitigation				
Funding to Leeward Haleakalā Watershed Restoration Project (LHWRP) to restore 6 acres of dryland forest in the Auwahi Forest Restoration Project	HCP, Sections 4.2.3 & 6.5.1, Table 6-2	First payment to LHWRP within 30 days of obtaining permit and remainder of funds paid within 3 months	In compliance; completed	Full payment to LHWRP on April 17, 2012. A letter from LHWRP documenting the completion of restoration is provided in Attachment 4.

Requirement/Permit Condition	Document Source/Condition	Required Timeframe	Compliance Status	Actions Completed/Basis for Compliance
Hawaiian Goose Mitigation				
Research or management funding ($25K) provided to Haleakalā National Park Service (NPS)	HCP, Section 6.4, Table 6-2	Within 60 days of obtaining permit	In compliance; completed	Full payment to NPS April 17, 2012. A letter from the NPS summarizing the status and use of funds is provided in FY 2013 HCP annual report (Tetra Tech 2013) with updates in section 3.4.
Red ʻIlima (*Abutilon menziesii*) Mitigation				
ʻUlupalakua Ranch will plant 10 red ʻilima from its on-going conservation efforts. Report plant survival (3 years)	HCP, Section 4.2.3	After construction/site restoration is complete	In compliance; completed	Plants propagated at the ʻUlupalakua Ranch nursery in 2013. Successfully out-planted and are thriving. Plant survival reported in Section 3.5.
Fire Management Plan (FMP)				
Implementation of FMP associated with lands owned by ʻUlupalakua Ranch	HCP, Section 4.2.4; Fire Management Plan	Education of employees, fuel reduction in high priority areas via grazing, firebreaks in high priority areas, and construction/availability of a water source to fire department	In compliance; ongoing	Annual review and management of FMP with ʻUlupalakua Ranch, ongoing employee, training, water source (site well) available to fire department. Irrigation system installed in FY 2017 and FMP updated in FY 2018. Vegetation control for fuel reduction conducted monthly through contractor. Landing zone and staging area for firefighting efforts maintained in FY 2019.

2.0 Post-Construction Mortality Monitoring

Auwahi Wind's HCP lays out a long-term monitoring approach consisting of 2 years of intensive monitoring followed by interim years of less intensive but systematic monitoring. Post-construction mortality monitoring (PCMM) was initiated in December 2012. Searching methods for all years includes regular fatality searches, searcher efficiency trials, and carcass persistence trials (Tetra Tech 2013, Sempra Energy 2014, Sempra Energy 2015, Sempra Energy 2016, Tetra Tech 2017, Tetra Tech 2018). On January 22, 2018, Auwahi Wind began systematic searching of roads and pads using a canine search team at a weekly interval.

A Migratory Bird Special Purpose Utility permit (Permit No. MB92518A-0) for handling migratory bird carcasses was reissued by USFWS on April 1, 2018. A State Protected Wildlife Permit (Permit No. WL17-08) for handling native bird and bat carcasses was reissued by DOFAW on April 6, 2018.

Table 2 shows a summary of trial data for the fiscal year (July – June). Take analysis is conducted on a calendar year basis unless other analysis periods are required to account for changes to the search protocol or changes in avoidance and minimization measures, as discussed in Section 2.1.

Table 2. Post-Construction Mortality Monitoring Summary, FY 2019

Variable	Systematic (July 2018 – June 2019)
Study Metrics for Fatality Estimates	
Total number of Project turbines	8
Number of turbines searched	8
Sample plot size	Pads and roads within 100-meter (328-foot) radius of turbine
Met tower search plot size	10 meters (33 feet) around the base of the met tower
Search interval	7 days (July 2018 – June 2019)
Fatalities of Covered Species	
Hawaiian Petrel	
Number of fatalities documented	0
Indirect take	0
Hawaiian Goose	
Number of fatalities documented	0
Indirect take	0
Hawaiian Hoary Bat	
Number of fatalities documented	3 + 1 incidental
Indirect take	~0 – 1 adult equivalent (indirect take will be officially calculated when genetic testing results become available)

Variable	Systematic (July 2018 – June 2019)
Fatalities of Other Species[1]	
Fatalities found during searches	12
Fatalities found incidentally	7
1. Includes seven MBTA species fatalities.	

2.1 Systematic Carcass Searches

USFWS/DOFAW agreed on December 12, 2014, that Auwahi Wind could begin modified systematic searches in January 2015. Modified systematic searches were conducted along all pads and roads within a 100-meter (328-foot) radius of turbines July 1, 2018 – June 30, 2019. Pads and roads have regularly scheduled vegetation management that improves the detectability of fatalities and decreases the risk of injuries for the searchers. Canine handlers use the environmental conditions to determine a search pattern to ensure all search areas are monitored. The search area size and configuration varied among turbine pads. The areas searched at the Project represented a total of 56 percent of the large-bird distribution and 76 percent of the bat distribution, which are consistent with results based on a theoretical carcass distribution model (Hull and Muir 2010). The canine search team conducted weekly searches of roads and pads throughout FY 2019 (Table 3). Downed wildlife detected outside of the search area and/or outside the scheduled search day were categorized as incidental finds.

Table 3. Average Search Interval Between Standardized Carcass Searches, FY 2019

Month	Average 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 meteorological tower.	

Twenty-four fatalities were documented at the Project in FY 2019; fifteen of these fatalities were documented during systematic carcass searches (Table 4). Four fatalities were Covered Species: four Hawaiian hoary bats (*Lasiurus cinereus semotus*). In six and a half years of PCMM, no fatalities have been observed at the meteorological tower.

Table 4. Documented Fatalities, including Threatened and Endangered Species, FY 2019

Species	Legal Status[1]	Found Date	Turbine	Type of Detection	Outside Search Area	Outside Scheduled Search
Wedge tail Shearwater (*Ardenna pacifica*)	MBTA	8/2/2018	3	Incidental Finding		X
Great Frigatebird (*Fregata minor*)	MBTA	8/13/2018	4	Carcass Survey		
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)	T&E	8/13/2018	6	Incidental Finding	X	
Gray Francolin (*Francolinus pondicerianus*)	None	8/27/2018	3	Carcass Survey		
Common Myna (*Acridotheres tristis*)	None	9/3/2018	6	Carcass Survey		
Great Frigatebird (*Fregata minor*)	MBTA	10/1/2018	8	Carcass Survey		
Gray Francolin (*Francolinus pondicerianus*)	None	10/25/2018	1	Incidental Finding	X	X
Spotted Dove (*Spilopelia chinensis*)	None	11/12/2018	5	Carcass Survey		
White tailed Tropicbird (*Phaethon aethereus*)	MBTA	11/14/2018	3	Incidental Finding		X
Cattle Egret (*Bubulcus ibis*)	MBTA[2]	11/19/2018	1	Incidental Finding		
African Silverbill (*Euodice cantans*)	None	12/17/2018	1	Carcass Survey		
Common Myna (*Acridotheres tristis*)	None	12/28/2018	5	Incidental Finding		X
African Silverbill (*Euodice cantans*)	None	1/21/2019	2	Carcass Survey		
African Silverbill (*Euodice cantans*)	None	1/31/2019	6	Incidental Finding		X
African Silverbill (*Euodice cantans*)	None	2/11/2019	6	Carcass Survey		
African Silverbill (*Euodice cantans*)	None	2/11/2019	6	Incidental Finding		X
African Silverbill (*Euodice cantans*)	None	2/18/2019	4	Carcass Survey		

Species	Legal Status[1]	Found Date	Turbine	Type of Detection	Outside Search Area	Outside Scheduled Search
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)	T&E	5/6/2019	2	Carcass Survey		
Eurasian Skylark (*Alauda arvensis*)	MBTA	5/2/2019	5	Carcass Survey		
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)	T&E	5/20/2019	1	Carcass Survey		
Great Frigatebird (*Fregata minor*)	MBTA	5/29/2019	2	Incidental Finding		X
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)	T&E	6/3/2019	6	Carcass Survey		
Spotted Dove (*Spilopelia chinensis*)	None	6/17/2019	3	Carcass Survey		
Gray Francolin (*Francolinus pondicerianus*)	None	6/17/2019	3	Carcass Survey		

1. T&E: Threatened or Endangered under the ESA and/or HRS 195D. MBTA: Protected under the Migratory Bird Treaty Act.
2. Cattle Egrets, although protected by the MBTA, have a federal control order and are listed as a state injurious species.

2.2 Carcass Persistence Trials

Four carcass persistence trials were conducted during FY 2019, and are summarized for each carcass size class in Table 5. Each trial had ten surrogate bat carcasses and five large bird carcasses. Cattle egrets (*Bubulcus ibis*), were used as surrogates for large birds, and medium sized black rats (*Rattus rattus*) were used as surrogates for bats.

Table 5. Carcass Persistence Estimates for Systematic Searches, FY 2019.

Carcass Size Class	N	Probability of Carcass Persistence until Next Search[1]	95 Percent Confidence Interval	Search Interval
Bats	41	0.746	[0.649, 0.839]	7
Large Birds	20	0.999	[0.971, 1]	7

1. Where carcass persistence trials have no carcasses removed in the monitoring period, a distribution approximating an r value (probability of persistence to the next search) of 1 is substituted. As such a value of 1 is not possible for carcass persistence.

Carcasses were placed at randomly generated points on turbine pads and roads within active search plots. Carcasses were checked every 1 –3 days until they were no longer detectable or the trial period was complete. Trial periods lasted 28 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 persistence 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).

Auwahi Wind has continually implemented predator control on site since the fall of 2013. The probability that a carcass would persist until the next search was similar to that estimated in FY 2018 (Table 5). All large birds persisted through the entire trial period resulting in a very high probability of persistence until the next search in FY 2019.

2.3 Searcher Efficiency

Searcher efficiency trials were conducted during FY 2019, consistent with methods from previous years (Table 6; Tetra Tech 2018). Sixteen searcher efficiency trial days occurred during FY 2019, consisting of 33 individual trials. Cattle egrets were used as surrogates for large birds, and medium sized black rats were used as surrogates for bats. Searcher efficiency for large birds and bats remained high at 100 percent in FY 2019. This high proficiency is likely due to the ease of searching well-maintained pad and road search plots, and the use of a canine search team.

Table 6. Searcher Efficiency Estimates for Systematic Searches, FY 2019

Carcass Size Class	Search Method	Number Placed[1]	Number Found	Average Searcher Efficiency	95 Percent Confidence Interval	Overall Average Searcher Efficiency
Bats	Canine	30	30	1	[0.92, 1]	1
Large birds	Canine	3	3	1	[0.464, 1]	1

1. Excludes carcasses that were placed in the field but removed by scavengers prior to the survey (i.e., were not available to be found by searchers or tester).

2.4 Take

2.4.1 Direct Take

To ensure an accurate measurement of take and verify compliance under the ITL/ITP, fatality rates are adjusted based on the PCMM results. During the six and a half years of PCMM at the Project (January 2013-June 2019), there were 26 fatalities of Covered Species as described in Table 7.

Table 7. Observed Fatalities of Covered Species

Category	Hawaiian hoary bat	Hawaiian petrel
PCMM	20	1
Incidental[1]	4	1
Total	**24**	**2**

1. Incidental as described here refers to fatalities not recorded in PCMM, therefore not included in the EoA analysis. All fatalities are incidental to the operation of the wind farm as required by the ESA and HRS 195D.

To account for unobserved and incidental (as described in Footnote 1 of Table 7) fatalities, statistical models or estimators are used for calculating fatality rates. Given the limitations of the available statistical tools when dealing with small sample sizes, Auwahi Wind and USFWS/DOFAW agreed to use the EoA software. Interpretation of model output presents a regulatory challenge with respect to determining whether or not a take limit has been reached or exceeded because EoA does not produce an exact estimated number of fatalities (i.e., a point estimate of take).

The agreed upon approach uses two pieces of information produced by the EoA to evaluate the likelihood that the number of fatalities has reached or exceeded the take limit: 1) The "maximum likelihood value" or where the probability of number of fatalities is greatest; and 2) The one-sided confidence interval surrounding the "most likely value," based on a credibility level of 80 percent. The EoA user manual states "An M*[mortality estimate] based on a credibility level of $1-\alpha=0.5$ [50 percent credible level] is the most accurate" (page 31, Dalthorp et al. 2017). The use of the 80-percent credible level results in a higher take estimate with a greater certainty that the actual take will not exceed predicted take.

Auwahi Wind used the EoA software and ran the model with PCMM data collected over the past six-and-a-half years for bats and large birds (Table 8). 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 8 represent values for operational years, with the period from January 1, 2018 through June 30, 2018 representing 2018 (year 6). Therefore, values differ from those reported for the full FY 2018 in the sections above.

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Table 8. Summary of PCMM Data, From Project Start through June 2019 (FY 2013 – FY 2019)

Calendar Year	Curtailment (5 m/s)	Curtailment (6.9 m/s)	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[2]	Cumulative Indirect Take Estimate[3, 4]
Hawaiian hoary bat										
2013	No	No	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[5]	Yes	No	3	0.76	3-4	0.879	0.667	0.62	39	5 (4.25)
2018	Yes	Yes[7]	1	0.76	4-7	0.768	1	0.52	41	5 (4.25)
2019[6]	Yes	Yes[7]	4	0.76	7	0.746	1	0.63	45	6 (5.05)
Hawaiian petrel										
2013	No	No	1	0.91	9	0.79	0.74	0.67	3	0.63
2014	No	No	0	0.91	5	0.98	0.75	0.84	2	0.63
2015	Yes	No	0	0.56	3	0.993	0.89	0.55	2	0.63
2016	Yes	No	0	0.56	3	0.96	0.96	0.48	3	0.63
2017	Yes	No	0	0.56	3-4	0.99	0.96	0.55	3	0.63
2018	Yes	No	0	0.56	4-7	0.99	1	0.55	3	1.26
2019[6]	Yes	Yes[7]	0	0.56	7	0.99	1	0.37	3	1.26

1. Detection bias calculated using Evidence of Absence software (Dalthorp et al. 2017).
2. Calculation of direct take based on 80% UCL of EoA estimate for search periods (see Attachment 1).
3. Calculation of indirect take based on USFWS (2016) guidance on the calculation of indirect take. Take estimates subject to change pending genetic analysis of observed fatalities. Calculations based on search periods (see Attachment 1). The actual value is presented in parentheses and the value rounded up to the nearest whole number is presented first.
4. For Hawaiian hoary bat, this is "Adult Equivalent." For Hawaiian petrel, this is "Juvenile."
5. Detection bias calculated using pooled data with custom search interval in single class module from Evidence of Absence software.
6. Calendar year 2019 includes the dates from January 1 through June 30.
7. 6.9 m/s curtailment from August 1 – November 1.

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Based on the 20 bat fatalities detected during six-and-a-half years of PCMM and 4 incidental carcasses found in 2017 –2019, it is most likely that direct take of 39 bats have occurred (Figure 1). The estimated upper limit for potential Project direct take using an 80-percent credibility level for bats is shown in Attachment 1. It can be estimated with 80 percent certainty that the number of direct take ranged from 24 to 45 over this survey period.

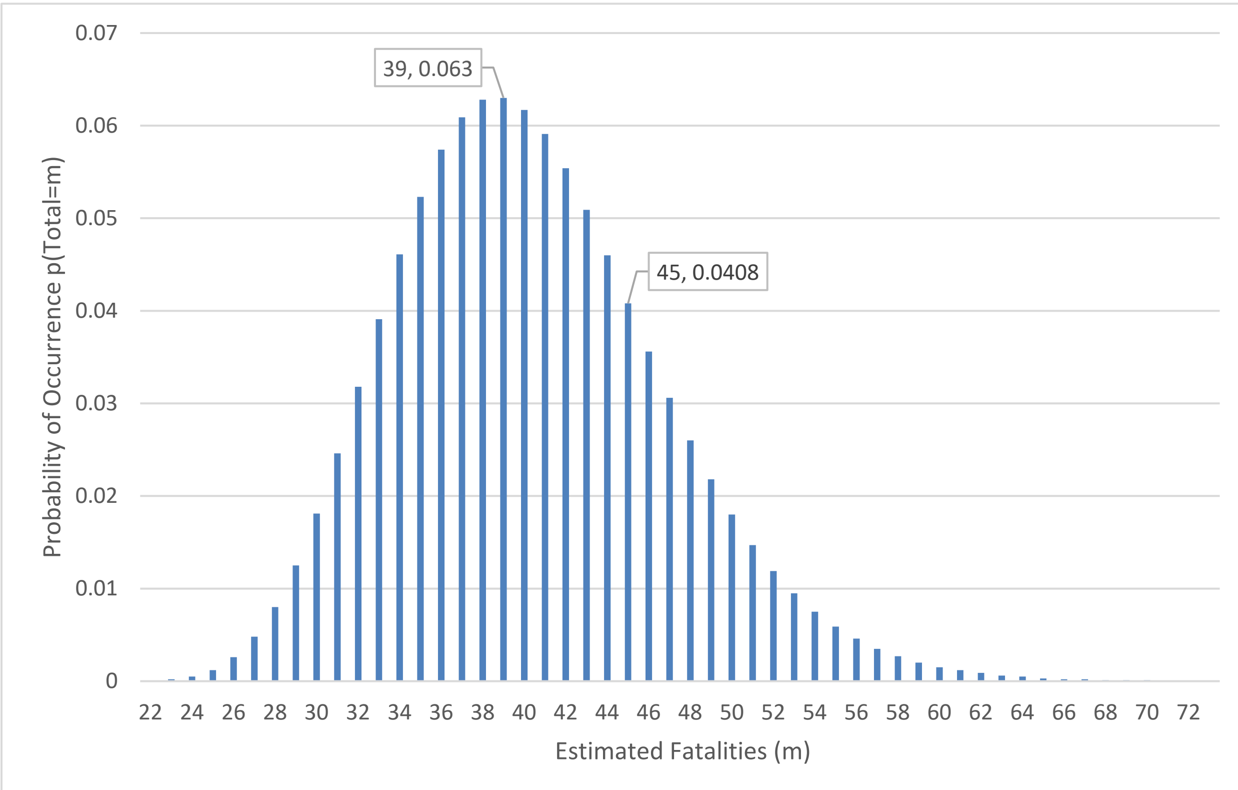

Figure 1. Posterior Probability Distribution for Hawaiian Hoary Bats Using the Evidence of Absence Software (Dalthorp et al. 2017)

Based on the one Hawaiian petrel fatality detected during six-and-a-half years of PCMM and one incidental carcass detected at the Project[1] in FY 2018, it is most likely that direct take of one petrel has occurred (Figure 2), the additional incidental petrel found at the Project is assumed to be attributable to project operation, thereby increasing the assumed minimum to two petrels. The estimated upper limit for potential Project direct take using an 80-percent credibility level for large birds is shown in Attachment 1. It can be estimated with 80 percent certainty that the number of fatalities did not exceed three over this survey period (Attachment 1).

[1] Does not include the Hawaiian petrel detected at the mitigation site in FY 2019, which is unassociated with turbine operation and is not included in EoA analysis.

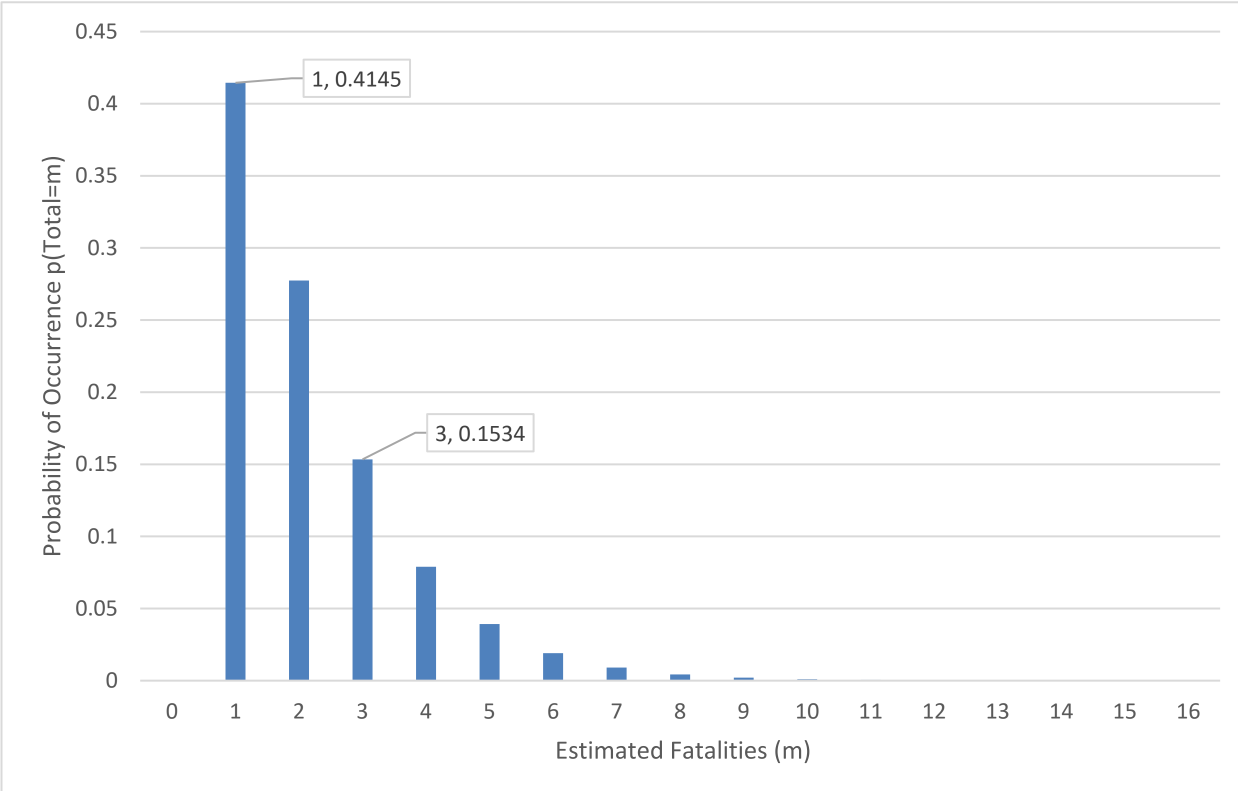

Figure 2. Posterior Probability Distribution for Hawaiian Petrels Using the Evidence of Absence software (Dalthorp et al. 2017)

2.4.2 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 seabird 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 (Auwahi Wind HCP, Section 5.2).

2.4.2.1 Hawaiian Hoary Bat

Section 7.1.2 of the approved HCP outlines the reporting process for accounting for indirect take of bat carcasses detected during the breeding season. The gender of observed fatalities is reported in Table 9. There have been five confirmed female bat fatalities during the breeding period at Auwahi Wind. Four fatalities of unknown gender were observed during the period when females may be pregnant or supporting dependent young (April 1 – September 15) and tissue samples have been submitted for genetic determination of gender. Auwahi Wind will reevaluate the potential for the collision-related fatalities to have resulted in indirect take based on the results of genetic determination of gender and report the results.

The USFWS provided guidance to standardize the process for estimating direct and indirect observed take in the absence of verified gender information (USFWS 2016). This report has utilized the USFWS methodology as an exercise to provide an interim indication of indirect take pending the results of genetic testing.

Table 9. USGS Genetic Determination of Gender Results (Pinzari and Bonaccorso, 2018).

Date Observed	Gender From Genotype
10/9/2013	Female
8/30/2014	Male
10/14/2014	Female
11/13/2014	Female
1/12/2015	Male
9/28/2015	NA[1]
6/10/2016	Male
7/7/2016	Female
8/15/2016	Female
8/30/2016	Male
9/2/2016	Male
9/26/2016	Male
9/29/2016	Female
8/5/2017	Female
8/28/2017	Male
9/1/2017	Female
9/5/2017	Male
9/13/2017	NA[1]
1/29/2018	Male
3/26/2018	Male
8/13/2018	Female
5/6/2019	NA[1]
5/20 2019	NA[1]
6/3/2019	NA[1]

1. Genetic determination of gender not yet available. Treated as unknown until a genetic determination of gender is final.

Based on the methodology provided by USFWS (USFWS 2016), the exercise resulted in an interim estimate of indirect take for FY 2019 calculated as:

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

- 5 (Females observed in the breeding season) * 1.8 (pups per female) = 9 juveniles based on observed take

Total observed take of unknown sex assumed to have dependent young (April 1 – September 15) [2]

- 4 (take during breeding season) * 0.47 (assumed sex ratio)[3] * 1.8 (pups per female) = 3.38 juveniles based on observed take.

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

- (45 [80 percent upper credible limit] – 24 [observed take]) * 0.47 (assumed sex ratio) * 0.25 (proportion of calendar year females could be pregnant or have dependent pups) * 1.8 (pups per female) = 4.44 juveniles based on unobserved direct take.

Total Interim Estimate of Juvenile Indirect Take = 16.82 (9+ 3.38 + 4.44)

- Total Adult equivalents = 6 (16.83 * 0.3) rounded up to the nearest whole number)

2.4.2.2 Hawaiian Petrel

The one Hawaiian petrel observed on site during PCMM was found September 23, 2013. One Hawaiian petrel was observed incidentally (outside of the search plot) on June 25, 2018. The detection of an adult Hawaiian Petrel recorded during the breeding season is assumed to result in the loss of one chick (Auwahi Wind HCP 2012). The average reproductive success for petrels on Maui has been previously measured at 63 percent (Simons and Hodge 1998). Thus, the indirect take associated with the adult Hawaiian Petrel fatality is equal to 1.26 juveniles (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)

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[2] Auwahi Wind is awaiting genetic testing results to identify the sex of bat carcasses that were too decomposed to determine sex based on morphology. Indirect take will be adjusted when this information becomes available.

[3] Ratio of males to females based on genetic determination of gender from observations at the Project. The use of the modified ratio was confirmed with the USFWS and DOFAW at the semi-annual report meeting in 2019.

2.5 Wildlife Education and Incidental Reporting

Auwahi Wind continues to implement a wildlife education and incidental reporting program for contractors, Project staff members, and other ʻUlupalakua Ranch staff who are on site regularly. This 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 107 contractors and new staff in FY 2019. The wildlife education program has expanded over the past year to include visits by educational groups, summer internships, and outreach events within the community. Groups that attended site presentations and tours in FY 2019 included: Hālau Kū Māna, State of Hawaiʻi Department of Health, Hui Waʻa O Kaulua, University of Hawaiʻi, Endangered Species Recovery Committee (ESRC), and the Ka Ipu Kukui Fellows.

3.0 Mitigation

3.1 Hawaiian Petrel Mitigation

Results from the 2018 petrel breeding season are fully described in Attachment 2. Beginning August 2013, implementation of the predator control strategy was applied within Kahikinui Petrel Management Area (Kahikinui PMA). This includes trapping and monitoring for Hawaiian petrel and predator activity. Results of the 2019 breeding season and predator control will be included and summarized in the FY 2020 HCP annual report.

3.1.1 Petrel Burrow Monitoring

In the 2018 breeding season, 72 petrel burrows were monitored, 31 showed consistent activity through the breeding season. By the end of the breeding season 9 burrows had successfully fledged a chick. The number of burrows known to have fledged a chick/number of active burrows within the management area was 29 percent. It cannot be confirmed that all active burrows were occupied by breeding birds; according to Simons (1985) 66 – 75 percent of the Hawaiian petrel burrows determined to be active contained eggs. The percentage of chicks fledged per confirmed eggs laid within the Kahikinui PMA was 82 percent. The reproductive success values of 29 and 82 percent represent the difference between using only those burrows confirmed to have eggs laid (i.e., burrows classified as successful, probably successful or failed = 9/11 = 82 percent) and assuming all active burrows had eggs laid (i.e., also including burrows classified as occupied by a non-breeder = 9/31 = 29 percent). Of the observed burrows at least 59 chicks have fledged in 7 years from the Kahikinui PMA, 3 chicks have probably fledged, and likely more given the number of unobserved burrows.

3.1.2 Predator Control

In the 2018 breeding season, Auwahi Wind continued to deploy tracking tunnels to assess rodent and mongoose activity across the entire 324-hectare (801-acre) Kahikinui PMA at the start and halfway through the breeding season. The 1-day tracking index was 3.2 percent (6 of 187) for rodents in early March. There was an increase from 3.2 to 7.4 percent (14 of 187) in the tracking index for rodents in September. No mongoose were detected along any of the transects, with the 3-day tracking index of zero percent.

The predator control grid was operational year-round between January and December of 2018 (see Attachment 2, Section 2.4 and 3.4). Predator control efforts in 2018 removed 116 targeted mammalian predators from Kahikinui PMA, including 70 mice, 45 rats, and 1 mongoose. Trapping was continued past November, after the chicks fledged, until the start of the following nesting season, when Hawaiian petrel adults started returning in February. All traps were checked and baited every two weeks. Baits were alternated between trap checks. Predator control efforts from the start of the project have removed 425 targeted mammalian predators from Kahikinui PMA, including 262 mice, 165 rats, 7 mongoose, and 2 cats.

On August 2, 2018, a Hawaiian petrel was discovered dead in a body grip trap in Unit 3. This fatality is attributable to management of the petrel colony, not the result of turbine operation. As noted in the ITP:

> *Up to a total of seven (7) Hawaiian petrels (adults, subadults, fledglings, nestlings) over the 25-year permit term, may be incidentally taken in the form of capture as a result of interactions with predator capture systems.*

As a result of this take, the use of body grip traps was discontinued in the mitigation area.

Auwahi Wind has continued to provide support (e.g., training, deployment, monitoring) to the Maui Nui Seabird Recovery Project and Haleakalā National Park through loaned traps used for predator control in the adjacent Kahikinui Natural Area Reserve and Haleakalā National Park. These traps removed an additional predator feral cat in a neighboring Hawaiian petrel colony.

3.1.3 Benefits

Auwahi Wind has measured reproductive success of Hawaiian petrels within Kahikinui PMA for the past seven years as well as predator activity for the past six years. In accordance with assumptions in the HCP, predator control conducted by Auwahi Wind is anticipated to have had a positive effect on the reproductive success of Hawaiian petrels within Kahikinui PMA, and may also have reduced predation in adjacent areas managed by NPS (Haleakalā National Park), Maui Nui Seabird Recovery Project (State of Hawaiʻi Kahikinui Natural Area Reserve), Leeward Haleakalā Watershed Partnership (State of Hawaiʻi Department of Hawaiian Homelands) and the National Science Foundation - Daniel K. Inouye Solar Telescope (DKIST). Auwahi Wind supported predator control efforts from the start of the project have removed 2 cats from the surrounding conservation lands. Ongoing monitoring continues to benefit the petrel colony by providing new information on the extent of the colony, reproductive success, and fledging activity, which were previously unknown. Over the course of seven years, 18 new burrows have been located, adding to the original 54 burrows located with extensive surveys in 2012 for a total of 72 burrows observed in 2018. Deployment of Reconyx cameras in the PMA has also given the scientific community unique insight into the activity and exact fledging dates of Hawaiian petrels within the PMA and the larger East Maui population.

The number of burrows existing within the Kahikinui PMA colony is not consistently at the level needed to ensure that the success criteria for Tier 1 mitigation under the HCP are met. The original HCP included a demographic model which assumed an average of 33 active burrows and a reproductive success rate of 60 percent with predator trapping (see Table 6-4 in the original HCP); as of 2018, on average there have been 33 active burrows monitored each year between 2013–2018 (ranging from 27 to 37) and an average reproductive success rate of approximately 29 percent using the conservatively low value (see Attachment 2). Therefore, the assumed benefit of predator control based on the reproductive success rate (29 percent instead of 60 percent) in the Kahikinui PMA is insufficient to produce enough adult petrels, based on estimated population growth, to offset the amount of authorized petrel take under the ITP/ITL, using the metrics described in the HCP (Section 6.3 in the original HCP). Therefore, Auwahi Wind proposes to continue petrel mitigation efforts at the Kahikinui PMA in the 2019 breeding season, and add mitigation efforts (monitoring and predator control) to the adjacent DKIST site in 2020 to partner with DOFAW for the management of a portion of the site nearest to Kahikinui PMA. Such a transition was identified as a potential adaptive management option within the Auwahi Wind's approved HCP if the mitigation efforts at the Kahikinui PMA colony were insufficient to provide the necessary benefit (Tetra Tech 2012a). Given the large number of burrows (359) and reported reproductive success at the DKIST site (10 – 41 percent; Attachment 2), predator control is expected to produce enough petrels to meet Tier 1 mitigation success criteria by the end of the permit term. See Attachment 2 for additional detail.

3.2 Hawaiian Hoary Bat Mitigation and Monitoring

Implementation of Tier 1 – 3 bat mitigation is on-going at the Waihou Mitigation Area, located on ʻUluplalakua Ranch. Tier 1 mitigation consists of the restoration of native forest on approximately 53-hectares (132 acres) 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. All tiers of mitigation have been funded and are being implemented in accordance with mitigation plans approved by USFWS and DOFAW. In FY 2019, Tier 2 and 3 mitigation was completed by USGS and the report is publicly available.

3.2.1 Tier 1 Mitigation

Auwahi Wind is in its fifth year of habitat restoration efforts at the 53-hectare (132 acre) 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 status of each major activity is summarized below.

Management of non-native species continues to be implemented successfully. The ungulate exclusion fence surrounding the parcel was inspected quarterly in FY 2019, and the parcel remains ungulate-free. Biannual vegetation management activities continued in FY 2019 to maintain control of the target invasive species coverages well below the required 50 percent success criteria. Follow-up management within the plots has begun to focus on the removal and suppression of non-targeted invasive species such as non-native grass and blackberry (*Rubus argutus*).

Native species outplanting has had a significant positive impact by creating bat habitat in former pasture lands. Auwahi Wind completed extensive native tree out-planting in FY 2016, with over 13,000 plants on over 16.2 hectares (40 acres) of open pasture within the Puʻu Makua site (Auwahi Wind 2016). Out-planted trees were predominately koa (*Acacia koa*), ʻōhiʻa lehua (*Metrosideros polymorpha*) and māmane (*Sophora chrysophylla*). Some specialty native plants were mixed into out-planting efforts to create more diversity within plots. These specialty plants included māmaki (*Pipturus albidus*), kāwaʻu (*Ilex anomala*), hala pepe (*Chrysodracon auwahiensis*), ʻōhelo (*Vaccinium reticulatum*), and ʻōhe mauka (*Polyscias hawaiensis*). Follow-up management within the plots continued in FY 2019, and included replacing lost out-planted native trees with new native plants. The next vegetation monitoring will be conducted in FY 2020.

The implementation of the restoration at the mitigation site is ahead of the proposed timeline. Additional bat habitat enhancements at Pu'u Makua include; addition of a diversity of native Hawaiian plants and adding blackberry to the list of target species to control within the management unit.

3.2.2 Tier 2 and 3 Mitigation

Auwahi Wind worked with Tetra Tech and Dr. Frank Bonaccorso from 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 to track the success of restoration efforts in the Waihou Mitigation Area. The Tier 2 research plan was approved by USFWS/DOFAW in March 2014 (Sempra Energy 2014). The Tier 3 research plan expanded the sampling and scope of the approved Tier 2 research plan. The final Tier 2 – 3 research plan was approved in May 2016. This combined research plan includes acoustic monitoring (2015 – 2018), seasonal radio telemetry (2016 – 2017) with two additional phases of radio-telemetry to be completed and timed based on results from on-going acoustic monitoring efforts, an insect prey base study (2016), and a food habit assessment (2016 – 2017; Appendix 3). The results of research for Tiers 2 and 3 have been published by the USGS (Pinzari et al. 2019) and can be found in Attachment 3.

3.2.3 Benefits

Completion of the fence, removal of ungulates, and habitat restoration will benefit the Hawaiian hoary bat through the creation and protection of roosting and foraging habitat. Auwahi Wind is in compliance with the Tier 1 mitigation requirement to offset the take of 6 bats through implementation of habitat restoration measures which have met interim success criteria. A total of 8 bats have been tagged and released from the area including 2 pregnant females by USGS in 2017.

Research has been identified as an important recovery action under the Hawaiian hoary bat recovery plan (USFWS 1998), and as an HCP mitigation action in the ESRC Bat Guidance (DOFAW 2015). Auwahi Wind's Tier 2 and 3 research has filled in gaps in our knowledge of Hawaiian hoary bat diet, prey availability, and plant/prey associations. The results of this study have improved the understanding of how to manage habitat to benefit the Hawaiian hoary bat. This research identified pasture and water features that are being used for foraging by the Hawaiian hoary bat, and developing a nuanced understanding of how such features support the bat's life history requirements will be an important step in improving Hawaiian hoary bat mitigation efforts.

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 (6 acres) of dryland forest at the Auwahi Forest Restoration Project. A letter from the Auwahi Forest Restoration Project providing an update on use of funding during FY 2019 and the completion of mitigation requirements is provided in Attachment 4, which includes the location and description of habitat. A total of 1,500 of the proposed 1,500 ʻaiea (*Nothocestrum latifolium*) have been out-planted into 4.5 hectares (11 acres). Auwahi Forest Restoration Project has fulfilled their MOU obligations.

3.4 Hawaiian Goose

As stated in the 2012 annual report, Auwahi Wind provided a one-time payment on April 17, 2012, of $25,000 to the NPS for use in building a Hawaiian goose rescue pen and predator fence to support egg, gosling, and adult rescue efforts in Haleakala 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). One adult was rehabilitated and released in 2011.

3.5 Red ʻIlima

Auwahi Wind has fulfilled its HCP requirement to out-plant 10 Red ʻilima on ʻUlupalakua Ranch to offset potential Project impacts. Plants were propagated at the ʻUlupalakua Ranch nursery in 2013. In FY 2018, 37 additional Red ʻilima were planted in the newly constructed 0.4 hectare (1-acre) ungulate free fenced site at the base of Puʻu Hokukano. 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.

4.0 Adaptive Management

4.1 Minimization

Under adaptive management, Auwahi Wind has made the following changes to improve minimization measures at the wind facility:

- Auwahi Wind voluntarily implemented low wind speed curtailment on February 5, 2015, turbine blades are now feathered below a cut-in speed of 5 m/s, from one hour before sunset until one hour after sunrise, year-round;
- Beginning in June 2018, Auwahi Wind incorporated thermal imagery paired with acoustic monitoring to gather data on the wildlife interactions with the turbines. Specifically, this effort work consisted of:
    - A year-long acoustic study of bat activity at the nacelles beginning in August 2018, and
    - Performing thermal imagery studies at the turbines included in the acoustic survey during the high-risk months, August through October, to refine the understanding of risk at the Project.
- To further minimize negative hazards associated with operating turbines at low wind speeds, Auwahi Wind began implementing a raised cut-in speed of 6.9 m/s, with feathering, nightly during the high-risk months of August through October, in FY 2019.

4.2 Post-Construction Mortality Monitoring

Under adaptive management, Auwahi Wind has made the following changes to improve post-construction mortality monitoring:

- Under the recommendation of USFWS/DOFAW, Auwahi Wind continues to implement predator control at the site. Predator traps are deployed across all turbine search plots and are used year-round to remove scavengers and increase carcass persistence. Carcass persistence has increased across the site as a result.
- Beginning in January 2015, Auwahi Wind implemented quarterly vegetation management on pads and roads to increase visibility during fatality searches. Vegetation is cut back and maintained at 50 – 100 mm (2 – 4 inches) along pads and roads year-round. These efforts have increased the detectability of carcass surrogates during searcher efficiency trials. Monthly vegetation management efforts were initiated in March of 2017.
- Beginning in January 2015, Auwahi Wind switched to systematic searching of pads and roads within a 100-meter (328-foot) buffer of the turbine. Searcher efficiency and carcass persistence trials continue within this area to better refine fatality estimates for the life of the Project.

- Beginning in January 2018, Auwahi Wind incorporated the use of a canine search team into post-construction mortality monitoring to increase searcher efficiency on site.
- To identify threats to Hawaiian hoary bats, necropsies were requested of 2 carcasses found near the turbines. A histopathology is being performed by USGS to identify any other factors contributing to bat fatalities.
- The canine search team was also incorporated into the carcass persistence trials and in some cases was able to extend persistence by finding moved/scavenged carcasses.

4.3 Blackburn's Sphinx Moth Avoidance and Minimization

Auwahi Wind continues to implement avoidance and minimization measures for the Blackburn's sphinx moth as described in the HCP. Monthly surveys continue to be conducted for Blackburn's sphinx moth and manual removal of tree tobacco (*Nicotiana glauca*) has been completed, in addition to translocating any Blackburn's sphinx moth larvae and eggs found on tree tobacco at the Project (USFWS/DOFAW email instructions February 7, 2014). Areas within 33 feet (10 meter) of roadsides and edges of turbine pads are targeted because they may present a hazard for the moth, due to exposure to dust, possible trampling, and increased chance of collisions with vehicles. Through continued maintenance on-site there has been a decrease in plants within hazard areas. During FY 2019, six plants were removed from the Project with most plants observed to be in the immature vegetative state. In FY 2019, no larvae were detected and translocated during visual surveys of tree tobacco. In collaboration with ʻUlupalakua Ranch, Auwahi Wind created a 0.4 hectare (1-acre) protected dryland forest restoration site. Larvae can be translocated from removed tree tobacco within the Project area to tree tobacco near the dryland forest restoration site in hopes that the area can support a population of translocated larvae among the reintroduced native plants.

5.0 Changed or Unforseen Circumstances

The Project has seen higher than expected take of the Hawaiian hoary bat at its facility in the first six and a half years of operations. On February 25, 2015, Auwahi Wind met with USFWS/ DOFAW to discuss its pursuit of a major amendment to their joint ITL/ITP. Auwahi Wind has been actively engaged with USFWS, DOFAW, and the ESRC to finalize an Amendment to the Auwahi Wind HCP. The proposed major amendment will be limited exclusively to address take of the federally listed Hawaiian hoary bat, incidental to activities associated with the operation, maintenance, and decommissioning of the Project. The amendment process is currently under way. The amendment is expected to be approved in FY 2020. A summary of the amendment process is provided below:

- From FY 2014 through FY 2018:
    - February 25, 2015, Auwahi Wind met with the USFWS and DOFAW to discuss Auwahi's intent to pursue a major amendment of its HCP and ITP/ITL.
    - Four drafts of the HCP Amendment were submitted to USFWS and DOFAW between 2016 and 2018

  - Auwahi Wind presented the HCP Amendment before the ESRC in 2016
  - Auwahi Wind met regularly with USFWS and DOFAW to continue to development of the Final HCP Amendment.
- In FY 2019:
  - August 30, 2018, Auwahi Wind presents the updated Tier 4 mitigation to ESRC for comments.
  - August 31, 2018, Auwahi Wind submitted the fifth draft HCP Amendment to USFWS and DOFAW.
  - September 28, 2018, Auwahi Wind submitted the sixth draft HCP Amendment to USFWS and DOFAW.
  - October 25, 2018. Auwahi Wind presented the HCP Amendment to the ESRC.
  - January 4, 2019. Auwahi Wind submitted the seventh draft HCP Amendment to USFWS and DOFAW.
  - February 15, 2019 ESRC site visit to Auwahi Wind and Mitigation sites.
  - April 30, 2019, Auwahi Wind submitted the eighth Draft HCP Amendment to USFWS and DOFAW.
  - May 17, 2019, Auwahi Wind submitted the ninth Draft HCP Amendment to USFWS and DOFAW.
  - June 19, 2019 Auwahi Wind presented the HCP Amendment to the ESRC for a recommendation of approval. ESRC voted to recommend revisions to the HCP Amendment.
  - FY 2019 ended June 30, 2019.

6.0 Annual Workplan and Schedule

A work plan for FY 2019 is provided in Attachment 5. This work plan identifies major monitoring and mitigation activities and their associated timelines.

7.0 Cost Expenditures and Budget

A summary of HCP-related expenditures for FY 2019 is provided in Attachment 6. This summary lists costs (including staff labor) that Auwahi Wind has expended toward fulfilling the terms of the HCP in FY 2019, as well as cumulatively, and compares them against the budgeted amounts specified in Appendix 7 of the HCP.

8.0 References

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Attachment 1

Evidence of Absence Software Inputs and Outputs – Fatality Estimation

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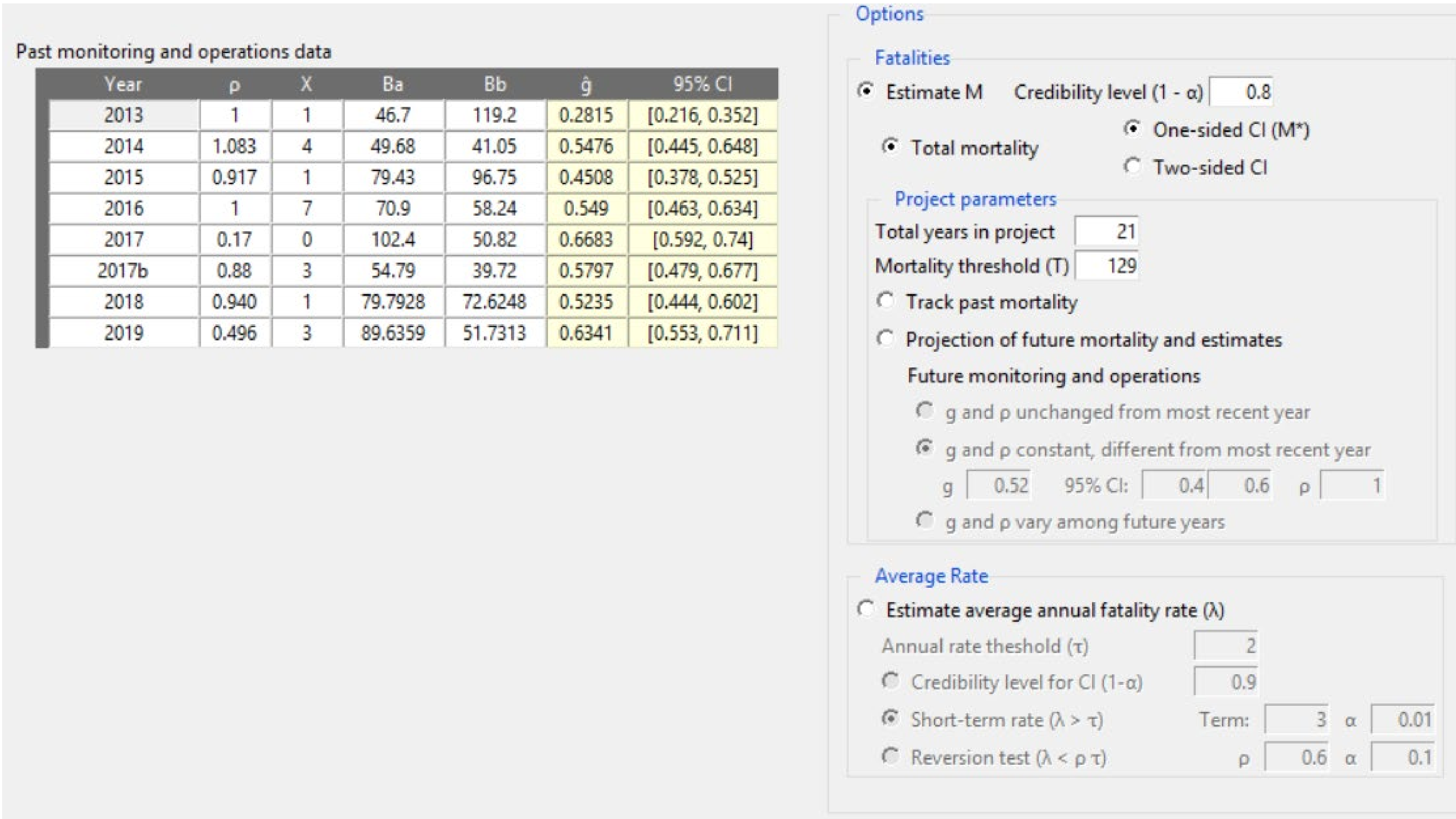

Past monitoring and operations data

Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	1	1	46.7	119.2	0.2815	[0.216, 0.352]
2014	1.083	4	49.68	41.05	0.5476	[0.445, 0.648]
2015	0.917	1	79.43	96.75	0.4508	[0.378, 0.525]
2016	1	7	70.9	58.24	0.549	[0.463, 0.634]
2017	0.17	0	102.4	50.82	0.6683	[0.592, 0.74]
2017b	0.88	3	54.79	39.72	0.5797	[0.479, 0.677]
2018	0.940	1	79.7928	72.6248	0.5235	[0.444, 0.602]
2019	0.496	3	89.6359	51.7313	0.6341	[0.553, 0.711]

Figure 1. Evidence of Absence software input for Hawiian hoary bats multi-year analysis (Dalthorp et al. 2017).

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Summary statistics for total mortality through 8 years
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Results
M* = 45 for 1 - a = 0.8, i.e., P(M <= 45) >= 80%

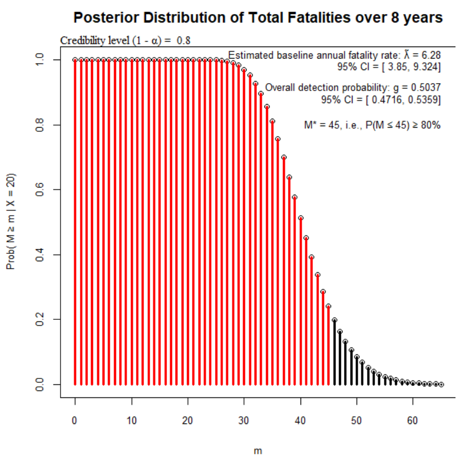
Estimated overall detection probability: g = 0.504, 95% CI = [0.472, 0.536]
   Ba = 467.83, Bb = 460.87

Estimated baseline fatality rate: lambda = 6.284, 95% CI = [3.85, 9.32]


Test of assumed relative weights (rho) and potential bias              Fitted rho
Assumed rho     95% CI
      1      [0.065, 1.936]
   1.08      [0.400, 2.354]
  0.917      [0.031, 1.337]
      1      [0.839, 3.260]
   0.17      [0.001, 0.567]
   0.88      [0.225, 1.881]
   0.94      [0.029, 1.239]
  0.496      [0.197, 1.751]

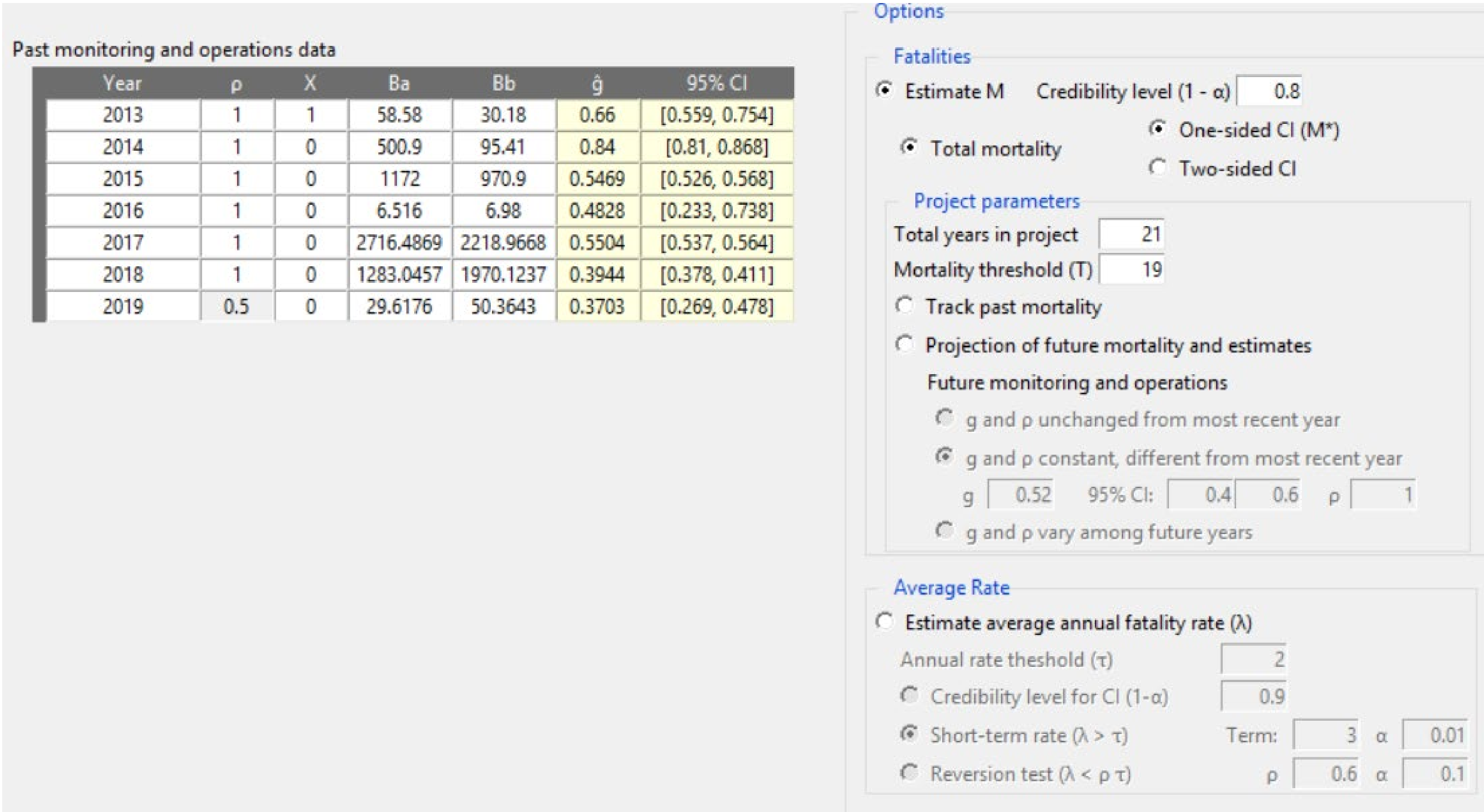
p = 0.31676 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 1.034

Posterior distribution of M
m      p(M = m) p(M > m)
0       0.0000   1.0000
[values removed] ...
21      0.0000   1.0000
22      0.0000   0.9999
23      0.0002   0.9998
24      0.0005   0.9992
25      0.0012   0.9980
26      0.0026   0.9954
27      0.0048   0.9906
28      0.0080   0.9826
29      0.0125   0.9701
30      0.0181   0.9520
31      0.0246   0.9274
32      0.0318   0.8956
33      0.0391   0.8565
34      0.0461   0.8103
35      0.0523   0.7580
36      0.0574   0.7006
37      0.0609   0.6397
38      0.0628   0.5770
39      0.0630   0.5140
40      0.0617   0.4522
41      0.0591   0.3932
42      0.0554   0.3378
43      0.0509   0.2869
44      0.0460   0.2409
45      0.0408   0.2001
46      0.0356   0.1645
47      0.0306   0.1339
48      0.0260   0.1079
49      0.0218   0.0861
50      0.0180   0.0681
51      0.0147   0.0534
52      0.0119   0.0415
53      0.0095   0.0320
54      0.0075   0.0245
55      0.0059   0.0186
56      0.0046   0.0141
57      0.0035   0.0105
58      0.0027   0.0078
59      0.0020   0.0058
60      0.0015   0.0042
61      0.0012   0.0031
62      0.0009   0.0022
63      0.0006   0.0016
64      0.0005   0.0011
65      0.0003   0.0008
66      0.0002   0.0006
67      0.0002   0.0004
68      0.0001   0.0003
69      0.0001   0.0002
70      0.0001   0.0001
71      0.0000   0.0001
72      0.0000   0.0000
73      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             0.170   0  102.4  50.82 0.668 [0.592, 0.740]
2017b            0.880   3  54.79  39.72 0.580 [0.479, 0.677]
2018             0.940   1  79.79  72.62 0.524 [0.444, 0.602]
2019             0.496   3  89.64  51.73 0.634 [0.553, 0.711]
```

Figure 2. Evidence of Absence software output for Hawiian hoary bats multi-year analysis (Dalthorp et al. 2017).



Past monitoring and operations data

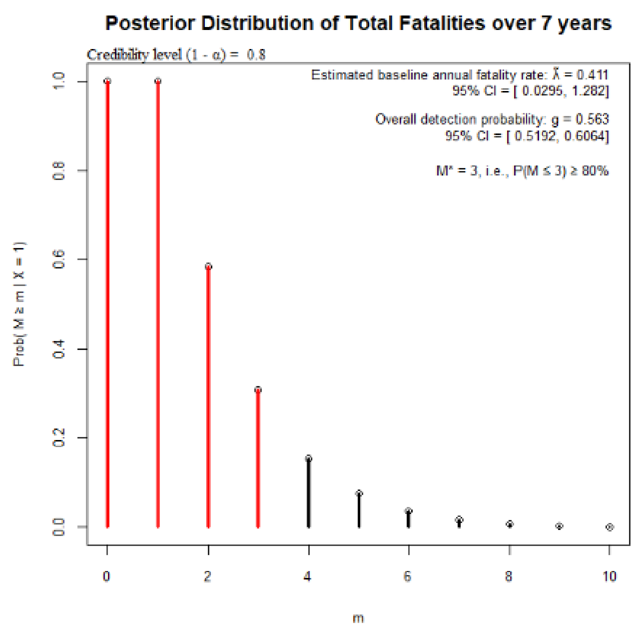
Year	ρ	X	Ba	Bb	ĝ	95% CI
2013	1	1	58.58	30.18	0.66	[0.559, 0.754]
2014	1	0	500.9	95.41	0.84	[0.81, 0.868]
2015	1	0	1172	970.9	0.5469	[0.526, 0.568]
2016	1	0	6.516	6.98	0.4828	[0.233, 0.738]
2017	1	0	2716.4869	2218.9668	0.5504	[0.537, 0.564]
2018	1	0	1283.0457	1970.1237	0.3944	[0.378, 0.411]
2019	0.5	0	29.6176	50.3643	0.3703	[0.269, 0.478]

Figure 3. Evidence of Absence software output for Hawiian petrels multi-year analysis (Dalthorp et al. 2017).

```
Test of assumed relative weights (rho) and potential bias          Fitted rho
Assumed rho      95% CI
      1      [0.164, 4.731]
      1      [0.002, 2.347]
      1      [0.003, 3.079]
      1      [0.005, 3.383]
      1      [0.003, 3.268]
      1      [0.006, 3.687]
    0.5      [0.007, 4.147]

p = 0.75451 for likelihood ratio test of H0: assumed rho = true rho
Quick test of relative bias: 0.952

Posterior distribution of M
m      p(M = m) p(M > m)
0       0.0000   1.0000
1       0.4145   0.5855
2       0.2774   0.3080
3       0.1534   0.1546
4       0.0790   0.0757
5       0.0392   0.0364
6       0.0191   0.0174
7       0.0091   0.0082
8       0.0043   0.0039
9       0.0021   0.0018
10      0.0010   0.0008
11      0.0005   0.0004
12      0.0002   0.0002
13      0.0001   0.0001
14      0.0000   0.0000
15      0.0000   0.0000
16      0.0000   0.0000
===================================
```




```
Input
Year (or period) rel_wt  X    Ba     Bb    ghat     95% CI
2013             1.000   1  58.58  30.18 0.660 [0.559, 0.754]
2014             1.000   0  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   1283   1970 0.394 [0.378, 0.411]
2019             0.500   0  29.62  50.36 0.370 [0.269, 0.478]
```

Figure 4. Evidence of Absence software output for Hawiian petrels multi-year analysis (Dalthorp et al. 2017).

Attachment 2

Kahikinui Management Area Hawaiian Petrel Monitoring Report

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AUWAHI WIND FARM

2018 Auwahi Wind Farm Hawaiian Petrel Report

Prepared for:

&

Auwahi Wind Energy, LLC

20100 Piilani Hwy

Kula, HI 96790

Prepared By:

30 August 2019

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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, Hawaii, 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), which was 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 Hawaii Department of Land and Natural Resources on February 9, 2012, and an incidental take permit (ITP) from the U.S. Fish and Wildlife Service (USFWS) on February 24, 2012. To address the reporting requirements under the HCP for Hawaiian petrels (*Pterodroma sandwichensis*; petrels), this report summarizes the petrel management activities executed in 2018 within the Auwahi Wind Kahikinui Petrel Management Area (Kahikinui PMA).

1.2 Kahikinui PMA

Kahikinui PMA is located on the Department of Hawaiian Homelands (DHHL) portion of the Kahikinui Forest Reserve (Figure 1). The management area consists of approximately 356 hectares with petrel burrows scattered throughout. Kahikinui PMA is located on a south-facing slope along the southwestern flank of Haleakalā crater. The elevation within Kahikinui PMA ranges from 2,560 to 2,972 meters above sea level. The Kahikinui PMA is divided into four management units (Figure 1).

1.3 Objectives of 2018

In the Auwahi Wind HCP, take and mitigation are accounted for 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). The predator control strategy continues to focus on controlling feral cats, mongooses and rodents within the entire Kahikinui PMA.

As in previous years, the objectives of the 2018 management season were to continue petrel burrow monitoring to assess the number of active burrows in Kahikinui PMA, determine petrel reproductive success, and continue implementation of the predator control strategy. These objectives were met using four main tactics:

1. Burrow checks conducted at known burrows to estimate the number of active burrows and their reproductive success.

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 implementation of predator control (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.

2.0 Methods

2.1 Burrow Activity and Reproductive Success

Burrow checks were conducted twice a month from April to November 2018 (the petrel breeding period). 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 2018 were marked, mapped, and added to the monitoring dataset. All known burrows were monitored using the "toothpick method" (NPS 2012, Island Conservation and Tetra Tech 2013) during each check through July, after which only active burrows were monitored (Figure 2). Burrows were classified 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 classified as prospecting or seasonally inactive were excluded.

Two metrics of reproductive success were utilized to allow for direct comparisons between previous monitoring years at Kahikinui PMA and other local petrel studies:

1. **Percent Chicks Fledged per Active Burrow**—This metric is represented by Equation 1 below, and calculates the reproductive success from all burrows which were consistently active during the egg-laying season.
2. **Percent Chicks Fledged per Eggs Laid**—This metric is represented by two values, one derived with assumptions providing a minimum value (Low; Equation 1 below) and a second derived with assumptions providing a maximum value (High; Equation 2 below).

Equation 1

Low Value

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

Equation 2

High Value

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

The trend in the percent chicks fledged per active burrow across the 7 years of monitoring (2012–2018) 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 six monitoring seasons for which the entire season was monitored (2013–2018).

2.2 Game Camera Monitoring

Reconyx Hyperfire cameras have been used since 2012 to provide supplemental information on burrow activity and reproductive success. Methods for game camera monitoring are reported in the FY 2018 annual report (Tetra Tech 2018).

2.3 Tracking Tunnels

Tracking tunnels were 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) in March and September 2018. Methods for tracking are reported in the FY 2018 annual report (Tetra Tech 2018)

2.4 Predator Control

The predator control strategy was initiated on a regular basis starting in March 2018, and informed by the results of the March tracking tunnel study. The trapping grid was left active after the 2017 season and checked once during January prior to the start of the breeding season. A combination of five trap types was used which included 18 Belisle body grip traps, 49 DOC250 kill traps, 44 Goodnature A24 self-loader kill traps, 14 Victor foothold traps and 39 KaMate traps. Of 164 traps, 158 were placed within a 200-meter buffer of the petrel burrows using gridded spacing (Figure 3). The Goodnature traps and DOC250 traps were each spaced at 150-meter intervals. All trap types, excluding footholds, were housed in rock cubbies, wooden boxes, or plastic coverings to reduce the risk of seabird bycatch. Foothold traps were placed seasonally, approximately 3 to 5 meters apart, and clustered in areas where cat activity was documented or typically occurs (fence lines, pathways, etc.).

The trapping grid was fully operational by March 28, 2018 (Figure 3). All traps were visually checked by Auwahi Wind technicians, every 2 weeks from March to late November. Belisle body grip traps were baited primarily with beef hotdogs; bait types within DOC250 traps were rotated every check between tuna/sardines, peanut butter, beef hotdogs, and a variety of other items such as catnip, baby food, and wax bait; Goodnature traps were baited with cinnamon or peanut butter; foothold traps were baited primarily with tuna/sardines and fish oils; and KaMate traps were primarily baited with macadamia nuts.

3.0 Results

3.1 Burrow Activity and Reproductive Success

During the 2018 breeding season, bi-weekly visits to monitor burrow activity began on February 28, 2018, and ended on November 27, 2018, at which time all the burrows had ceased to be active. A total of 72 burrows were monitored within the Kahikinui PMA (70 initially located prior to the 2018 season and 2 burrows located during 2018 surveys).

Forty (56 percent) of the 72 burrows were active during the 2018 breeding season, and 32 burrows (44 percent) were seasonally inactive (Figure 2; Table 2). Of the 40 active burrows, 31 were consistently active and were used to calculate reproductive success for Kahikinui PMA in 2018. 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. Two of the active burrows had eggs rollout and were classified as failed. None of the burrows with reproductive sign showed evidence of depredation. The remaining 20 burrows that were consistently active either failed or were occupied by a non-breeder. The cause of nest failures/abandonment is unclear. 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, although game cameras did document goat trampling (See Section 3.2 Game Camera Monitoring Section).

Reproductive success in 2018 was between 29 and 82 percent. Based on the survey findings, eggs were assumed to have been laid in 11 to 28 of the consistently active burrows; the range represents the difference between using only those nests where reproductive sign was confirmed versus assuming all consistently active nests had eggs laid. The percentage of chicks fledged per active burrow within the Kahikinui PMA was 29 percent (Figure 4). The percentage of chicks fledged per confirmed eggs laid was 82 percent. There was no significant difference in reproductive success in the 7 years of monitoring (χ^2=4.3095, df =12 P=0.9772), using the conservatively low value for reproductive success or the high value for reproductive success (χ^2=11.089, df =12 P=0.5213).

3.2 Game Camera Monitoring

Game cameras were deployed at 37 burrows in 2018 (Table 3). Game cameras confirmed activity at 31 of the 72 burrows and documented the successful fledging of nine chicks. Successful fledging was recorded between October 13 and November 2, 2018 (Table 3). Game cameras recorded one visitation by a cat at burrow 50 on November 19, 2018. This visit occurred after the breeding season at a burrow that was classified as occupied by a non-breeder/failed.

Game cameras also captured visitation by goats at the entrances of both Successful and Occupied by Non-Breeder/Failed burrows. Goats were detected by cameras at burrows most frequently between May and August (Figure 6). Goats were observed at burrows within all four units (Figure 2), and 51 percent of all burrows with cameras showed sign of trampling by goats. Rodents were detected on at least one game camera in each month of game camera monitoring in 2018. No mongooses were detected by game cameras in 2018.

3.3 Tracking Tunnels

In March, rodents (mouse and rat) were detected along three of the eight transects, using the 1-day rodent index. The 1-day tracking index was 3.2 percent (6 of 187, mean percentage of tunnels with tracks) for rodents in March. Halfway through the trapping season in September, rodents (mice only) were detected along four transects[1]. There was a slight increase from 2.1 to 7.5 percent (14 of 187) in the tracking index for rodents in September, all of which was mouse activity.

No mongooses were detected in March along any of the transects, with the 3-day tracking index of zero percent. Halfway through the trapping season in September, no mongooses were detected along any of the transects.

Investigating the activity index across the entire management period (Fall of 2013 – Fall of 2018), there do not appear to be any noticeable trends. The overall activity trend for both rodents and mongoose is low across the site and across all monitoring periods. Mongoose activity has stayed below 2.5 percent since Fall of 2015 (Figures 7 and 8).

3.4 Predator Control

The predator control grid was operational for all of 2018. Predator control efforts removed 116 targeted mammalian predators from Kahikinui PMA, including 70 mice, 45 rats, and 1 mongoose. Animals removed per month ranged from zero to 12 (Figure 9).

On August 2, 2018, a Hawaiian Petrel was found in a Belisle body grip trap. As noted in the ITP:

> *Up to a total of seven (7) Hawaiian petrels (adults, subadults, fledglings, nestlings) over the 25-year permit term, may be incidentally taken in the form of capture as a result of interactions with predator capture systems.*

This was the first time a petrel was observed interacting with a trap within the mitigation area. As a result of the bycatch, all Belisle body grip traps were taken out of service. Wooden boxes or plastic coverings will be used when possible, rather than rocks, if Belisle body grip traps are reinstalled in Kahikinui PMA.

Auwahi Wind has continued to provide support (e.g., training, trap and sensor deployment, and monitoring) to the Maui Nui Seabird Recovery Project (MNSRP) and Haleakalā National Park (HNP). This support occurred in the adjacent Kahikinui Natural Area Reserve and HNP. Traps removed one feral cat from Haleakalā.

[1] Mouse and rat tracks are distinguished by size.

4.0 Discussion

4.1 Reproductive Success

Throughout 2018, 40 burrows showed signs of activity at some point during the breeding season. Since monitoring began in 2012, we have seen a regular seasonal decline in active burrows in the month of September. 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 juvenile non-breeders. This results in large confidence intervals surrounding reported reproductive success percentages.

From 2012 to 2018, the total number of burrows reported in the management area has increased by 18. However, the increase in burrows within the colony has not resulted in an increase in the number of active burrows in each 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 active burrows has remained relatively constant throughout the 7 years of monitoring (28 to 33 active burrows). Unit 1 contains the largest proportion of consistently active burrows (46 percent; Figure 2).

One of the assumptions of the population model in the HCP was the reproductive success associated with predator control. A significant increase in the reproductive success has not been documented within the management area since predator control implementation. However, there has been a mostly positive trend (Figure 4) since 2014, when predator control was fully implemented. Similarly, the adjacent Daniel K. Inouye Solar Telescope (DKIST) mitigation site reported low reproductive success (Chen et al. 2018).

The Kahikinui PMA and DKIST sites appear to have low reproductive success compared with historic values from the nearby HNP (42 to 61 percent, Hodges 1994). Although current reproductive success data from HNP is comparable to the results at adjacent sites (39.5 percent ±10.4 percent; NPS 2018). Previous annual reports discussed alternative explanations for the lower reproductive success, 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 management area than Haleakalā and DKIST;
- 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; and
- 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.

- Of the observed burrows at least 61 chicks have fledged in 7 years from the PMA and likely more given the number of unobserved burrows.

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. Predator control efforts from the start of the project have removed 425 targeted mammalian predators from Kahikinui PMA, including 262 mice, 165 rats, 7 mongoose, and 2 cats. Mongoose activity levels have remained low in the years since initial trapping was completed in 2015 (Sempra Energy 2015). In 2018, no mongoose were detected (Figure 2).

Rodent activity appears to have seasonal pulses, based on the tracking tunnel and trapping results (Figure 7). Pulses in rodent activity are typically observed in the fall (September – November), and this 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 2018 (Figure 8); however, one cat was trapped in a neighboring management area by partners using foothold traps with remote sensor technology provided by Auwahi Wind. Coordinating predator control with neighboring projects based on game camera monitoring helped guide Auwahi Wind's efforts to remove potential predators. Similar to previous years, a low level of cats were detected on camera (Figure 5) and one cat was removed through trapping. This suggests the site may experience a stable rate of immigration of new individuals to replace those removed. Individual cats can have a substantial impact on bird populations. For example, in New Zealand, the Stephens Island wren is reported to have been driven to extinction by a single cat (Gross 2016). And at Haleakalā, predators were documented to predate up to 34 percent of active burrows, significantly impacting reproductive success (Simons 1985).

4.3 Proposed Transition to DKIST Site

Tier 1 mitigation is intended to compensate for the incidental take of 19 adult petrels and 7 chicks over 25 years. The reproductive success rate within the Kahikinui PMA has not been at the level needed to ensure that the current success criteria will be met, as described in the HCP (Section 6.3). The original HCP noted that in the event that additional mitigation would be required to meet success criteria, Auwahi Wind "will focus mitigation efforts on one or more of the alternate mitigation sites" (Tetra Tech 2012). Under adaptive management Auwahi Wind may assume management of a portion of the petrel colony at the adjacent DKIST site, after mitigation obligations under the HCP for DKIST (ATST 2010) had been met. In 2018 the obligation of the HCP for DKIST were completed and the completion was approved by the ESRC on March 6, 2019. As of the 2017 breeding season, the DKIST site included 189 active petrel burrows surrounded by an ungulate exclusion fence (Chen at al. 2018). Based on discussion with USFWS and DOFAW, Auwahi Wind has proposed to assume management of a section of the DKIST site in 2020 and continue management through 2033 (Year 20 of the permit term). A more complete discussion of acquiring the DKIST site was included in the 2016 Auwahi Wind Energy Hawaiian Petrel Report (Tetra Tech 2016). Auwahi Wind is working in coordination with USFWS, DOFAW and MNSRP to determine what level of management and support is needed to offset the remaining mitigation credit needed.

4.4 Summary and Recommendations for 2019

- Since completion of comprehensive surveys in 2012, there has been a net increase of 18 burrows within the breeding colony.
- The use of game cameras for 6 consecutive years has allowed 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.
- Predator assessments (tracking tunnels) 2013 – 2018 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 predators within Kahikinui PMA, followed closely by KaMate traps.
- Auwahi Wind has started to assess the effectiveness of Reconyx game cameras with text message reporting within the management area.
- Auwahi Wind has been working in coordination with USFWS and DOFAW to take steps to assume management of part of the DKIST petrel management site in the 2020 breeding season. A plan has been proposed and specifics for mitigation credit will be determined prior to implementing management actions in 2020.
- Auwahi Wind will deploy artificial burrows in areas prone to goat trampling.
- The use of Body Grip traps has been discontinued due to the threat of trapping Hawaiian petrels.

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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[1] 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[2] during any burrow checks.</td><td colspan="3">Excluded</td></tr>
<tr><td colspan="5">1. Reproductive sign includes: egg, eggshell, chick down, chick.
2. Activity sign includes: bird on camera, droppings, tracks, feathers, and odor.</td></tr>
</table>

Table 2. Seasonal Status of Hawaiian Petrel Burrows in 2018

<table>
<tr><th rowspan="2">Seasonal Status</th><th rowspan="2">No. of Burrows</th><th colspan="3">Categories for Assessing Reproductive Success</th></tr>
<tr><th>Active</th><th>Consistently Active</th><th>Breeding Activity</th></tr>
<tr><td>Successful</td><td>9</td><td rowspan="5">40</td><td rowspan="4">31</td><td rowspan="3">11</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>20</td><td>Excluded</td></tr>
<tr><td>Prospecting</td><td>9</td><td colspan="2">Excluded</td></tr>
<tr><td>Seasonally Inactive</td><td>32</td><td colspan="3">Excluded</td></tr>
<tr><td>TOTAL</td><td>72</td><td colspan="3">–</td></tr>
</table>

Table 3. Game Camera Hawaiian Petrel Burrow Monitoring Summary, 2018

Burrow Number	Seasonal Status	Camera Deployment Date	Last Date of Activity	Successfully Fledged Date
3	Successful	15-Mar-18	26-Oct-18	26-Oct-18
32	Successful	14-Mar-18	21-Oct-18	21-Oct-18
33	Successful	14-Mar-18	13-Oct-18	13-Oct-18
34	Successful	14-Mar-18	28-Oct-18	28-Oct-18
42	Successful	14-Mar-18	18-Oct-18	18-Oct-18
51	Successful	15-Mar-18	29-Oct-18	29-Oct-18
52	Successful	14-Mar-18	2-Nov-18	02-Nov-18
68	Successful	14-Mar-18	29-Oct-18	29-Oct-18
74	Successful	25-Sep-18	27-Oct-18	27-Oct-18
7	Seasonally Inactive	15-Mar-18	-	
30	Seasonally Inactive	14-Mar-18	-	
61	Seasonally Inactive	15-Mar-18		
4	Occupied by Non-Breeder/ Failed	15-Mar-18	28-Aug-18	
6	Occupied by Non-Breeder/ Failed	15-Mar-18	30-Jul-18	
9	Occupied by Non-Breeder/ Failed	15-Mar-18	13-Aug-18	
13	Occupied by Non-Breeder/ Failed	10-Apr-18	22-Jun-18	
15	Occupied by Non-Breeder/ Failed	15-Mar-18	15-Aug-18	
20	Occupied by Non-Breeder/ Failed	14-Mar-18	07-Jul-18	
22	Occupied by Non-Breeder/ Failed	14-Mar-18	19-Aug-18	
23	Occupied by Non-Breeder/ Failed	14-Mar-18	05-Jul-18	

Burrow Number	Seasonal Status	Camera Deployment Date	Last Date of Activity	Successfully Fledged Date
31	Occupied by Non-Breeder/ Failed	14-Mar-18	09-Aug-18	
39	Occupied by Non-Breeder/ Failed	14-Mar-18	03-Aug-18	
54	Occupied by Non-Breeder/ Failed	15-Mar-18	27-Aug-18	
55	Occupied by Non-Breeder/ Failed	15-Mar-18	11-Aug-18	
58	Occupied by Non-Breeder/ Failed	15-Mar-18	05-Aug-18	
59	Occupied by Non-Breeder/ Failed	15-Mar-18	15-Aug-18	
62	Occupied by Non-Breeder/ Failed	15-Mar-18	15-Aug-18	
63	Occupied by Non-Breeder/ Failed	14-Mar-18	26-Jul-18	
67	Occupied by Non-Breeder/ Failed	23-May-18	12-Jul-18	
70	Occupied by Non-Breeder/ Failed	15-Mar-18	20-Jul-18	
73	Occupied by Non-Breeder/ Failed	20-Jun-18	09-Aug-18	
25	Failed[1]	14-Mar-18	22-Aug-18	
72	Failed[2]	06-Jul-18	03-Sep-18	
5	Prospecting	20-Jun-18	08-Jul-18	
19	Prospecting	-	05-Jul-18	
21	Prospecting	-	07-Jul-18	
30	Prospecting	-	29-Aug-18	
38	Prospecting	-	14-Aug-18	
50	Prospecting	28-Mar-18	15-Jul-18	

Burrow Number	Seasonal Status	Camera Deployment Date	Last Date of Activity	Successfully Fledged Date
53	Prospecting	14-Mar-18	28-Aug-18	
60	Prospecting	-	06-Jul-18	
65	Prospecting	14-Mar-18	25-Mar-18	
71	Prospecting	-	06-July-18	

[1] An egg was found outside burrow on Aug 7, 2018 (most likely from this season).

[2] An egg was found outside burrow on June 20, 2018 (most likely form this season).

- No bird on viewed on burrow camera. Burrow status determined applying toothpick method

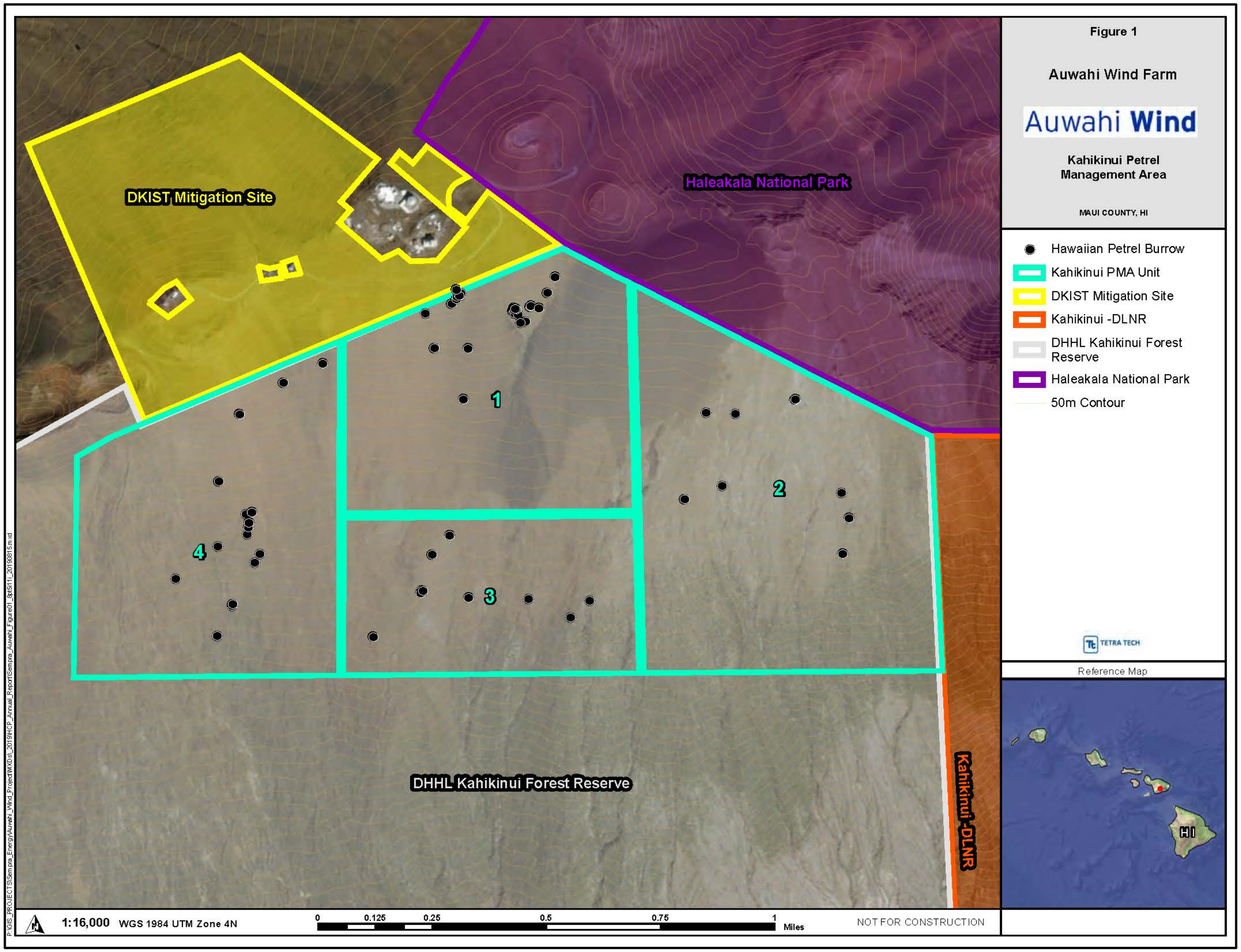

Figure 1. Kahikinui Petrel Management Area

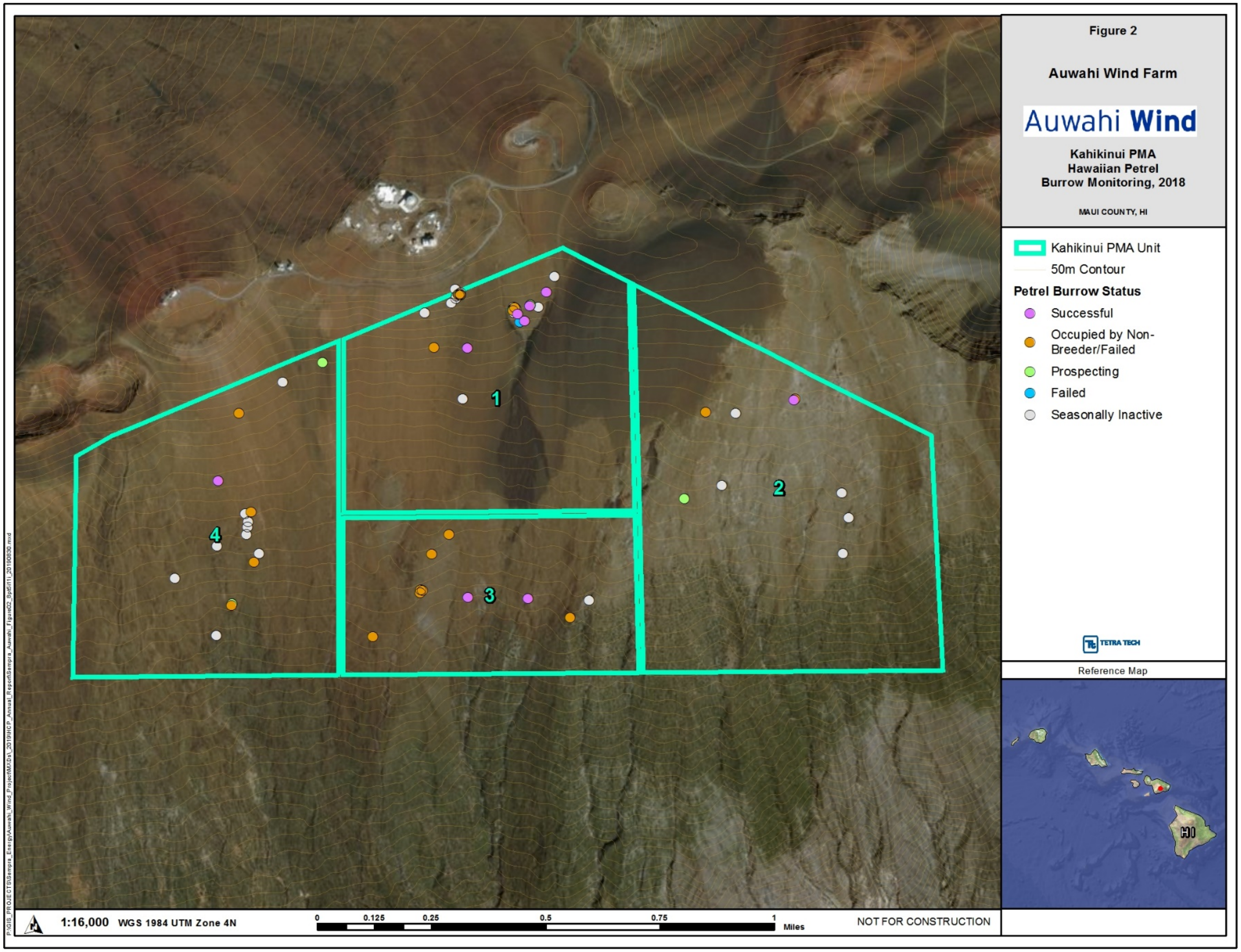

Figure 2. Kahikinui PMA Hawaiian Petrel Burrow Monitoring, 2018

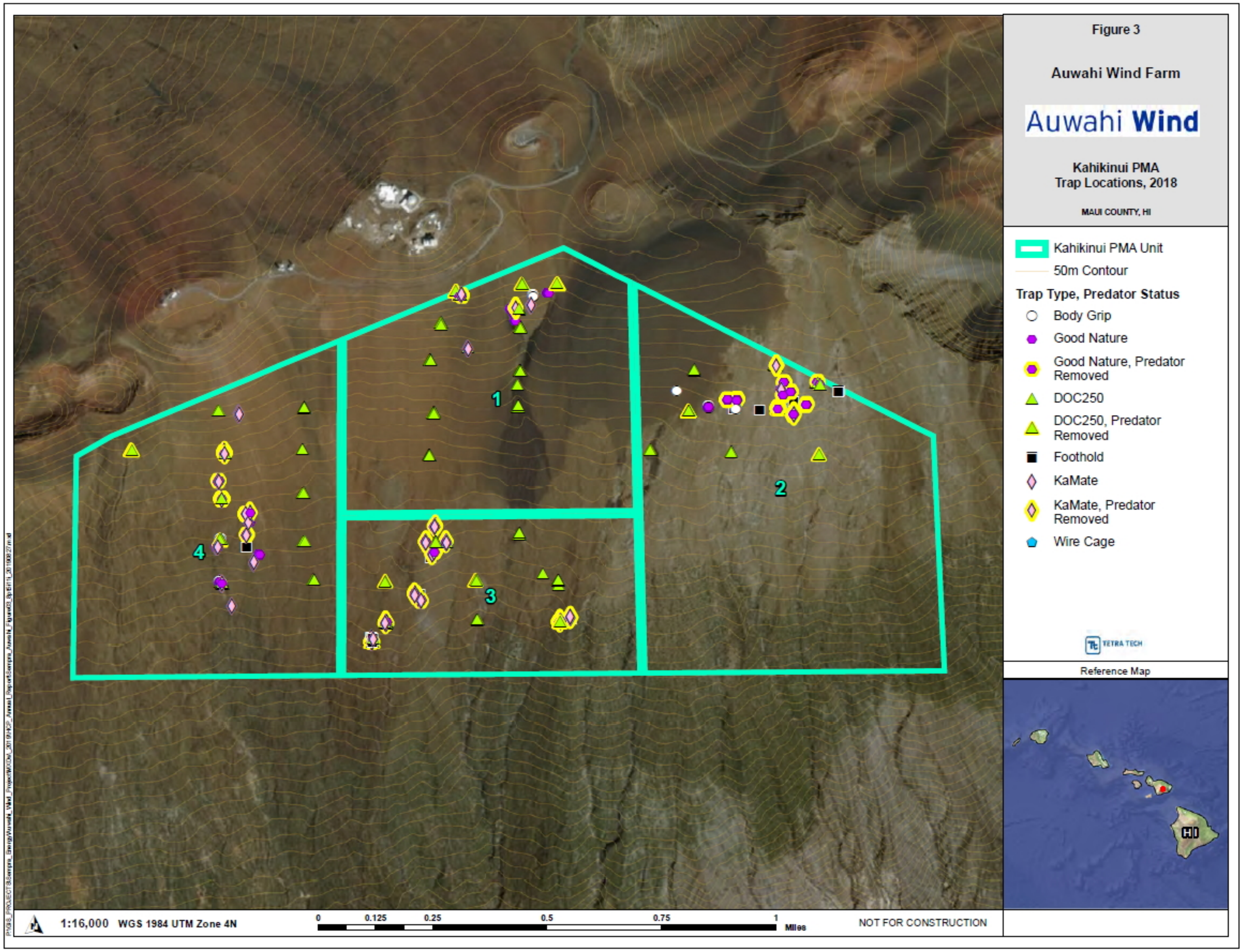

Figure 3. Kahikinui PMA Trap Locations, 2018

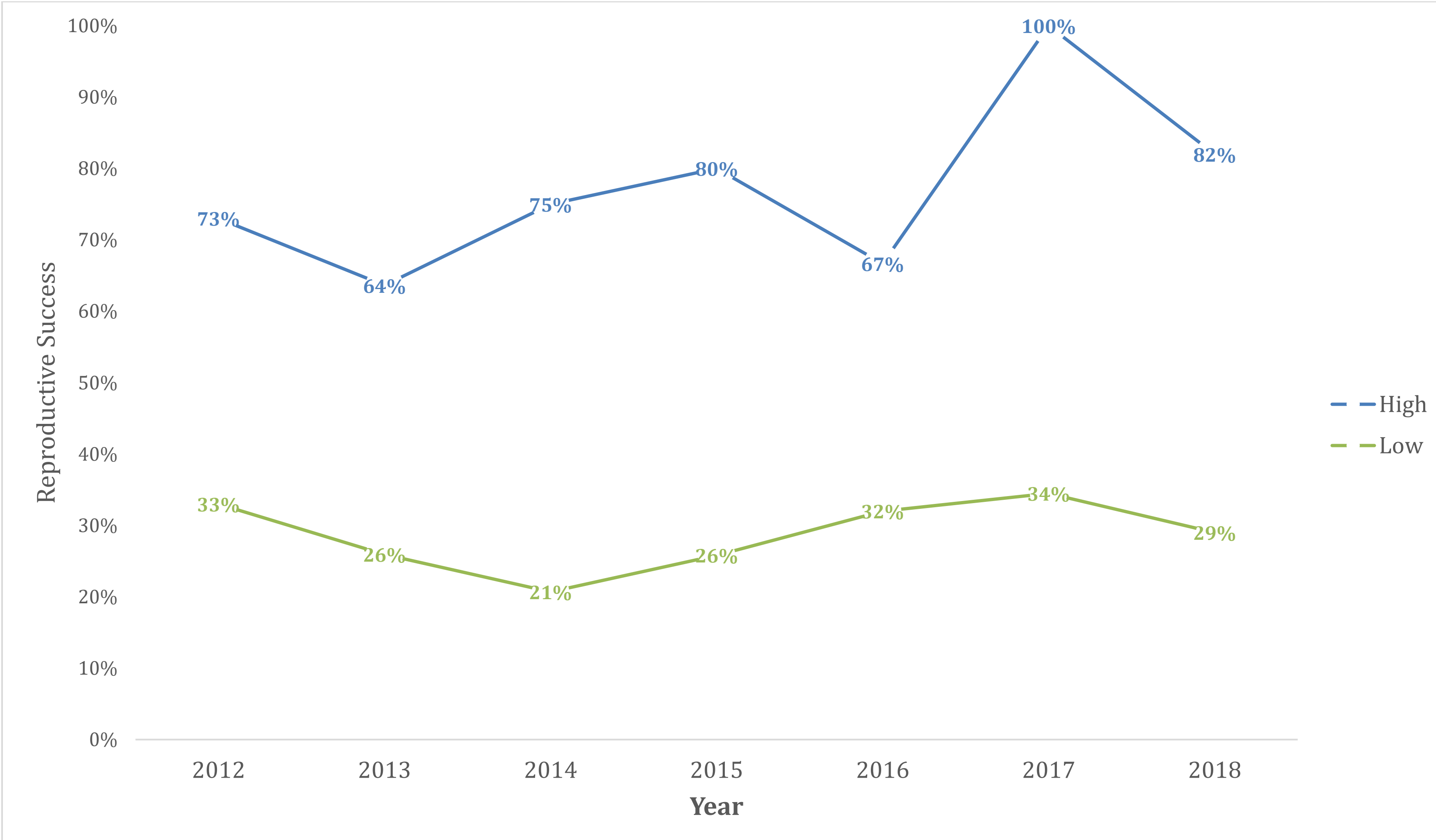

Figure 4. Reproductive Success within Kahikinui PMA, 2012 – 2018

(High assumes only those burrows with reproductive sign had breeding adults; and low assumes all consistently active burrows had breeding adults.)

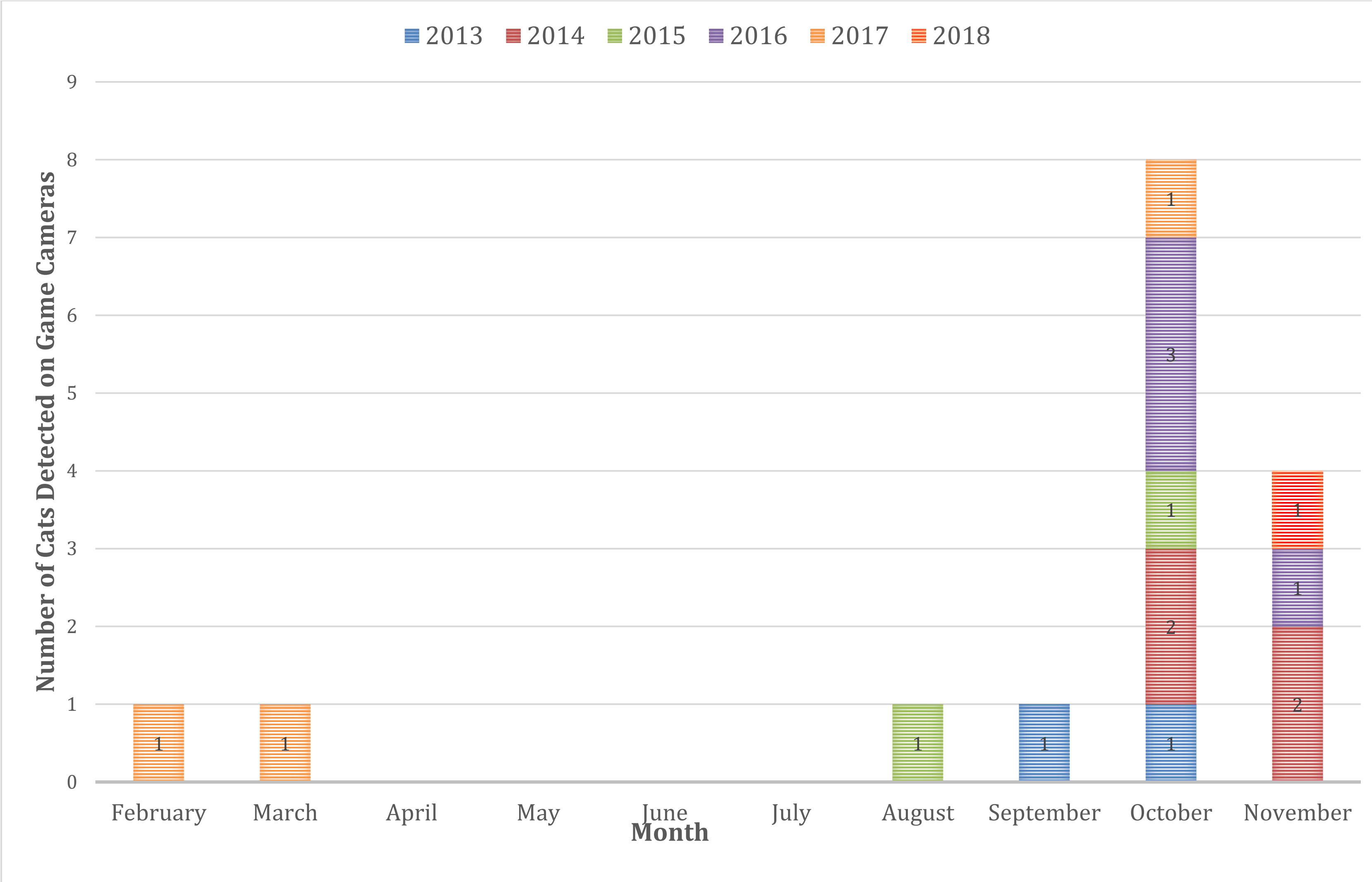

Figure 5. Seasonal Occurrence of Cats Detected at Burrows by Game Cameras, 2013-2018

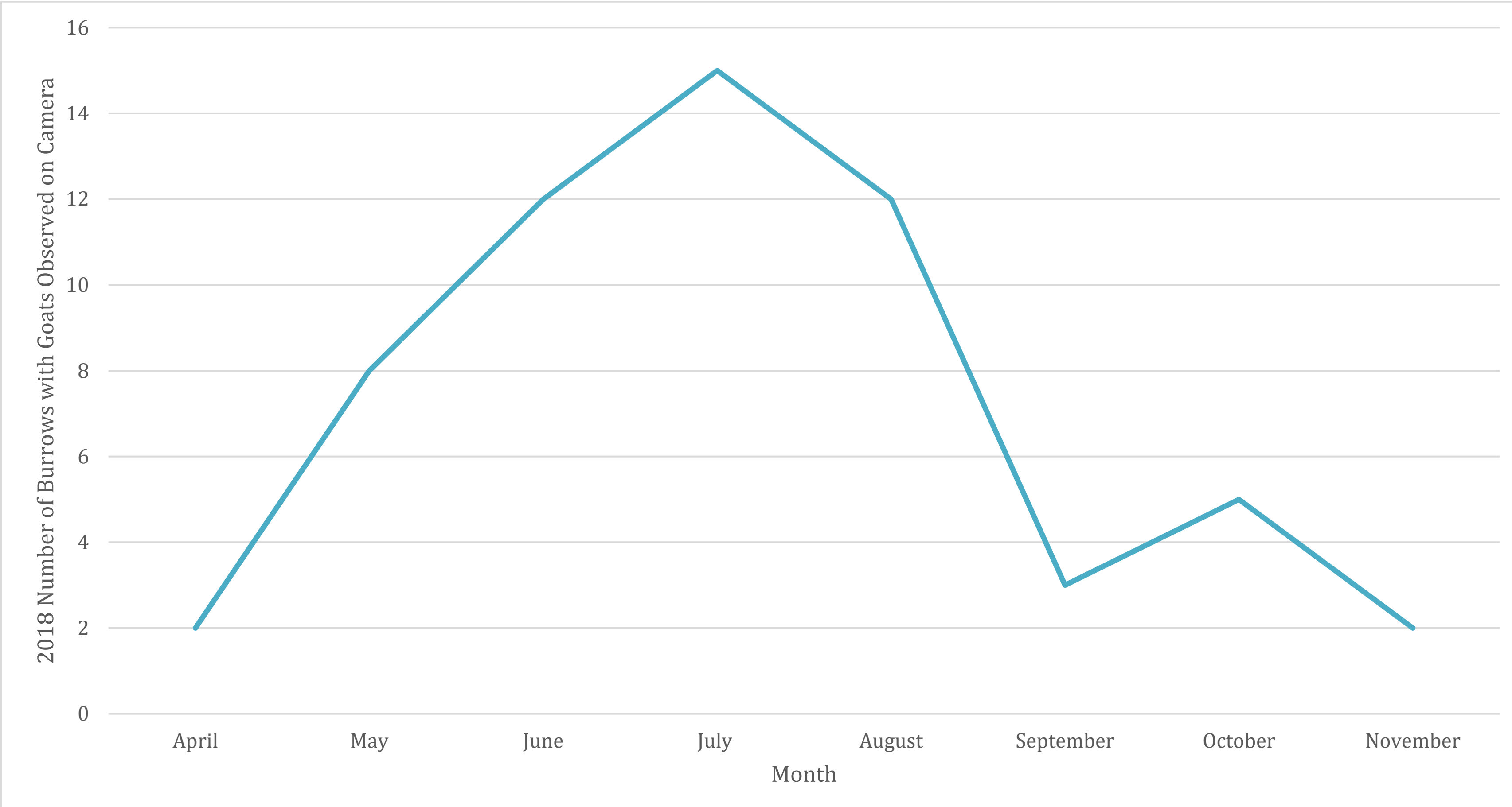

Figure 6. Seasonal Occurrence of Goats Detected at Burrows by Game Cameras, 2018

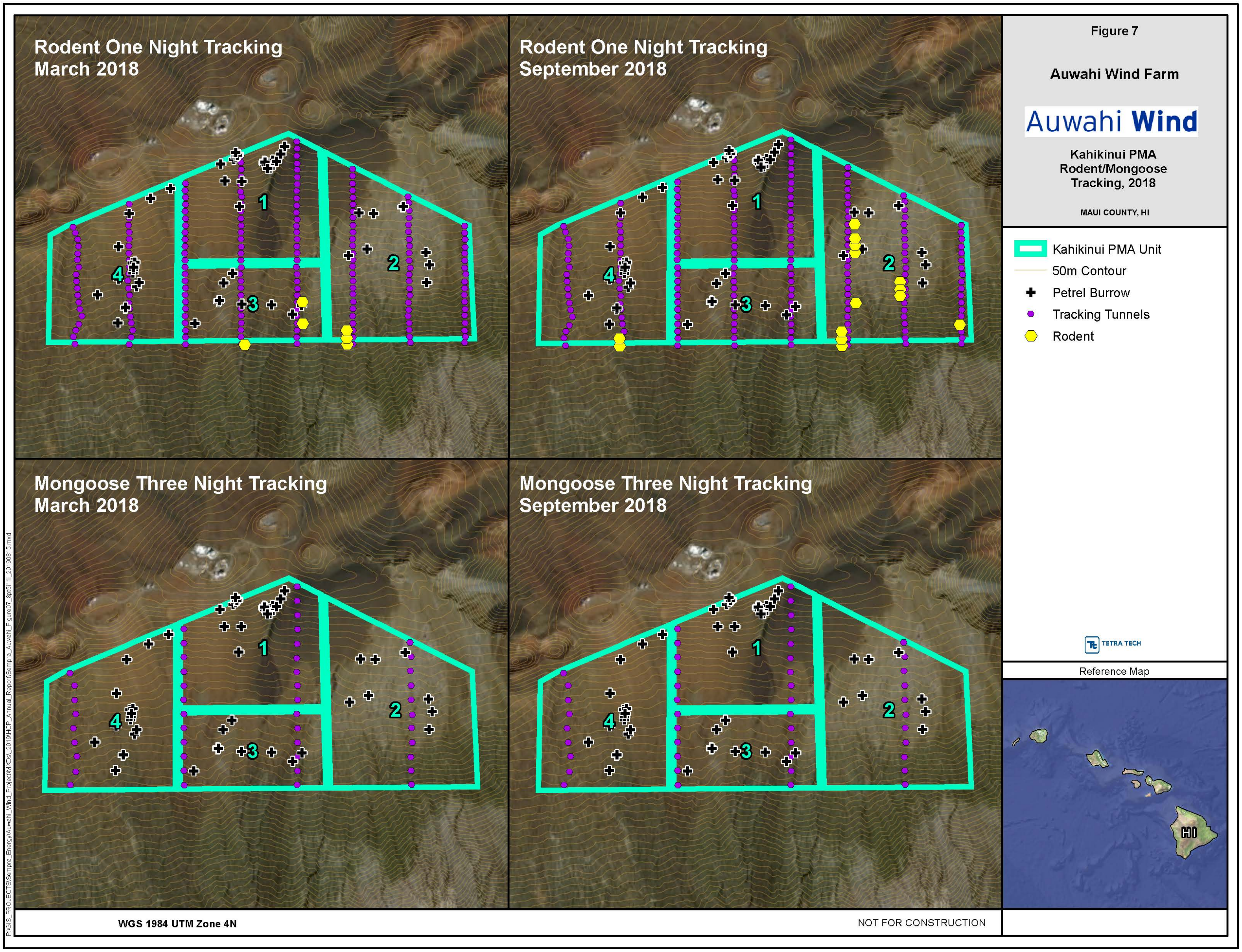

Figure 7. Kahikinui PMA Rodent/Mongoose Tracking, 2018

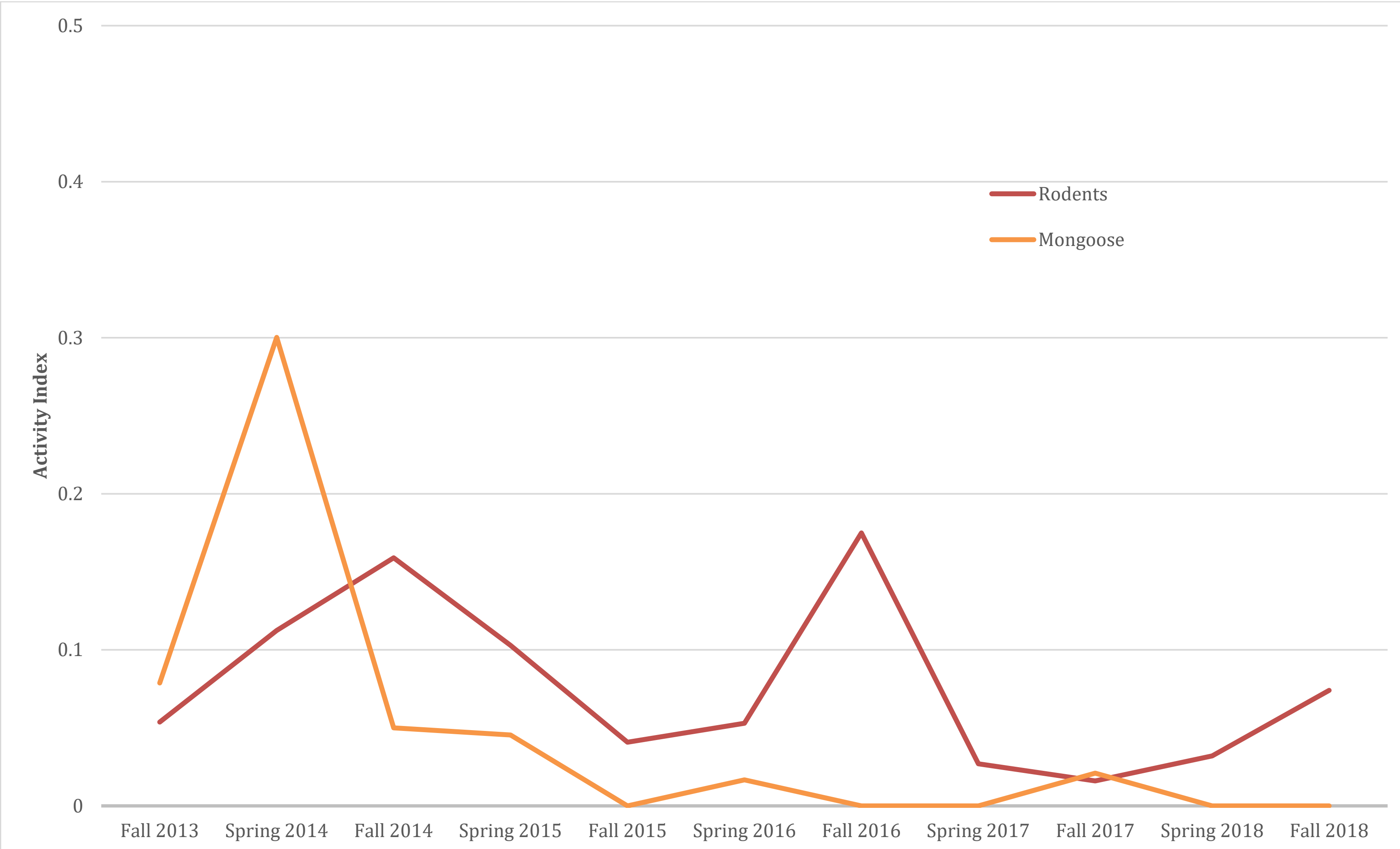

Figure 8. Summary of Rodent and Mongoose Tracking Tunnel Results, 2013 – 2018

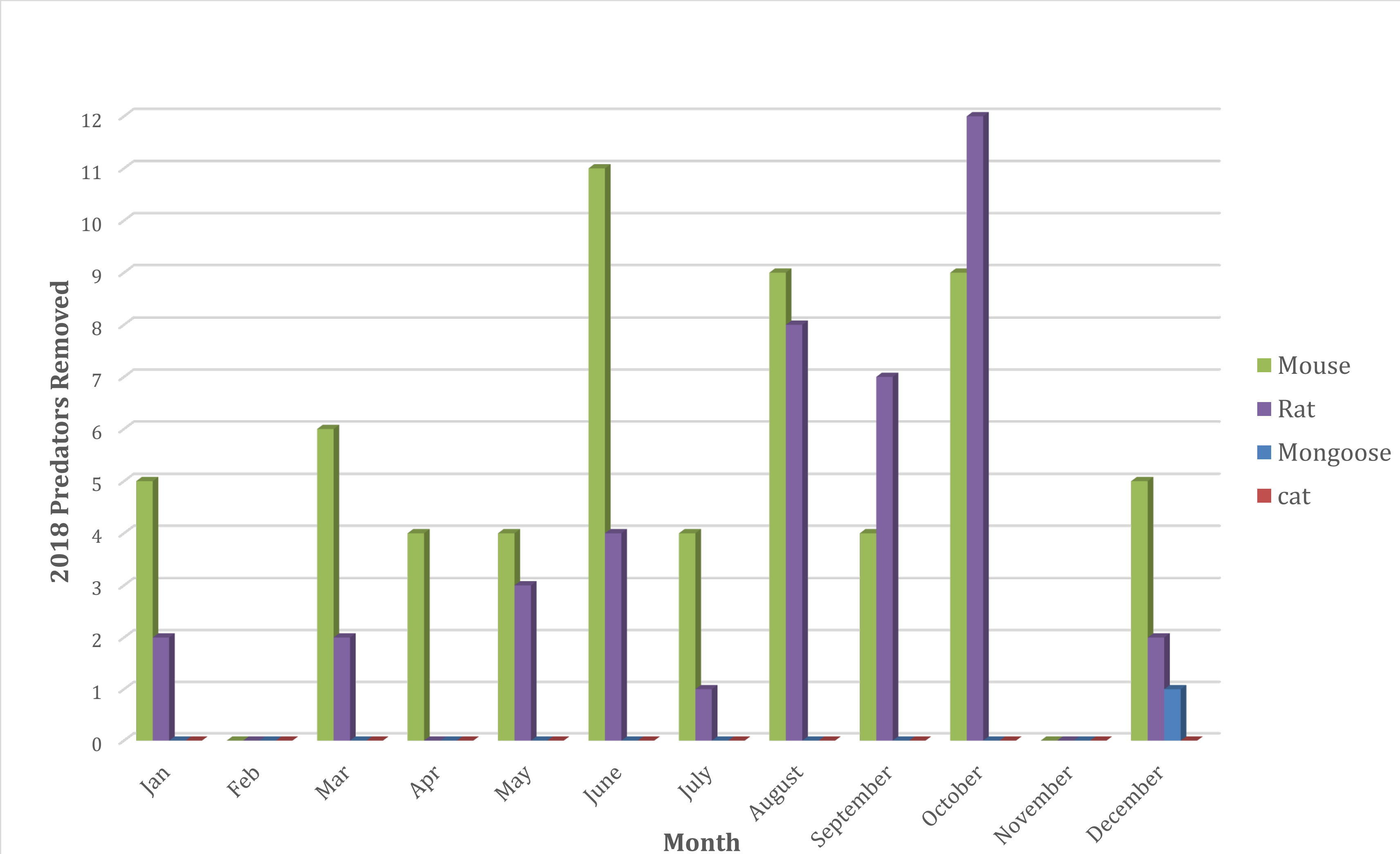

Figure 9. Monthly Summary of Predator Trapping Results, March – November 2018

Attachment 3
Hawaiian Hoary Bat Tier 2 & 3 Research Summary

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Technical Report HCSU-090

HAWAIIAN HOARY BAT (*LASIURUS CINEREUS SEMOTUS*) ACTIVITY, DIET AND PREY AVAILABILITY AT THE WAIHOU MITIGATION AREA, MAUI

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Abstract

Habitat use, diet, prey availability, and foraging ecology of the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*, Vespertilionidae), was examined in the east Maui region inclusive of the Waihou Mitigation Area, Puʻu Makua Restoration Area and the wind energy facility operated by Auwahi Wind Energy, LLC. The study was conducted to inform the mitigation and management requirements of Auwahi Wind Energy. Acoustic monitoring over the three-year period demonstrated that bats are present and actively forage year-round at the Waihou Mitigation Area. Over an 8-month span, 11 bats were uniquely color-banded and released, three of which were pregnant or lactating females, and highlights the importance of the area to breeding residents. Our study included the first genetic analysis of Hawaiian hoary bat diet, and confirms the inclusion of Coleoptera, Lepidoptera, Diptera, Hemiptera, and Blattodea among the prey items of this bat identified in previous microscopy-based studies. Hawaiian hoary bats consumed both native and non-native insect species, including several invasive species damaging to crop agriculture. Moths were the primary dietary component, both in prevalence among individual bats and the proportion of gene sequence counts. Through genetic analysis, we identified 18 Lepidoptera families (dominated by Noctuidae, Geometridae, Crambidae, Oecophoridae and Tortricidae) including 24 genus- or species-level taxa. Lepidoptera collected as caterpillars directly from vegetation did not appear in the diet of the 8 bat guano samples at the genus or species level. However, the occurrence of moth larva on native plants suggests that reforestation that includes host plants for these insect families may provide food for locally foraging bats.

Introduction

Wind energy has emerged as a potential threat to the Hawaiian hoary bat (*Lasiurus cinereus semotus*, Vespertilionidae), a federally and state listed endangered subspecies (USFWS 1998) and the only land mammal endemic to the Hawaiian Islands. Also known as the ʻŌpeʻapeʻa, the species occurs on all of the high islands (Tomich 1986). The Hawaiian hoary bat is closely related to the North American subspecies (*L. c. cinereus*), the latter of which makes up about 40% of all bat fatalities at wind turbines in the United States and Canada (range: 650,000–1,306,000 fatalities for all species in 2010–2011; Arnett and Baerwald 2013). Although in absolute numbers, turbine fatalities of hoary bats in Hawaiʻi are few compared to continental North America, population-level susceptibility of Hawaiian hoary bats to turbines remains unknown. Presently, Hawaiʻi has 206 megawatts of installed wind turbine capacity on the islands of Hawaiʻi, Maui, and Oʻahu (AWEA 2019), and Hawaiian hoary bat fatalities have been recorded at every wind energy facility on these islands. Bat fatalities may influence decisions concerning future wind energy development in Hawaiʻi.

To fulfill requirements for mitigating bat fatalities under its approved incidental take permit, Auwahi Wind Energy, LLC (Auwahi Wind) provided funding for a research project focused on the ecology of Hawaiian hoary bats on the Waihou Mitigation area. The objectives of the study presented herein were to determine within and in the vicinity of the Waihou Mitigation Area on east Maui: (1) bat occurrence and seasonal activity patterns; (2) the availability and diversity of nocturnal aerial insect prey; and (3) diet composition of captured bats. More specifically, the study objectives included quantitatively demonstrating current foraging activity for the purpose of evaluating the area's baseline importance to bats as recently planted native vegetation matures over the course of long-term restoration efforts within the Waihou Mitigation Area. Additionally, this report summarizes observations of the Hawaiian hoary bat and insect prey in the study area over a 37-month period from March 2015 to March 2018.

METHODS

Study Area

The study area was located on ʽUlupalakua Ranch on east Maui, and was comprised of the Waihou Mitigation Area and a separate property in proximity to the wind energy facility operated by Auwahi Wind (Figure 1, Table 1). The mitigation area is situated adjacent to the Kula Forest Reserve and the Kanaio Natural Area Reserve, and is dominated by pasture, with a small tract of land containing native koa (*Acacia koa*) and ʽōhiʽa (*Metrosideros polymorpha*) forest, and non-native conifers (Figures 2 and 3). Land-cover upslope from the area is comprised of non-native coniferous forest plantations. An ungulate-proof exclosure comprising the 53 ha (130 acre) Puʽu Makua Restoration Area within the Waihou Mitigation Area is protected by a conservation easement and the focus of native trees and shrub out-planting and restoration efforts by Auwahi Wind. In addition to the Puʽu Makua Restoration Area, the study area also included the mid-section of the Waihou Mitigation Area; referred herein as "upper Waihou". Elevation in the parcel ranges from 1,611 m (5,285 ft) above sea level (asl) at the top of a steep, south-facing slope to 1,298 m (4,259 ft) asl in the gently sloping pasture below. The area adjacent to the Auwahi Wind facility spans a low elevation gradient (10–363 m [33–1,191 ft] asl) dominated by dryland vegetation composed of open grassland, wiliwili (*Erythrina sandwicensis*) groves, kīawe (*Prosopis juliflora)*, and an ephemeral anchialine pond on ʽaʽā lava substrate close to the coast (Figures 4 and 5).

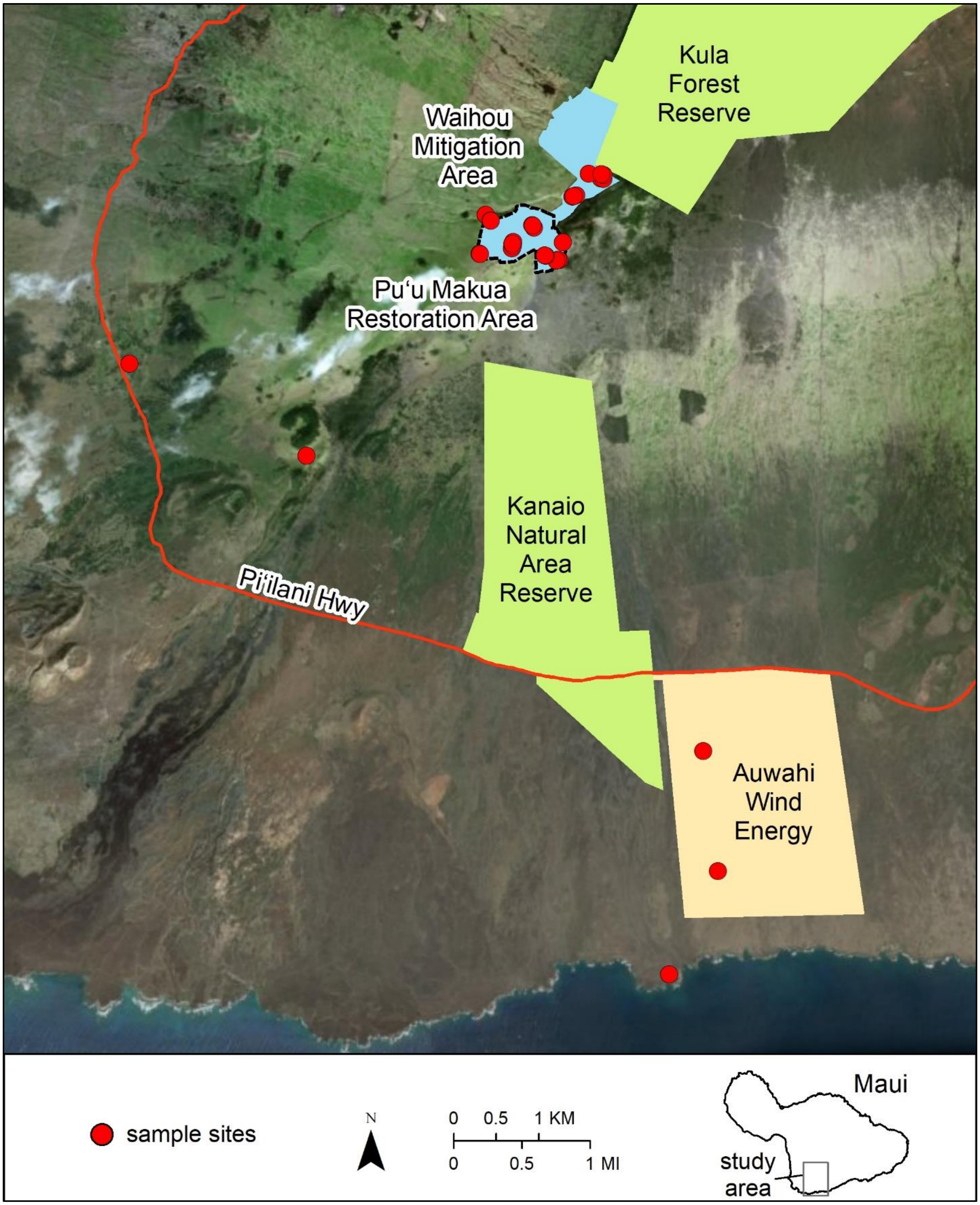

Figure 1. The east Maui study area, including the Pu‘u Makua Restoration Area (dash outline) within the Waihou Mitigation Area (blue polygon) and the Auwahi Wind Energy facility (orange polygon). Red circles represent sample sites used for acoustic monitoring, bat netting, and/or insect collection. Site names are shown in subsequent study area figures.

Table 1. Site names, coordinates (Easting and Northing, Universal Transverse Mercator Zone 4 WGS 1984), elevation (m), general location, sample type (bat acoustic, "A"; bat netting, "N"; insect collection, "I-light" or "I-malaise"). Sites are listed by sample type and general location. Coordinates and elevations collected using Garmin eTrax 10 GPS unit.

Site	Easting, Northing	Elevation	Location	Sample type
AUW1	775756, 2286710	1,611	Pu'u Makua	A
AUW2	776015, 2286954	1,606	Pu'u Makua	A
AUW3	776353, 2286781	1,607	Pu'u Makua	A
AUW4	776315, 2286576	1,515	Pu'u Makua	A
AUW5	775447, 2287108	1,396	Pu'u Makua	A
AUW6	776465, 2287322	1,644	upper Waihou	A
AUW7	776801, 2287532	1,647	upper Waihou	A
AUW8	778005, 2280800	363	wind energy facility	A, I-malaise
AUW9	777602, 2278171	10	below facility	A
AUW10	778179, 2279384	150	wind energy facility	A
CABIN	776512, 2287336	1,633	upper Waihou	N
POND1	776831, 2287528	1,659	upper Waihou	N
POND2	776660, 2287589	1,606	upper Waihou	N
RANCH	771254, 2285353	595	below Pu'u Makua	N, I-light
TANK	773335, 2284271	883	below Pu'u Makua	N
RIDGE	775764, 2286741	1,593	Pu'u Makua	N
REST1	775502, 2287044	1,370	Pu'u Makua	I-light
REST1	775507, 2287036	1,370	Pu'u Makua	I-malaise
REST2	775376, 2286650	1,413	Pu'u Makua	I-light
REST2	775380, 2286647	1,413	Pu'u Makua	I-malaise
MAM1	776298, 2286581	1,507	Pu'u Makua	I-light
MAM1	776276, 2286570	1,507	Pu'u Makua	I-malaise
MAM2	776149, 2286627	1,517	Pu'u Makua	I-light
MAM2	776139, 2286632	1,517	Pu'u Makua	I-malaise
PUU1	775992, 2286984	1,587	Pu'u Makua	I-light
PUU1	775997, 2286978	1,587	Pu'u Makua	I-malaise
PUU2	775771, 2286786	1,604	Pu'u Makua	I-light
PUU2	775761, 2286767	1,604	Pu'u Makua	I-malaise
PINE1	776479, 2287325	1,649	upper Waihou	I-light
PINE1	776479, 2287325	1,649	upper Waihou	I-malaise
PINE2	776833, 2287576	1,657	upper Waihou	I-light
PINE2	776805, 2287583	1,657	upper Waihou	I-malaise

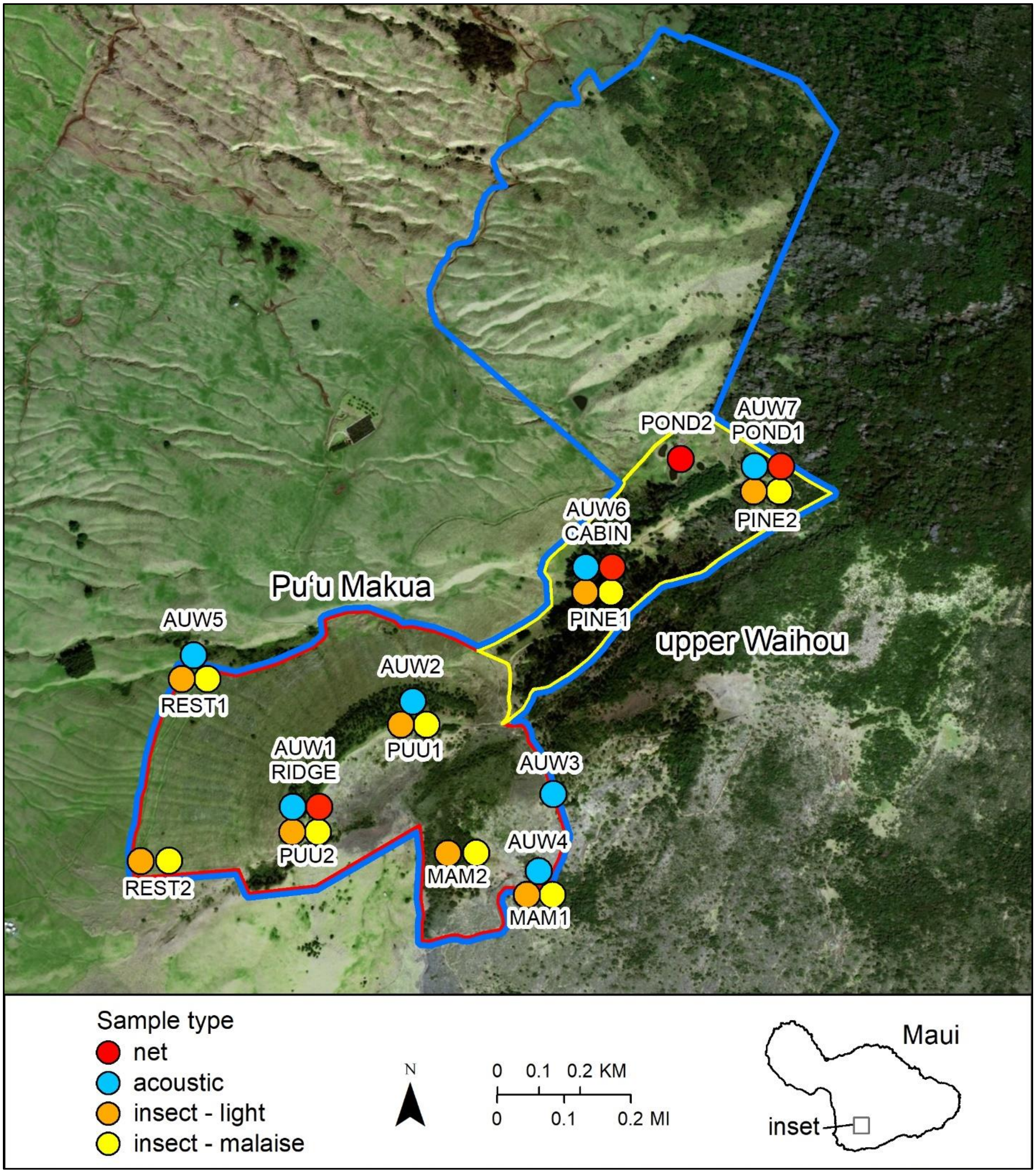

Figure 2. Sample sites within the Waihou Mitigation Area (blue polygon) include the mid-section (referred herein as "upper Waihou"; yellow polygon) and the Pu'u Makua Restoration Area parcel (red polygon) on east Maui, Hawai'i. Sample types include seven acoustic recording sites (blue circles; AUW1 through AUW7), eight paired light and malaise traps (orange and yellow circles) and Hawaiian hoary bat mist net locations (red circles).

Figure 3. Bat acoustic recording site AUW5 in the Puʻu Makua Restoration Area (top). Bat monitoring site AUW7 next to Pond1 (bottom).

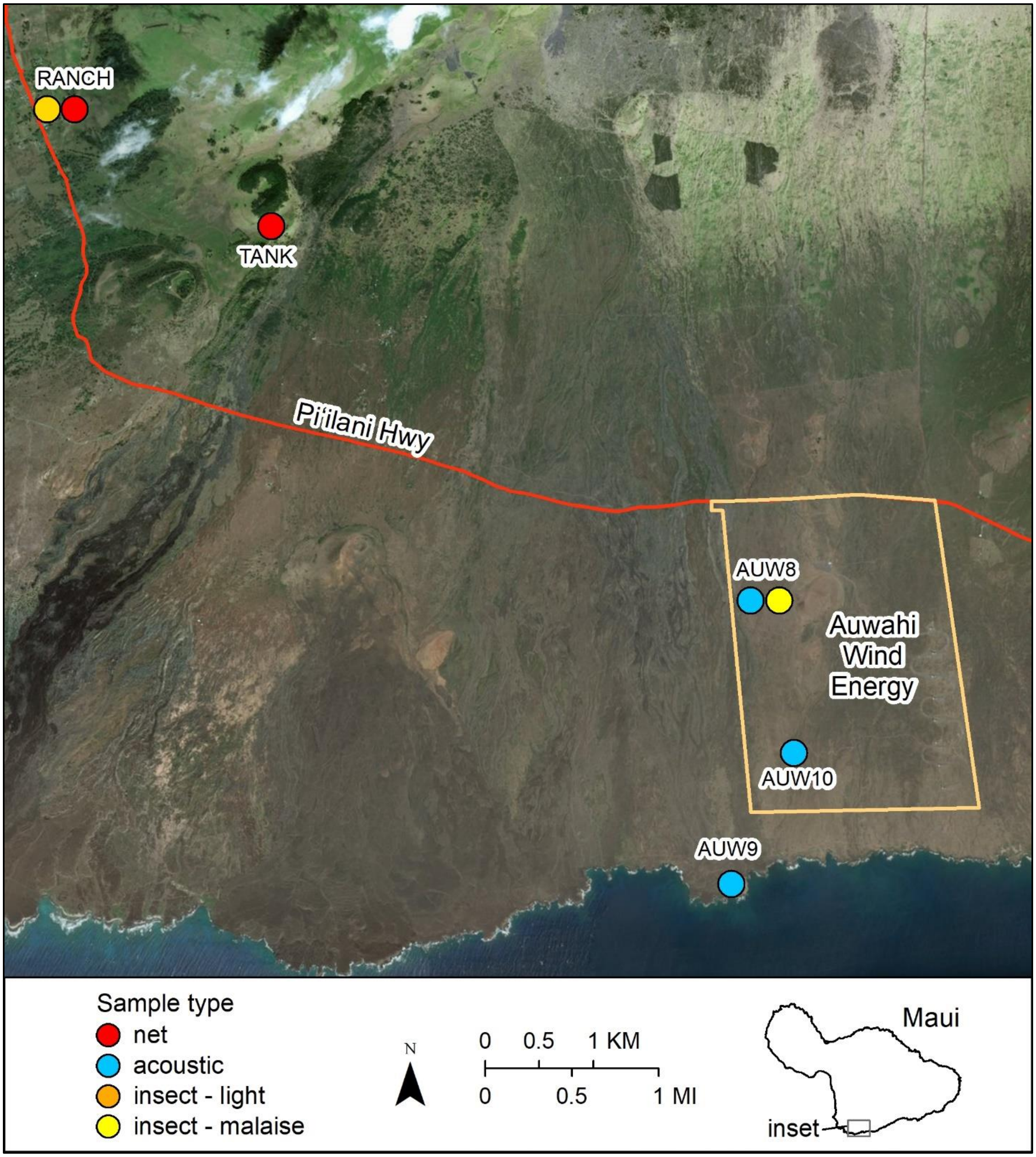

Figure 4. Sample sites within and adjacent to the Auwahi Wind Energy facility on east Maui, Hawai'i. Sample types include three acoustic recording sites (blue circles; AUW8 through AUW10), insect light (yellow circle) and malaise traps (orange circle), and Hawaiian hoary bat mist net locations (red circles).

Figure 5. Bat acoustic recording sites AUW8 (top), AUW9 (center), and AUW10 (bottom) at the Auwahi Wind Energy facility and surrounding habitats.

Acoustic Monitoring

Acoustic sampling of bat occurrence and activity was conducted between March 2015 and March 2018 (Figures 2 and 4; Table 1). On 17 March 2015, five sites were established within the Puʻu Makua Restoration Area (sites AUW1–AUW5) and one outside the parcel at a site deemed potentially good for mist-net capture of bats (AUW6). One additional site (AUW7) was established on 18 April 2017 at POND1, one of four artificial ponds constructed for wetland bird habitat in the area. These seven sites were located at an average elevation of 1,575 m asl. Three additional acoustic monitoring sites (AUW8, AUW9, AUW10) were activated between 13–20 June 2017 adjacent to the Auwahi Wind Energy facility at elevations ranging from 10 to 363 m asl. Additional photographs of bat acoustic recording sites showing equipment and surrounding habitat are presented in Appendix I.

Each site consisted of an SM2BAT+ detector equipped with an SMX-US microphone that records ultrasound between 10 and 100 kHz (Wildlife Acoustics Inc., Concord, MA), and powered by a 6V external battery connected to a 6W solar panel. Between October 13 and October 15 2016, the SMX-US microphones were replaced with upgraded model SMX-U1 microphones. A 6-week session of acoustic recording to compare microphone model performance was conducted at two sites following the replacement, and the results of microphone recording differences are presented in Appendix II. Each detector had the microphone affixed to the top of metal conduit 2 to 3 m above the ground and connected by cable to the microphone port. Both the SMX-US and the SMX-U1 are omnidirectional and capable of detecting bat calls at distances up to 30 m (Adams *et al.* 2012) under ideal conditions (i.e. no wind or rain, low humidity). To ensure quality recordings, detectors were equipped with new microphones every three to four months.

The ultrasonic, full spectrum detectors were triggered by acoustic signals and operated every night for up to three months, from one hour prior to sunset until one hour after the following sunrise. Acoustic events were recorded without digital compression as full-spectrum Waveform Audio File format (.wav) sound files onto Secure Digital (SD) cards with a sampling rate of 192 kHz; analog high pass filter at 1 kHz and 36 decibel gain (SMX-US) or 12 decibel gain (SMX-U1); microphone bias off; digital high pass filter at fs/24; digital low pass filter off; trigger level 18 SNR signal-noise ratio; trigger window 2.0 sec; trigger max length 8 sec; frequency division ratio 16. Detectors were checked at 2 to 3-month intervals to exchange SD cards and to test battery levels and microphone function.

Kaleidoscope Pro (version 4.1.0a; Wildlife Acoustics, Inc.) software was used to filter acoustic background noise with the following settings: 10–70 kHz, 1–7 ms pulse duration, 250 ms maximum inter-syllable gap, and a minimum of 2 pulses per event. Subsequently, all files containing bat echolocation pulses were visually and aurally inspected as sonograms with Kaleidoscope Pro to ensure that there were no false positives. Ultrasonic vocalizations by Hawaiian hoary bats were categorized by type, and terminal-phase calls ("feeding buzzes" emitted just prior to an attempted insect catch; Griffin *et al.* 1960) were qualitatively distinguished from search and approach-phase calls by a rapid increase in the call rate (Figure 6). Call files were visually assessed for evidence that there were two or more bats concurrently vocalizing at a site.

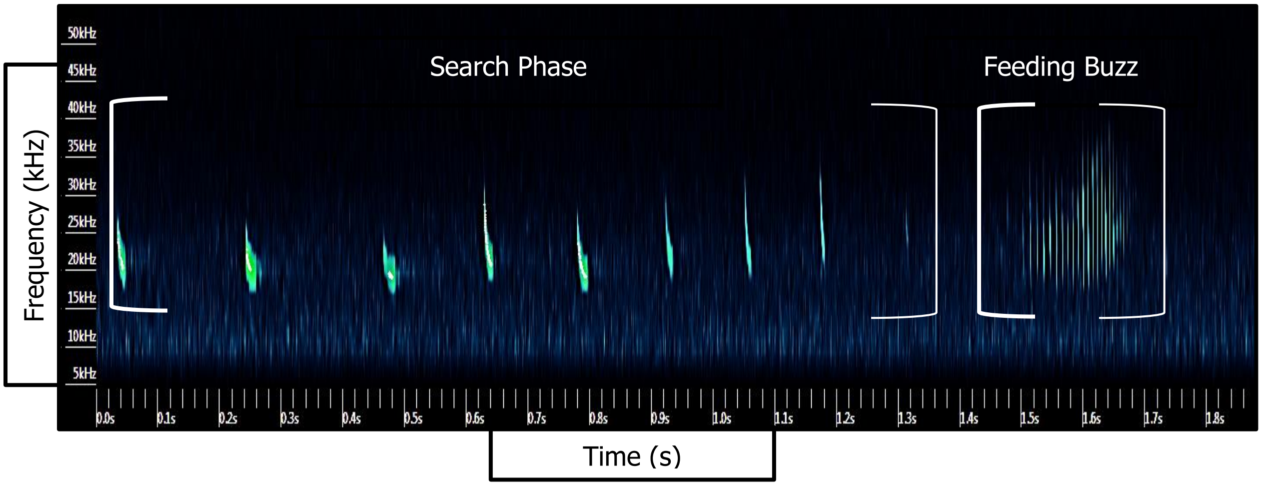

Figure 6. Spectrogram of a Hawaiian hoary bat echolocation call-event with search-phase pulses (left hand bracket set) followed by a terminal-phase or feeding buzz call (right hand bracket set).

The frequency of echolocation as determined by the number of bat acoustic files and the incidence of feeding buzzes were each summed by recording site and night. Acoustic data are available at https://doi.org/10.5066/P9U0KRMY (Pinzari *et al.* 2019). The resulting detection history was used to calculate the proportion of total nights with observed bat activity throughout the year. For the subset of sites with at least one detection, the frequency of detection per month was calculated for each survey location as the total number of nights with detections divided by the total number of nights sampled (effectively weighting the values by sampling effort).

Hawaiian hoary bat reproductive or "breeding" season (as adapted from Menard 2001) includes periods of pregnancy (May to June) and lactation (late June to August). The remainder of the year includes a fledging/post-lactation period (September to October) and a pre-pregnancy period or "post-partum" (November to April), during which there is no reproductive or parental care shown by adult females.

Because the change of microphone model in October 2016 resulted in a noticeably higher rate of calls, comparisons of bat occurrence and activity were necessarily limited to the late autumn and winter periods of 2016 and 2017, corresponding to the end of the fledging/post-lactation and pre-pregnancy periods. For the high elevation sites (AUW1–AUW6) we used comparable monthly data collected after the improved microphones were added in October 2016. This resulted in two six-month periods with which to compare bat occurrence and activity over two years: winter 2016 (October 2016 to March 2017) and winter 2017 (October 2017 to March 2018).

To assess how the frequency of acoustic detections changed between winter periods we used log-linear regression to model the number of call files as a function of year, month, and the interaction of year and month. To account for zero values, 0.5 was added to all nightly tallies of detections. Prevalence of bat occurrence as determined by acoustic detections, and more specifically, feeding activity as indicated recordings of feeding buzzes was compared for the two winter periods with repeated measures logistic regression. The effect of year (as a fixed effect coded by the year in which the six-month span began), month (as a random effect), and year + month as an interactive variable were modeled and compared to a null model of random variation among sites. We used the Akaike Information Criterion corrected for small sample size (AICc) to compare models. Prevalence of bat occurrence per month or site is presented herein as percentages and calculated as monthly means weighted by the number of sample nights in each month.

Bat Capture

Mist-netting to capture bats was conducted between October 14 and December 7, 2016 (13 nights), and again between June 8 and July 5, 2017 (20 nights). Netting locations included a clearing around site AUW6 (CABIN site) and over water at the POND1 and POND2 sites (Figure 7). A combination of single high and triple high nets of various lengths (6-, 9-, 12-, and 18-m) were used within the first five hours after sunset. A UltraSoundGate Player BL Light acoustic lure (Avisoft Bioacoustics, Glienicke, DE) broadcasting locally recorded hoary bat social calls was deployed for 2 nights in 2016 and 12 nights in 2017. Capture rates for each of the two netting periods were calculated as the total net-hours (length of mist nets times hours deployed each night) divided by number of bats captured.

We recorded age class, sex, reproductive condition, weight, forearm length, and noted the collection of wing tissue biopsies, guano samples, and hair clippings. Each captured bat received uniquely colored plastic bands on the right forearm. The protocol for handling bats was approved by the Institutional Animal Care and Use Committee (IACUC #04-039-12) of the University of Hawaiʽi at Hilo and followed guidelines of the American Society of Mammologists. Biological samples were collected under permits USFWS TE003483-31 and Hawaiʽi DLNR-DOFAW WL16-04.

Insect Sampling

Insect sampling focused on Lepidoptera (moths) and Coleoptera (beetles), the primary prey of Hawaiian hoary bats (Whitaker and Tomich 1983, Jacobs 1999, Todd 2012). The insect prey base available to Hawaiian hoary bats in the Waihou Mitigation Area was examined over late autumn and early summer periods using malaise traps, ultraviolet (UV) light traps, and by shaking insects from vegetation using cloth beating sheets (Figure 8). Paired malaise and light traps were placed at eight sites, two of each which comprised paired samples for each of four sites: REST, PUU, MAM, PINE (Figure 2; Table 1). Malaise traps operated continuously from October 25 to December 7, 2016, and June 7 to July 3, 2017. Light traps were run for the first three hours of the night during October 26 to December 1, 2016, and June 20 to 22, 2017. An opportunistic site (AUW8) was established in proximity to the Auwahi Wind Energy facility.

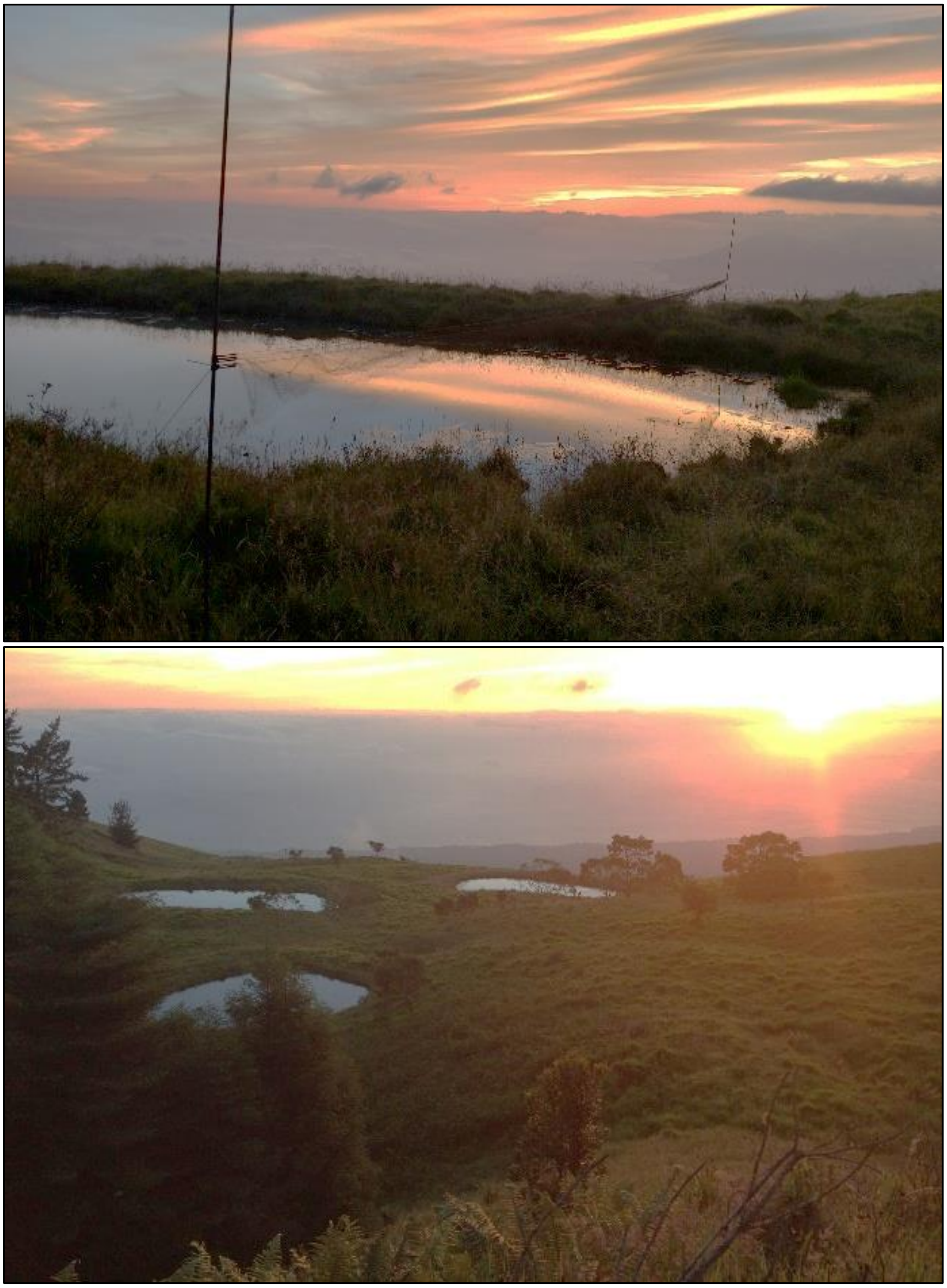

Figure 7. POND2 site (top) in the upper portion of the Waihou Mitigation Area (see Fig. 2). Bats were captured in mist nets at these artificial ponds constructed for wetland bird habitat (bottom).

Each light trap was set at ground level and positioned a minimum of 200 meters from acoustic detectors. Light traps consisted of a 22W UV light bulb situated above a funnel and bucket trap (Model #2851M; Bioquip Products Inc., Rancho Dominguez, CA). Light traps were powered by

12-V marine deep cycle batteries. A timer allowed the light to begin operating 30 min after sunset. Samples were collected the following morning. The malaise traps (Model 2875DG; Bioquip Products Inc., Rancho Dominguez, CA) were deployed slightly above ground level, and were emptied of contents at approximately weekly intervals. Trap samples were preserved by freezing for later sorting. During sorting, insects were identified to family level using keys from the Insects of Hawaii Series (Zimmerman 1958a, 1958b, 1978).

While malaise and light traps were aimed at sampling the general prey base at each site, sampling directly from vegetation was applied to identify larval Lepidoptera (caterpillars) and Coleoptera associated with particular plant species. Insects associated with restoration plantings and pasture grasses were sampled from the dominant plant species within each area by gently shaking foliage October 26–28 and November 28–30, 2016, and on June 20, 2017. The plant species searched include ʽaʽaliʽi (*Dodonaea viscosa*), an unidentified grass, koa (*Acacia koa*), māmaki (*Pipturus albidus*), māmane (*Sophora chrysophylla*), naio (*Myoporum sandwicense*), ʽōhiʽa (*Metrosideros polymorpha*), pūkiawe (*Leptecophylla tameiameiae*), black wattle (*Acacia mearnsii*), redwood (*Sequoia sempervirens*) and Monterey pine (*Pinus radiata*). Caterpillars collected on these plants were conveyed to the lab and reared to the adult stage to facilitate identification.

Insect counts at each site were adjusted by sampling effort to produce separate indices of capture rates (number per trap night) for malaise and light trap samples, and collections directly from vegetation (Appendix III). The capture rate indices for malaise and light trap samples were subsequently combined to provide a measure of overall abundance for each site. The body lengths of all moths were measured and samples were assigned to size classes: small (<10 mm), medium (10–15 mm) and large (>15 mm). Representative insect samples are held as a voucher collection at Kīlauea Field Station. Insect count data are available at https://doi.org/10.5066/P9U0KRMY (Pinzari *et al.* 2019).

Bat Diet Sampling and Genetic Analyses

Insect reference library

Genomic sequence data on public databases are not well represented for Hawaiian arthropods (i.e., records with accurate species identifications do not exist). Therefore, a reference library of potential bat prey items collected in the vicinity of the Waihou Mitigation Area was prepared for comparison to items in the bat diet subsequently identified by genomic analysis. Seventy insects collected using the three trapping techniques (light, malaise, vegetation beating) were preserved for barcoding to create the reference library. Insects represented taxa from four orders and included 62 Lepidoptera (10 families), five Coleoptera (three families), one Diptera, and two Hemiptera. The Diptera and Coleoptera families were collected from cow dung in the pasture below the Waihou Mitigation Area. The insects selected for barcoding, while a subset of the entire dataset, included many of the most common species available as potential bat prey. One to three legs were removed from moths, while for some smaller specimens, such as small moths, flies and beetles, the whole body was used for DNA extraction. Insect DNA was extracted using a DNAeasy Blood and Tissue Kit (Qiagen, USA) A mortar and pestle were used to grind insects following modifications in the Qiagen Supplementary Protocol for Purification of Total DNA from Insects.

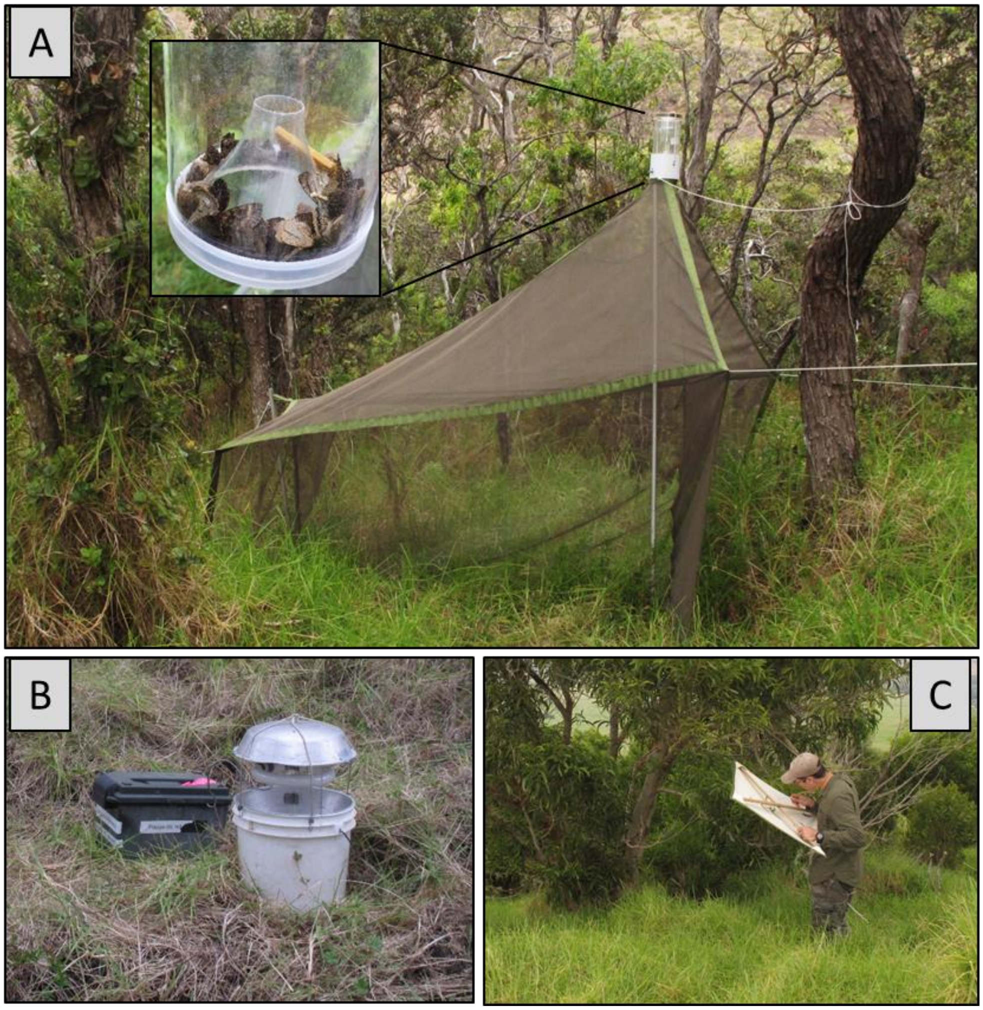

Figure 8. Methods used to collect Lepidoptera and Coleoptera across the study area include malaise traps ((A); inset shows numerous geometrid moths within the collection chamber), battery operated light traps (B), and shaking vegetation to dislodge insects (C).

Polymerase chain reaction (PCR) sequencing of mitochondrial DNA was used to develop the insect reference library and identify arthropod species in bat guano samples. Barcoding of the reference library samples was conducted as follows: Folmer primers (Folmer *et al.* 1994) were used to amplify an approximately 657 base pair [bp] region of the COI gene sequence for reference library specimens (Table 2). Extracted DNA was amplified via PCR using Illustra Hot Start mix PCR beads (GE Healthcare, USA) in 25 µL reaction volumes, each containing 20.5 µL sterile water, 0.5 µL of each primer (10 µM concentration), and 2.5 µL of genomic DNA template. PCR cycling conditions consisted of 1 cycle at 94 °C for 1 minute; 5 cycles of 1 minute at 94 °C, 1 minute 30 seconds at 45 °C, 1 minute 30 seconds at 72 °C; 35 cycles of 1 minute at 94 °C, 1 minute 30 seconds at 50 °C, 1 minute at 72 °C, and a final extension period of 5 minutes at 72 °C (Folmer *et al.* 1994) and was carried out on an Eppendorf Pro S Thermal Cycler (Eppendorf, USA). PCR products were checked for desired fragment size using 1.5% gel electrophoresis and a 100-base pair (bp) ladder. PCR products were cleaned of excess nucleotides and primers using Exo-Sap (Affymetrix, Thermo Fischer, USA) according to manufacturer's protocol and quality checked using UV spectrometry. Sanger sequencing of both the forward and reverse primer PCR products was performed on an ABI Prism 3500 Genetic Analyzer (Applied Biosystems, USA) at the University of Hawai'i at Hilo Core Genomics Facility. Sequence chromatograms were manually trimmed, edited, and consensus DNA sequences were formed using Sequencher v5.2.4 (Gene Codes 2014).

Resulting sequences were compared to publicly available COI sequence data using the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool Nucleotide "BLASTn" (https://blast.ncbi.nlm.nih.gov/Blast.cgi, accessed February 2019) as well as using the Identification Engine on Barcode of Life Data System "BOLD" (Bold Systems v3) (http://www.boldsystems.org/index.php/IDS_OpenIdEngine, accessed February 2019). Order and family matches to arthropod sequences were considered informative for matches ≥87%, and followed in agreement with visual identifications. Genus and species level matches were considered for matches ≥93%, and which also agreed with visual identification given to insect before DNA extraction. The geographic validity of arthropod taxon matches and native/non-native status were confirmed by referencing the Hawaiian Terrestrial Arthropod Checklist, Fourth Edition (Nishida 2002), the online database at the Insect Museum at the University of Hawai'i (https://www.ctahr.hawaii.edu/insectmuseum/insectholdings.htm, accessed February 2019), consulting local state and university entomologists, and literature searches. Reference library insect barcode data are available at https://doi.org/10.5066/P9U0KRMY (Pinzari *et al.* 2019).

Guano collection and DNA extraction

Guano was collected from nine adult bats (3 females, 6 males) (Table 3). Eight live captures in the Waihou Mitigation Area vicinity during November 2016 and June/July 2017 provided guano. One guano pellet was obtained from a fresh female bat carcass collected at Auwahi Wind Energy Facility on August 15, 2016. One to four guano pellets were used for DNA extraction per individual (average 2.2 pellets per individual), and no more than 20 micrograms of guano were used per extraction. Pellets were combined and homogenized during DNA extraction. DNA was extracted using a Qiagen DNA PowerSoil Kit (Qiagen, USA) following the manufacturer's protocol (2018 version), with modifications as described in Alberdi *et al.* 2018. We included one negative extraction control, and extractions were performed in a dedicated pre-PCR laboratory space.

Table 2. Details of the two primer sets used to explore diet of the Hawaiian hoary bat on Maui, and the primer set used to create barcodes for the insect reference library. Length refers to amplicon size excluding primers. Adapted from Alberdi *et al.* 2018.

General name	Region	Primer names	Forward primer 5′-3′	Reverse primer 5′-3′	Length (bp)	Target Taxa	Reference
Epp	16s	F: Coleop_16sc R:Coleop_16Sd	TGCAAAGGTAGCATAAT MATTAG	TCCATAGGGTCTTCTCG TC	106 [102–107]	coleoptera	Epp *et al.* (2012)
Zeale	COI	F: ZBJ-ArtF1c R: ZBJ-ArtR2c	AGATATTGGAACWTTA TATTTTATTTTTGG	WACTAATCAATTWCCA AATCCTCC	157 [157–159]	arthropoda	Zeale *et al.* (2011)
Folmer	COI	F: HCO2198 R: LCOI490	TAAACTTCAGGGTGACC AAAAAATCA	GGTCAACAAATCATAAA GATATTG	657	arthropoda	Folmer *et al.* (1994)

Table 3. Bats contributing guano samples for diet analysis. See Table 1 for details on sample locations.

Bat ID	Sex	Date	Time	Location	Number of pellets	Primers
M41	female	8/15/2016	unknown	Turbine 2	1	Epp, Zeale
M47	male	11/3/2016	18:50	POND1	4	Epp, Zeale
M48	male	11/15/2016	19:36	POND1	2	Epp, Zeale
M49	male	11/28/2016	21:00	POND1	2	Epp, Zeale
M50	male	6/20/2017	21:00	CABIN	4	Epp, Zeale
M51	male	6/20/2017	21:05	POND1	4	Epp, Zeale
M54	female	6/26/2017	22:05	POND1	2	Epp, Zeale
M55	male	6/28/2017	22:08	POND2	1	Epp only
M57	female	7/4/2017	22:13	POND2	1	failed

Metabarcode sequencing of bat guano

Bat guano samples are generally comprised of degraded and fragmented DNA, as such, sequencing required a "mini-barcode" approach (Alberdi et al 2012). For diet analyses, we used Zeale and Epp primers to target short COI gene sequences (Table 2). We used Zeale and Epp primers jointly to characterize taxonomic diversity because they cover different regions of the mitochondrial gene and Epp primers specifically target Coleoptera (Alberdi *et al.* 2018).

The following metabarcode library preparation and sequencing was performed at the Genomics Core Facility of the University of Tennessee. Each sample of amplified arthropod DNA obtained from bat guano was duplicated for each of the Zeale and Epp primer sets and included one reaction blank per primer set. Target gene sequences were amplified for each primer set by modifying the primers with adapters on the 5′ and 3′ end for the Illumnia MiSeq platform (Illumnia, USA). PCR was used for each primer-adapter set to amplify prey DNA in guano samples plus replicates, as well as two reaction blanks of water which were carried through the entire sequencing process. Amplification success was confirmed with gel electrophoresis. Initial PCR products with adapters were cleaned with Agencourt AMPure XP beads (Beckman Coulter, USA), and a second round of PCR and a Nextera XT library kit (Illumnia, USA) was used to attach unique combinations of MID tags (Illumnia, USA), allowing us to reference prey sequences to individual bats. Indexed PCR products received another round of purification with Agencourt AMPure XP beads, then were quantified using a fluorometer, combined into approximately equimolar pools and quantified on a Bioanalyzer (Agilent Technologies, USA) to verify MID tag additions and calculate final loading concentrations for sequencing. Samples and blanks were duplicated, diluted to 4 pM, combined with PhiX control DNA at a ratio of 10 % PhiX, then loaded onto a MiSeq Reagent Kit v2 250-cycle flow cell set for a paired-end read of 175 bases each (2 X 175). After sequencing, Illumina reads were automatically demultiplexed and MID tags and adapters were removed.

Bioinformatic analyses

The data analysis pipeline and taxonomic assignment methodology follow the procedure described in the R Notebook tutorial (Divoll *et al.* 2018; http://github.com/tdivoll/Bat-Diet-Metabarcoding/ accessed February 2019). Several tools were used to take raw sequence reads produced in the above section and create a table of filtered prey taxa for each individual bat. FastQC (Andrews 2010) was used to assess Illumina sequencing performance and determine quality-filtering thresholds. Analyses were performed using the Quantitative Insights Into Microbial Ecology software (QIIME version 1.9.1; Caporaso *et al.* 2010) run inside a Linux virtual machine (Oracle Virtual Box version 5.0.8 r103449).

Tools within QIIME and FASTX Toolkit 0.0.12 (Gordon and Hannon 2010) were used to join the forward and reverse paired end Illumina reads and determine average quality at expected read length (211 bp for Zeale, and 148 bp for Epp), then filter out base calls under Q25 Phred quality score and remove sequences less than 200 bp for Zeale and 137 bp for Epp. Sequences were clustered into operational taxonomic units (OTUs) with the SWARM method (Mahe *et al.* 2014), allowing for a 2 bp difference (98.5%; Hope *et al.* 2014). A high threshold allowed for greater representation of rare OTUs. Potential over inflation of OTUs and removal of chimeric sequences was accounted for by filtering to remove OTUs that did not occur ≥10 times in a sample. We used the custom Python script (provided in the tutorial) and employed the 'pandas' package (McKinney 2010) to filter by the threshold and extract the most abundant sequences for each OTU. After OTUs were generated from QIIME, taxonomic assignment and further filtering were done using R (version 3.5.2, R Core Team 2018).

Taxonomic matches were retrieved from the Barcode of Life Database (BOLD v4, February 2019; Ratnasingham and Hebert 2007) with the 'bold' package (Chamberlin 2017), using the 'dyplr' package (Wickham and Francois 2016) to filter out matches with <95% similarity. For each OTU, only the top 40 specimen matches were kept, then manually assigned to a taxon at ≥98.5% similarity from output tables (see *Manual Vetting of Results* section in the R Notebook tutorial from Divoll *et al.* 2018). OTUs assigned to the same taxonomy were collapsed into one OTU-based prey taxon. This approach assumes that potential chimeric sequences do not match any specimens in the BOLD reference database; however, substitution errors or single nucleotide polymorphisms may still persist, even when a match is ≥98.5%. False negatives may be increased by discarding prey that do not have records in BOLD and by collapsing higher taxonomic assignments into single prey taxa (e.g., two OTUs of different species in the same genus and the same percent similarity collapsed into one genus-based prey taxa). Taxonomy was mostly assigned using the final filtered dataset (consensus among top 40 matches), but representative OTU sequences were also manually input into BOLD to resolve discrepancies and in many cases, we left assignments at order or family if not resolved at the genus level. Species level assignments were rare, and all genus- and species-level matches were manually checked, with assignment restricted to those with known occurrence in Hawai'i. If multiple assignments shared the highest matching scores, taxonomy was assigned to Hawaii-present species or downgraded to the highest taxonomic level (usually family). Ultimately, ordinal-level taxonomy was assigned at >95% similarity, familiar-level taxonomy at >96.5%, and species-level ≥ 98% following Alberdi *et al.* 2018. This data analysis pipeline is appropriate for comparisons of identified prey (OTUs with assigned taxonomy). We used this pipeline to produce a set of OTUs for each desired gene, COI and 16s, and recorded which OTUs and taxonomic assignments appeared within one or both members of a duplicated guano sample. We also noted those that were unique to Zeale or Epp primer sets.

The dietary composition identified for individual bats and taxa identified to genus and species level are presented using only Zeale primer results. The Zeale primer produced a more robust dataset than the Epp primer, which previous bat diet studies have shown to be unreliable for species identifications (Alberdi *et al.* 2018, Kaunisto *et al.* 2017). Moreover, for maximum confidence, we report the order and family of prey items consumed by individual bats if OTUs were recovered from both members of a duplicated sample sequenced with Zeale primers. Current review of genetic dietary analysis recommends sequencing bat guano samples in duplicate or triplicate fashion (referred to as technical replication) and reporting prey items that are recovered from multiple samples of a set to counter stochasticity arising from DNA sequencing (Alberdi *et al.* 2018, Mata *et al.* 2019). However, to allow for a more inclusive assessment of dietary diversity (but with a concomitant decrease in the confidence of taxa identifications), we also report results for Epp primers. Given a low rate of OTU recovery for sequences obtained with Epp primers, we include taxa that were identified even when derived from only a single member of a duplicated sample. Relative representation of order and lepidopteran families were graphed as the prevalence among individual bats (i.e., proportion of bats in which the taxon was detected) and sequences recovered (i.e., proportion of sequences within an assigned taxon). The number of OTUs (i.e., read counts) is interpreted as an approximation of the relative abundance or biomass of insect taxa consumed by bats (Deagle *et al.* 2019). Insect OTU data used in analyses are available at https://doi.org/10.5066/P9U0KRMY (Pinzari et al. 2019).

RESULTS

Acoustic Monitoring

Bat occurrence and activity was observed at all ten sites from the onset of acoustic sampling on March 17, 2015, through March 21, 2018 (Appendix IV). Activity as indicated by the number of acoustic files per night demonstrated higher mean bat encounter rates during May to October when females are pregnant and lactating, and during the fledging/post-lactation period relative to the months when bats are reproductively quiescent from November to April (Figure 9). This seasonal pattern of higher encounter rates was observed at the higher elevation Waihou sites (AUW1–AUW6) in 2015 and 2016. Although bat activity was much lower at the Auwahi Wind Energy stations (AUW8–AUW10), a seasonal pattern of higher encounter rates persisted from July through October. However, the three-year time series collected in Waihou also demonstrated a marked difference in encounter rates at the resulting from the change in detector microphones in October 2016. Consequently, year-to-year comparisons are limited to periods with the same microphone type (i.e., "winter" periods spanning the months of October to March in both 2016 and 2017).

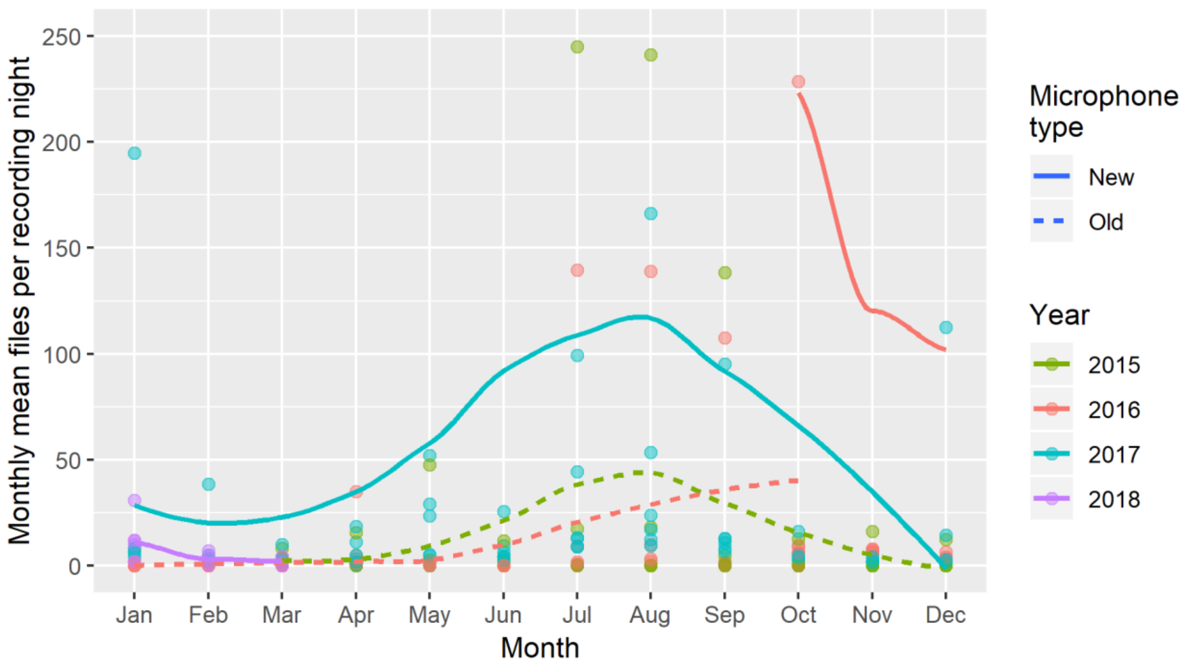

Figure 9. Frequency of bat detection by month from March 2015 to March 2018 in the Waihou Mitigation Area. Frequency is derived from the monthly mean number of nightly acoustic files with bat detections recorded at sites AUW1–AUW7 (points). Overall trend is shown with a LOESS smooth curve weighted by number of sample nights in a month. The change of detector microphones in October 2016 is distinguished by the dashed and solid lines. Periods were determined as the span of months for which detectors were both equipped with new microphones. See Appendix IV for acoustic detection details.

The frequency of bat detections, as measured by the monthly mean number of files per recording night, demonstrated lower within-night rates during winter 2017 compared to winter 2016 in both the monthly and site assessments (Figures 10 and 11; Tables 4 and 5). Log-linear regression (log of monthly mean files per night + 0.5) identified "month + year" as the top model, with 96% of the relative weight assigned by AICc (Table 6). The overall mean number of files were 9.0 per night in winter 2016 and 4.7 per night in winter 2017.

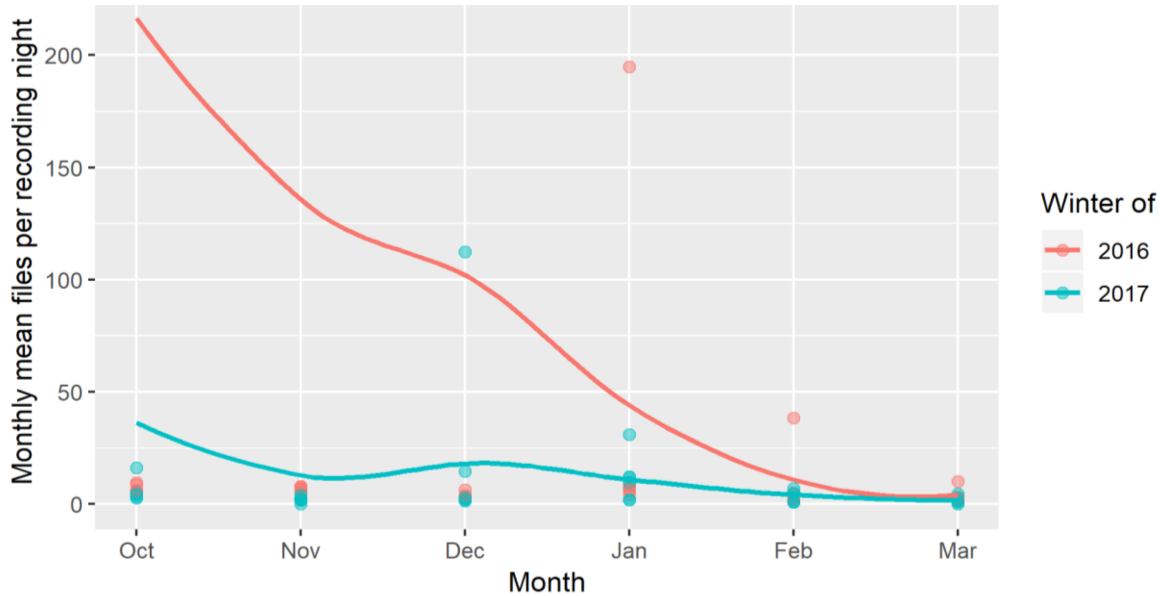

Figure 10. Mean number of nightly bat detections by month for the winters of 2016 and 2017 at sites AUW1–AUW7. Overall trend is shown with a loess smooth curve weighted by number of sample nights/month.

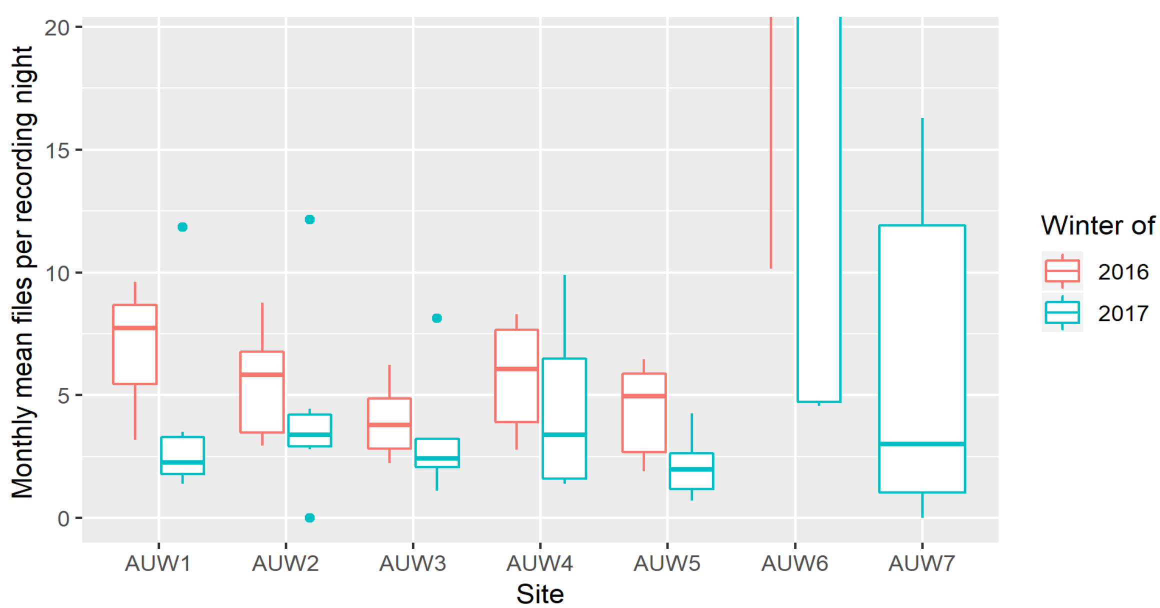

Figure 11. Mean number of nightly bat detections by site for the winters of 2016 and 2017. Boxplot whiskers denote values within 1.5 times the interquartile range above the 75th percentile and below the 25th percentile. To enhance the difference in monthly frequencies the y-axis is truncated at a maximum value of 20 (see Table 5 for mean values).

Table 4. Frequency of nightly bat detections by month for winter 2016 (AUW1–AUW6) and 2017 (AUW1–AUW7) monitoring periods, as measured by the mean number of detections weighted by number of sample nights in a month.

Winter	Oct	Nov	Dec	Jan	Feb	Mar
2016	223.1	120.3	101.9	44.0	10.4	4.1
2017	39.1	2.0	18.0	11.0	3.1	1.9

Table 5. Frequency of nightly bat detection by site for winter 2016 (AUW1–-AUW6) and 2017 (AUW1–AUW7) monitoring periods, as measured by the mean number of files weighted by number of sample nights in a month.

Winter	AUW1	AUW2	AUW3	AUW4	AUW5	AUW6	AUW7
2016	6.8	5.3	3.8	5.8	4.3	421.8	NA
2017	4.0	4.5	3.6	4.6	2.2	95.7	6.8

Table 6. Results of log-linear regression models of monthly mean number of files per recording night (AUW1–AUW6) for winter 2016 and 2017 monitoring periods. The model "month + year" tests for a year effect while controlling for month and site.

Model	Df	AICc	Δ AICc	AICcWt
month + year	5	217.3	0	98%
year	4	226.0	8.7	1%
month	4	227.1	9.8	1%
null	3	231.6	14.3	0%

Bat occurrence, as measured by the percent of nights within a month with at least one bat detection, demonstrated lower nightly prevalence of bats in winter 2017 compared to winter 2016 in both monthly and site assessments (Figures 12 and 13; Tables 7 and 8). Regression analysis identified the model "month + year" as having the best fit, with 100% of the relative model weight assigned to it by AICc (Table 9). The model estimated a significant declining effect for year from 2016 to 2017, such that the chance of detecting bats was 43% for a given night in 2017 relative to 2016.

Foraging activity, as measured by the percent of nights with at least one feeding buzz detection, demonstrated lower nightly foraging activity of bats in winter 2017 compared to winter 2016 in both monthly and site assessments (Figures 14 and 15; Tables 10 and 11). Regression analysis of the frequency of feeding buzz detections during the winters of 2016 and 2017 identified the model "month + year" as having the best fit, with 100% of the relative model weight assigned to it by AICc (Table 12). The model estimated a significant declining detection effect from 2016 to 2017, such that on average the chance of detecting a feeding buzz in 2017 was less than 10% that for a given night in 2016.

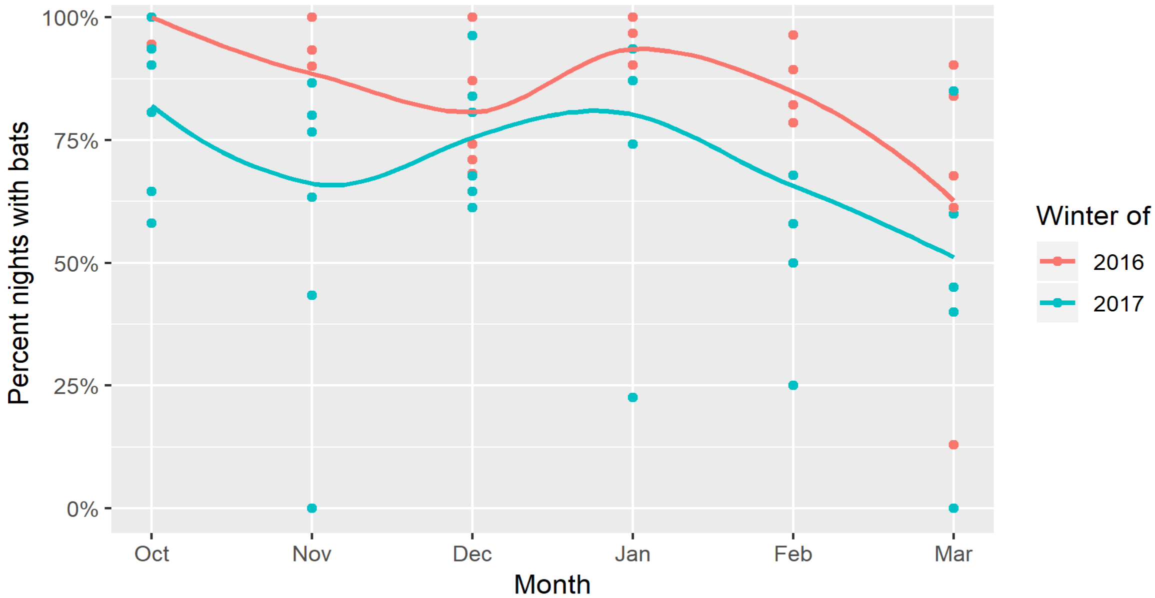

Figure 12. Percent of nights with bat occurrence by month for the winters of 2016 and 2017 at sites AUW1–AUW6. Overall trend is shown with a loess smooth curve weighted by number of sample nights/month.

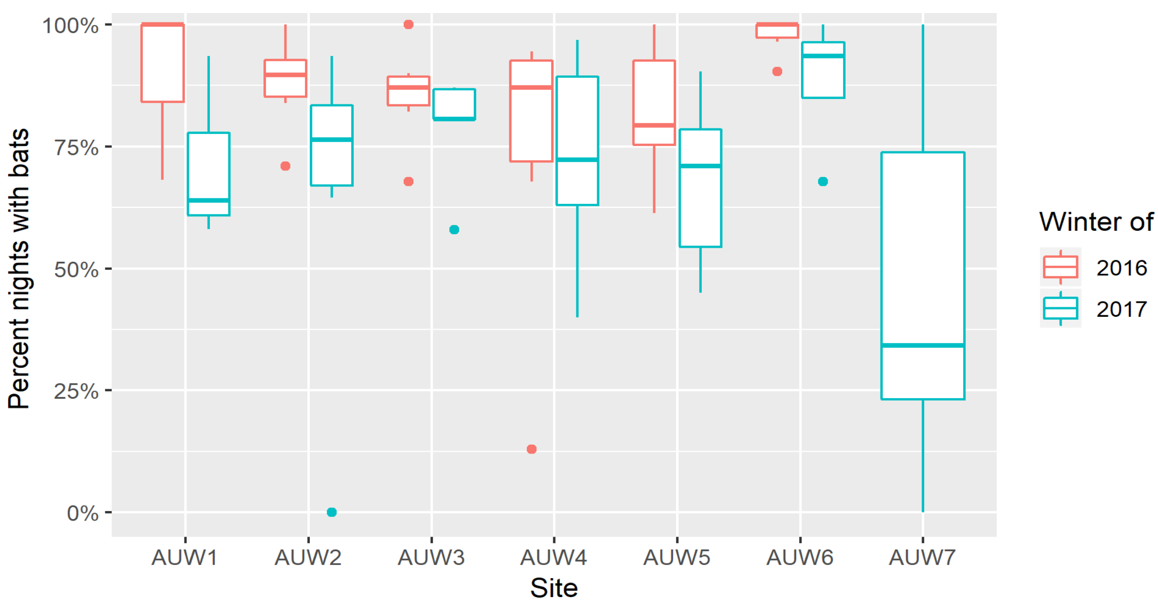

Figure 13. Percent of nights with bat occurrence by site for the winters of 2016 and winter 2017. Boxplot whiskers denote values within 1.5 times the interquartile range above the 75th percentile and below the 25th percentile.

Table 7. Mean percent of nights with bat detections by month for the winter monitoring of 2016 (AUW1–-AUW6) and 2017 (AUW1–AUW7).

Winter	Oct	Nov	Dec	Jan	Feb	Mar
2016	99%	92%	81%	94%	83%	63%
2017	82%	58%	75%	80%	61%	53%

Table 8. Mean percent of nights with bat detections by site for the winter monitoring of 2016 and 2017.

Winter	AUW1	AUW2	AUW3	AUW4	AUW5	AUW6	AUW7
2016	90%	87%	85%	72%	80%	98%	NA
2017	71%	65%	80%	75%	70%	86%	49%

Table 9. Logistic regression models of bat occurrence (determined by one or more acoustic detections) per night and by site for AUW1–AUW6 during the winter monitoring periods of 2016 and 2017. The model "month + year" tests for a year effect while controlling for month and site.

Model	Df	AICc	Δ AICc	AICc Wt
month + year	4	571.5	0	100%
year	3	615.5	44	0%
month	3	673.6	102.1	0%
null	2	702.8	131.3	0%

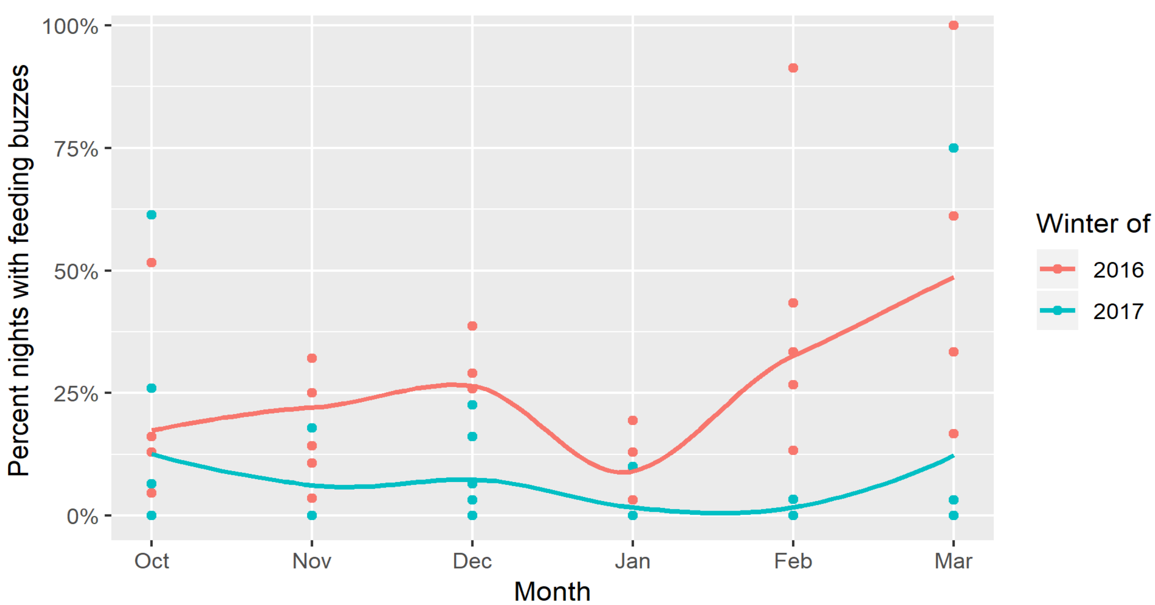

Figure 14. Percent of nights with feeding buzz detections by month for the winters of 2016 and 2017 at sites AUW1–AUW6. Overall trend is shown with a loess smooth curve weighted by number of sample nights/month.

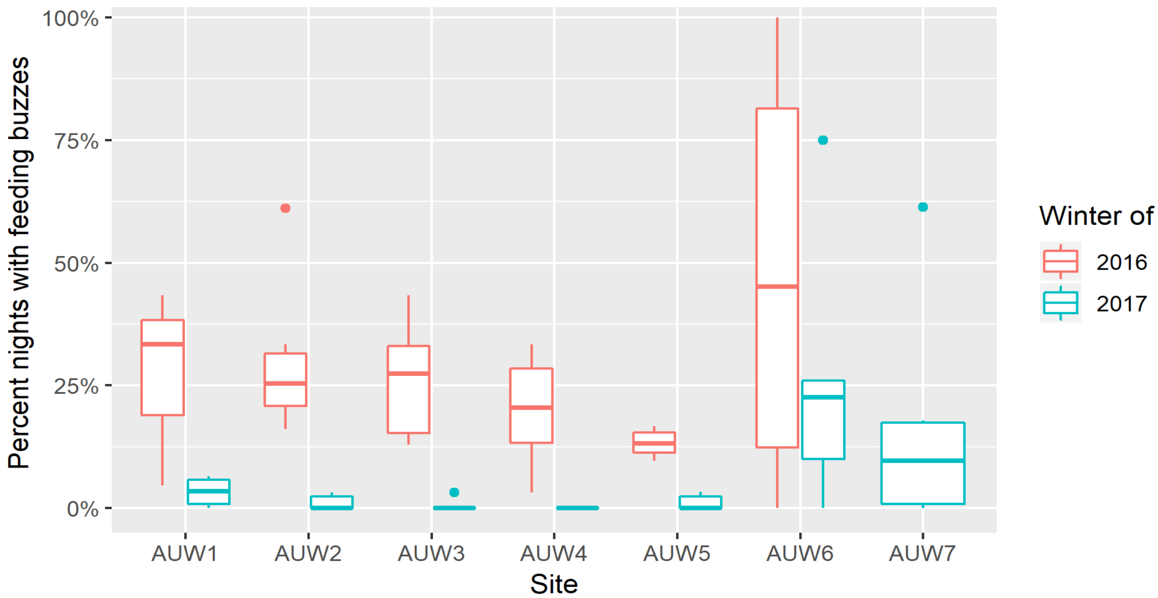

Figure 15. Percent of nights with feeding buzz detections by site for the winters of 2016 and 2017. Boxplot whiskers denote values within 1.5 times the interquartile range above the 75th percentile and below the 25th percentile.

Table 10. Mean percent of nights with feeding buzzes detected by month comparing the winter monitoring periods of 2016 (AUW1–AUW6) and 2017 (AUW1–AUW7).

Winter	Oct	Nov	Dec	Jan	Feb	Mar
2016	46%	40%	19%	26%	17%	9%
2017	4%	1%	13%	7%	3%	2%

Table 11. Mean percent of nights with feeding buzzes detected by site comparing the winter monitoring periods of 2016 and 2017.

Winter	AUW1	AUW2	AUW3	AUW4	AUW5	AUW6	AUW7
2016	29%	28%	25%	19%	13%	42%	NA
2017	4%	1%	1%	0%	1%	17%	18%

Table 12. Logistic regression models comparing bat feeding activity (determined by one or more detections of feeding buzz calls) per night and site at AUW1–AUW6 during the winters of 2016 and 2017. The model "month + year" tests for a year effect while controlling for month and site.

Model	Df	AICc	Δ AICc	AICcWt
month + year	4	412.3	0	100%
year	3	457	44.7	0%
month	3	611.7	199.5	0%
null	2	648.7	236.4	0%

The occurrence of multiple bat detections, as measured by the percent of nights within a month with at least one such event, demonstrated low occurrence that averaged 10% for both the winters of 2016 and 2017 (Figures 16 and 17; Tables 13 and 14). Note, however, that percent values of multiple bat detections for some months were occasionally large; these indicate months for which relatively few nights of sampling were available. Regression estimated a modest but not significant declining effect from 2016 to 2017 such that on average the chance of detecting multiple bats in 2017 was about 80% of that for a given night in 2016 (Table 15).

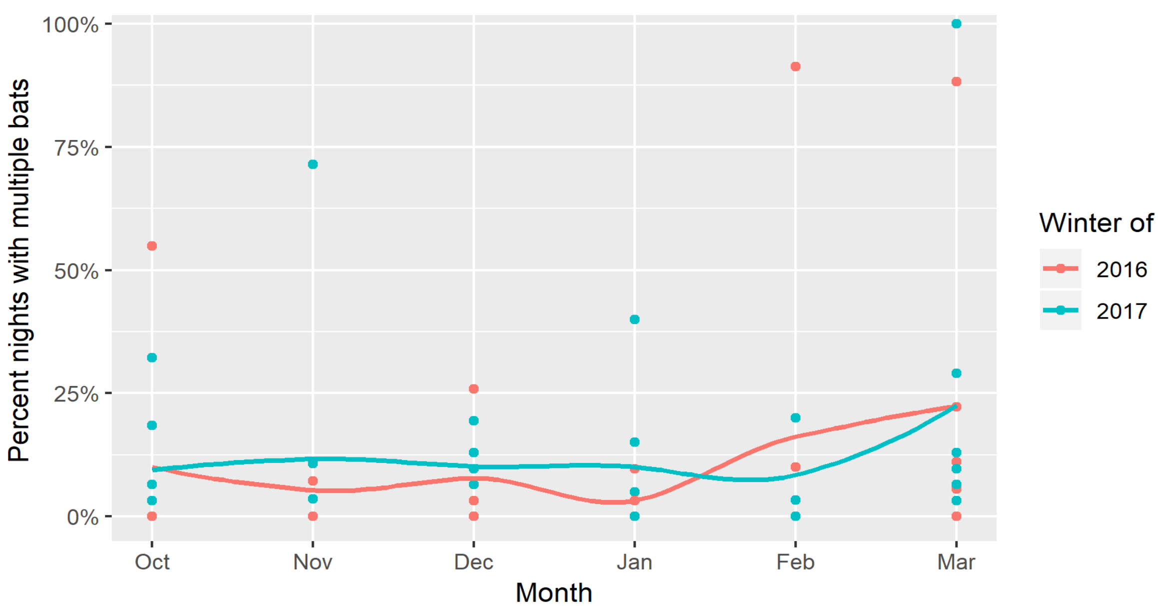

Figure 16. Percent of winter nights with multiple bats detections for the winters of 2016 and 2017 at sites AUW1–AUW6. Monthly trends are shown with LOESS smooth curves weighted by number of sample nights/month. Large values generally indicate months for which relatively few nights of sampling were available.

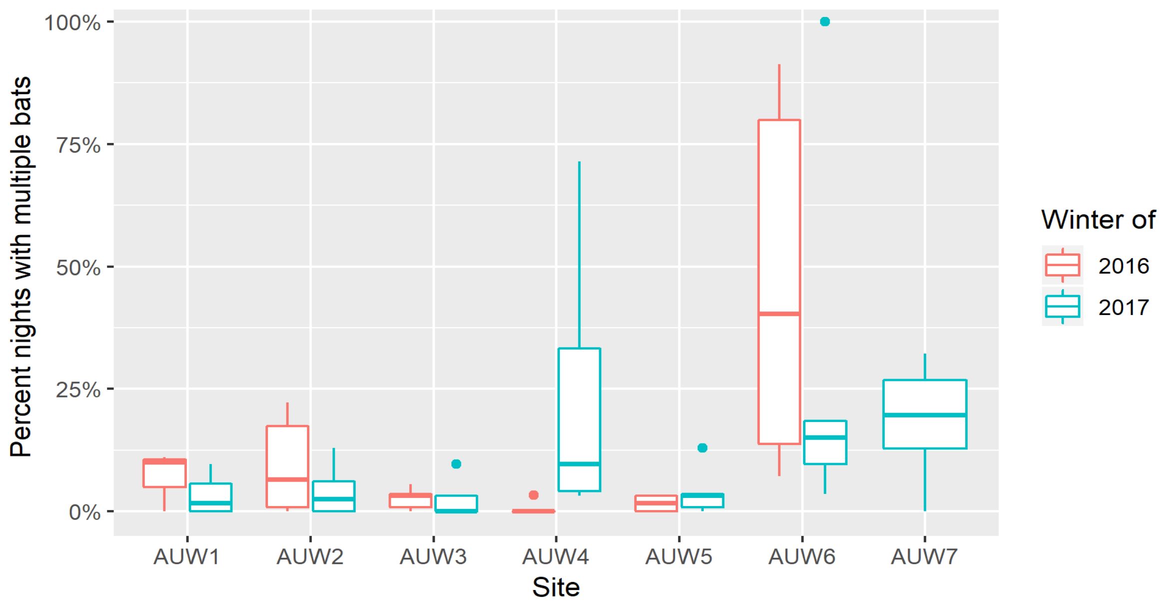

Figure 17. Percent of winter nights with multiple bats detections by site for the winters of 2016 and 2017. Boxplot whiskers denote values within 1.5 times the interquartile range above the 75th percentile and below the 25th percentile.

Table 13. Mean percent of winter nights from 2016 (AUW1-AUW6) and 2017 (AUW1-AUW7) with multiple bats detected by month.

Winter	Oct	Nov	Dec	Jan	Feb	Mar
2016	11%	2%	8%	3%	18%	21%
2017	9%	13%	10%	10%	4%	13%

Table 14. Mean percent of winter nights from 2016 and 2017 with multiple bats detected by site.

Winter	AUW1	AUW2	AUW3	AUW4	AUW5	AUW6	AUW7
2016	7%	8%	2%	1%	2%	41%	NA
2017	4%	4%	3%	21%	4%	15%	20%

Table 15. Logistic regression model results of winter nights from 2016 and 2017 with multiple bats detections per night and site for AUW1-AUW6. The model "month" controls for both a year and site effect, and "month + year" tests for a year effect while controlling for month and site.

Model	Df	AICc	Δ AICc	AICcWt
month	3	458.4	0.0	74%
month + year	4	460.5	2.1	26%
null	2	474.8	16.4	0%
year	3	476.8	18.4	0%

Bat Capture

Bats were captured by mist-net in the Waihou Mitigation Area during fall and summer months (Table 16). In 2016, nets were deployed for 13 nights for a total of 1,630 net-hours (averaging 125 net-hours and 30 meters of net/night) and produced a bat capture rate of 0.0025 bats/net-hour. Three adult male bats were captured adjacent to the pond at the net site CABIN (Figure 18). The male captured on November 3 was recaptured on November 15, over the pond where it was previously caught. None of the males exhibited externally visible signs of enlarged testes that is indicative of spermatogenesis. Fecal pellets were collected from two of these males for dietary analysis.

In 2017, nets were deployed for 20 nights for a total of 2,075 net-hours (averaging 104 net-hours and 24 meters of net/night) and resulted in a capture rate of 0.0039 bats/net-hour. Eight adult bats were captured in mist nets: five males and three females (Figure 19). There were no recaptures of marked bats during this effort. Two female bats were pregnant, confirming presence of reproductive females in the vicinity of the Waihou Mitigation Area. None of the males exhibited visible signs of enlarged testes. Fecal pellets were collected from five of these individuals (Table 16).

Insect Abundance

Insect captures at the Waihou Mitigation Area consisted almost entirely of Lepidoptera. The small number of Coleoptera collected included Coccinelidae (ladybugs), Curculionidae (weevils) and Elateridae (click beetles), and comprised <0.1% of the malaise and light trap samples in late autumn, with none collected in early summer by either method. In late autumn 3,697 and 709 individual lepidopterans were collected in the malaise and light traps, respectively (Appendix III). In early summer, malaise and light traps captured 1,356 and 687 Lepidoptera. Lepidoptera abundance and composition as measured by capture rates differed among the four sites and among seasons (Figure 20; Appendix III). Undetermined lepidopteran taxa (mostly <10 mm in body length) comprised the majority of the samples, ranging from 45% in early summer to 48% in late autumn at the PINE site. Samples identified to family or superfamily that made up >5% of overall samples included Crambidae, Erebidae, Gelechioidea, Geometridae, Noctuidae, Tineidae and Tortricidae. Noctuidae (owlet and miller moths) and Tortricidae (tortrix or leaf roller moths) together represented 40% of the late autumn captures and were most abundant at the REST site. In early summer the composition was dominated by Geometridae (geometer moths) and Noctuidae (52% of total). Gelechioidea were relatively abundant at all

Table 16. Bats captured in the Waihou Mitigation Area, November 2016 and June–July 2017.

Bat ID	Date	Time	Location	Sex	Weight (g)	Forearm (mm)	Band	Fecal	Reproductive condition
M47	11/3/2016	18:50	POND1	male	14.0	47.8	green/white	yes	testes not enlarged
M48	11/15/2016	19:36	POND1	male	16.5	49.0	orange	yes	testes not enlarged
M49	11/28/2016	21:00	POND1	male	15.8	48.5	blue	yes	testes not enlarged
M50	6/20/2017	21:00	CABIN	male	17.5	47.5	purple	yes	testes not enlarged
M51	6/20/2017	21:05	POND1	male	15.5	47.4	blue/red	yes	testes not enlarged
M52	6/22/2017	21:35	POND2	female	24.3	50.0	red/white	no	pregnant
M53	6/26/2017	20:05	POND1	male	19.3	49.0	yellow/orange	no	testes not enlarged
M54	6/26/2017	22:05	POND1	female	21.8	50.2	yellow/green	yes	lactating
M55	6/28/2017	22:08	POND2	male	18.0	46.5	white	yes	testes not enlarged
M56	7/3/2017	22:10	POND2	male	19.0	49.2	red/green	no	testes not enlarged
M57	7/4/2017	22:13	POND2	female	23.5	50.3	green	yes	pregnant

Figure 18. Adult Hawaiian hoary bats captured in 2016; male, bat M47 (top); male, bat M48 (bottom).

Figure 19. Adult Hawaiian hoary bats captured in 2017; male, bat M55 (top); female, bat M54, showing prominent nipples (bottom).

sites during this period, with Geometridae primarily caught at the PINE and PUU sites, and Noctuidae most numerous at the REST site. Although absent in the late autumn sample, large-bodied Erebidae were relatively abundant in early summer at the REST site (22% of the sample in this period).

During October and November 2016, and June 2017, 69 caterpillars were collected from seven host plants (ʻaʻaliʻi, koa, māmane, naio, redwood, black wattle and Monterey pine). Fifty-seven of these caterpillars emerged as adults or were identifiable to genus as caterpillars (Table 17). An unidentified species of the endemic *Scotorythra* genus (Geometridae) was the most common moth and occurred on the widest range of host plants sampled, including invasive black wattle, that is widespread in part of the study area. The non-native *Amorbia emigratella* (Tortricidae) was the second most common species and was reared from ʻaʻaliʻi, koa and redwood. The endemic butterfly *Udara blackburni* (Lycaenidae) and indigenous moth *Uresiphita polygonalis* (Crambidae) were collected from ʻaʻaliʻi, koa and black wattle.

Insect Reference Library
Of the initial 70 insect samples, 57 samples produced quality sequences for reference library inclusion (Table 18). Of these 57 samples, 49 were obtained from Lepidoptera, four from Coleoptera, one from Diptera, and two from Hemiptera.

Bat Diet Composition
Eight of the nine guano samples amplified successfully during PCR and were suitable for metabarcoding library preparation. One sample (pregnant female bat) failed to amplify PCR products and could not be sequenced possibly due to its small size (1 µg). We used two primer sets (Zeale, Epp) to evaluate diet composition, and each sample was successfully duplicated (Table 2). We sequenced both Epp and Zeale products in seven samples, however only Epp products were sampled in M55, due to space on the sequencing plate and the need to include blanks (Table GUANO). Blanks are necessary to check for artificially introduced contamination (such as in reagents) during the sequencing process, our blanks returned no concerns for contamination.

Using the Zeale primer, 145 arthropod OTUs were identified, while 14 OTUs were identified with the Epp primer. Thus, we identified 42 unique prey taxa from seven arthropod orders and 32 families (excluding three additional unknown families; Table 19, Figures 21 and 22). The taxa identified with Zeale data when considering single and duplicate sample OTU recoveries comprised all seven orders and 32 families, including 15 Lepidoptera families. OTU identifications with BOLD for Zeale data provided species confirmation for 13 species. Epp data identified three orders and 11 families, including eight Lepidoptera families. Gracillariidae, Momphidae [Batrachedridae], and Pyralidae were detected solely with Epp primers. Families that were confirmed by both primer sets included Nitidulidae and Scarabaeidae among Coleoptera, Cydnidae (Hemiptera), and among Lepidoptera, Crambidae, Hesperiidae, Noctuidae, Oecophoridae, Tortricidae. We also detected in the guano samples of Hawaiian hoary bats, fleas (Order Siphonaptera, Ceratophyllidae, *Orchopeas caedens*), freshwater ostracods (Order Podocopida, Cyprididae, Heterocypris sp.), and parasitic nematodes (order Rhabditida, Rhabditidae) that are not likely prey taxa in the bat's diet. These were removed from prey analysis but may warrant further study.

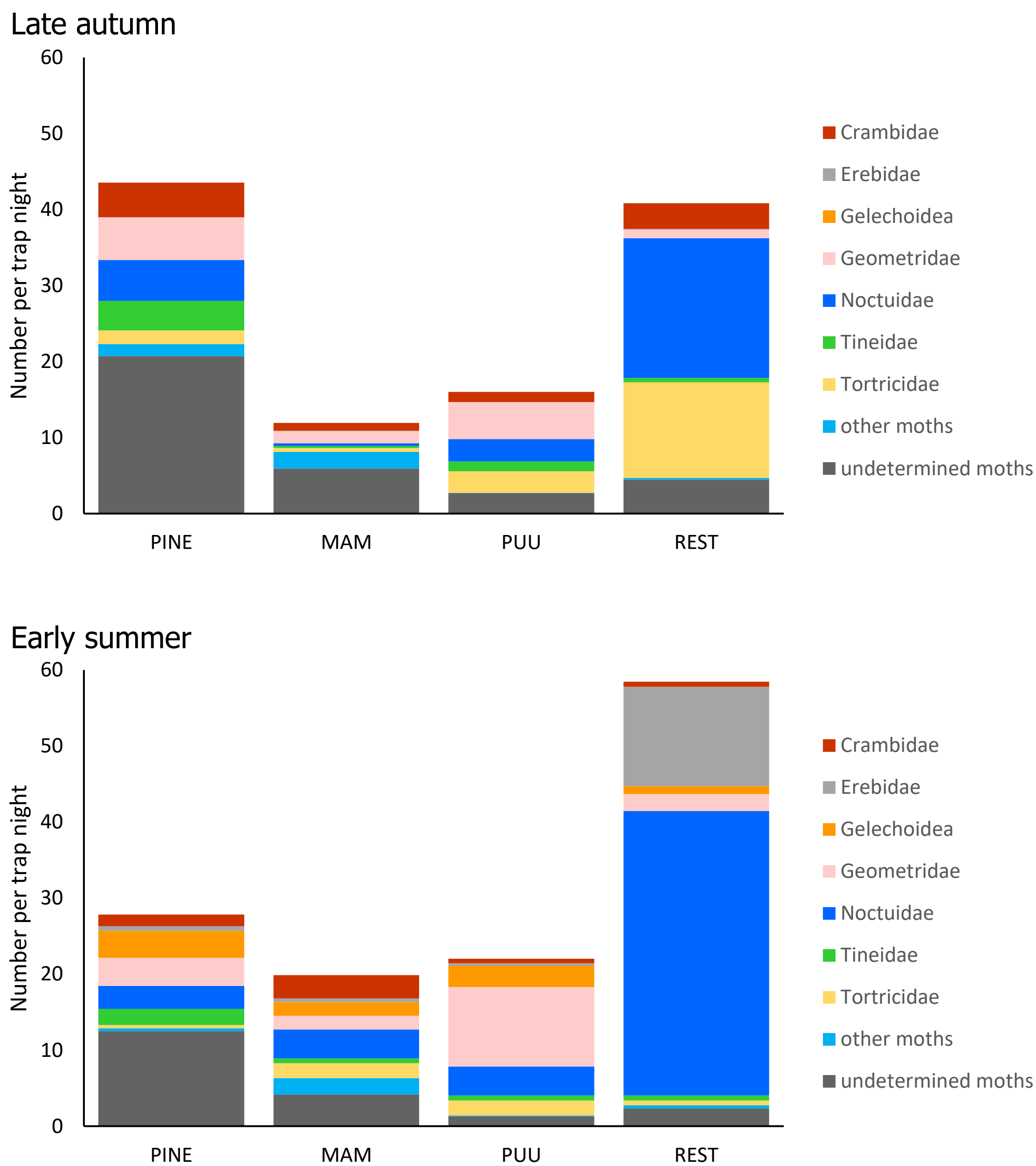

Figure 20. Site capture rates for Lepidoptera in late autumn (October 25–December 7, 2016) and early summer (June 7–July 3, 2017). Counts are adjusted for sampling effort from combined malaise and light traps for each pair of site samples. For graphical clarity, Lepidoptera families and superfamilies that comprised <5% of the overall seasonal sample were included as "other moths". Counts, sampling effort and capture rate details are presented in Appendix III.

Table 17. Lepidoptera reared from caterpillars collected on host plants in 2016 and 2017.

	Host plant					
Lepidoptera species	ʽaʽaliʽi	koa	māmane	naio	redwood	black wattle
Amorbia emigratella	11	1	0	0	5	0
Scotorythra sp.	15	7	0	5	0	4
Udara blackburni	3	1	0	0	0	2
Uresiphita polygonalis	0	0	3	0	0	0
Total	29	9	3	5	5	6

After filtering, Zeale raw reads (2,289,427 total) were reduced to 21,321 reads, and Epp raw reads (1,232 total) reduced to 262 reads. After removing chimeric sequences, the number of unique OTUs was reduced to 158 (0.74% of unfiltered reads) for Zeale and 14 (5.34% of unfiltered reads) for Epp. The mean number of OTUs detected per individual bat was 26.8 ± 19.0 using Zeale primers, and 4 ± 3.1 using Epp primers. Dietary composition by order and family as determined by Zeale data from duplicate samples was relatively similar among the seven bats captured at the Waihou Mitigation Area (Figure 23). At the order level, OTUs belonging to Lepidoptera were found in a preponderance of the diets of individual bats and accounted for the highest percentages of sequence counts (Figure 21). All other orders occurred in fewer than half of the bats. Coleopterans were identified in only three of the individuals, accounting for less than 20% of the Zeale sequence counts. The lepidopteran families Crambidae and Geometridae were found in all individual bats; whereas Noctuidae, Oecophoridae, Tortricidae, Xyloryctidae were identified in about three-quarters of these individuals (Figure 22). Other families comprised smaller proportions of Zeale-derived sequence counts (i.e., Crambidae and Oecophoridae ~40%, Noctuidae ~20% of counts). Although geometrids occurred in all the sampled bats, it accounted for ≤ 10% of the total sequence counts. The diet of the female captured in June included the highest number of lepidopteran families identified, and also included the dipteran families Culicidae (mosquitos) and Muscidae (flies) (Figure 23). In November, the diet of the three males captured in the Waihou Mitigation Area, was composed almost exclusively of Lepidoptera. The female bat found in August under a turbine at the Auwahi Wind Energy facility, had the most diverse diet of the eight bats examined, including all six orders identified by PCR. About a third of OTUs in this sample were from the dung beetle *Digitonthophagus gazella* (Coleoptera, Scarabaeidae).

Although ground-based insect traps and airborne bats may only mutually sample a fraction of the available prey, the captured insects used to develop the reference library were well represented at the order- and family-levels in the bat diet analysis. Four of the six orders and 11 of the 16 families captured were also present in guano samples (Tables 18 and 19). Furthermore, eight out of 29 genus-or species-level assignments matched that found in the bat diet.

Table 18. List of order, family, subfamily or genus, and species (where available) for insects barcoded for inclusion in the reference library. Taxa that may include species endemic to Hawai'i are denoted with an asterisk (*). Taxa included in the insect reference library samples and also found in bat diet samples (see Table 19) are indicated with a dagger (†).

Order	Family	Subfamily or Genus and Species	Individuals barcoded
Coleoptera	Hydrophilidae	*Sphaeridium scarabaeoides*	1
	Scarabaeidae †	*Aphodiinae* sp.	1
		Digitonthophagus gazella †	1
	Staphylinidae	*Philonthus* sp.	1
Diptera	Sepsidae	*Sepsis thoracica*	1
Hemiptera	Cydnidae†	*Pangaeus bilineatus*	1
	Lygaeidae	*Lygaeidae* sp.	1
Lepidoptera	Carposinidae †	*Carposina* sp. *	1
	Cosmopterigidae †	*Hyposmocoma* spp. *	5
	Crambidae †	*Omiodes* spp. *	4
		Udea sp.	2
		Uresiphita polygonalis *	1
		unknown sp.	2
	Erebidae †	*Melipotis indomita*	1
		Schrankia sp.	3
	Geometridae †	*Eupithecia* sp. *	2
		Scotorythra spp. *	7
		unknown sp.	1
	Noctuidae †	*Athetis thoracica*	3
		Chrysodeixis eriosoma	1
		Feltia subterranea †	1
		Ophiusa disjungens	1
		Peridroma saucia †	3
		Pseudaletia unipuncta †	1
		Spodoptera exempta	1
		unknown sp.	1
	Tineidae	*Opogona sacchari*	1
	Tortricidae †	*Acleris* spp.	2
		Amorbia emigratella	2
		Crocidosema sp. †	1
		unknown sp.	1
	Sphingidae †	*Hyles lineata*	1
	Xyloryctidae †	*Thyrocopa* sp. *	1

Table 19. List of prey items and associated information identified in Hawaiian hoary bat guano from the Waihou Mitigation Area and Auwahi Wind Energy facility. Order and family identifications are based Zeale and/or Epp primers sequencing, although and genus and species level identifications are based only on Zeale primer data. Total counts of operational taxonomic units (OTUs) by primer are noted in columns "s" if an item occurred in only one of a duplicate sample set, or under "d" if it's occurred in both samples. OTU counts apply only to the family level. Family and genus-level taxa that include species endemic to Hawai'i are denoted with an asterisk (*). Taxa found in bat diet samples included in the insect reference library samples are indicated with a dagger (†).

Order	Family	Zeale s	Zeale d	Epp s	Epp d	Genus	Species	Element or Vegetation
Blattodea	Kalotermitidae	1	3	0	0	*Neotermes*		wood
Coleoptera	Corylophidae *	1	0	0	0	*Sericoderus **		fungal spores
	Nitidulidae	0	1	1	0	*Phenolia*		decaying fruit
	Scarabaeidae †	0	5	0	3	*Digitonthophagus †*	*gazella* †	mammal dung
Diptera	Cecidomyiidae *	1	0	0	0			various plants
	Culicidae	0	3	0	0			nectar, blood
	Muscidae *	3	1	0	0	*Coenosia*		insect predators
	Tachinidae	0	1	0	0	*Eucelatoria*	*armiger*	insect parasitoids
	Sarcophagidae	1	0	0	0	*Blaesoxipha*	*plinthopyga*	carrion
	unknown	0	2	0	0			
Ephemeroptera	unknown	1	0	0	0			associated with water
Hemiptera	Cicadellidae *	1	1	0	0			various plants
	Pentatomidae †	1	2	1	0	*Nezara*	*viridula*	legumes, macadamia
						Piezodorus		legumes
	unknown	2	0	0	0			
Lepidoptera	Blastobasidae	1	0	0	0	*Blastobasis*		legumes
	Carposinidae *†	0	1	0	0	*Carposina *†*		unknown
	Coleophoridae	0	3	0	0	*Coleophora*		thistle
	Cosmopterigidae *†	0	7	0	0	*Pyroderces*		decaying vegetation
	Crambidae *†	1	32	3	6	*Nomophila*	*noctuella*	grasses

Order	Family	Zeale s	Zeale d	Epp s	Epp d	Genus	Species	Element or Vegetation
							Nomophila sp.	various plants
						Herpetogramma	*licarsisalis*	grasses
	Erebidae †	2	2	0	0	*Hypena*		grasses
	Gelechiidae *	6	3	0	0	*Dichomeris*		sourbush (*Pluchea*)
	Geometridae *†	5	15	0	0	*Eupithecia *†*		predatory, native plants
	Gracillariidae	0	0	2	2			various plants
	Hesperiidae	0	1	2	0			various plants
	Lycaenidae *	0	3	0	0			various plants
Lepidoptera (continued)	Momphidae (Batrachedridae)	0	0	0	1			various plants
	Noctuidae *†	11	46	2	0	*Athetis †*		grasses
						Feltia †	*subterranea* †	various plants
						*Peridroma *†*	*saucia* †	various plants
						*Pseudaletia *†*	*unipuncta* †	various plants
	Oecophoridae *	18	31	3	2			decaying vegetation
	Pyralidae *	0	0	2	0			various plants
	Sphingidae †	1	0	0	0			various plants
	Tortricidae *†	2	11	3	0	*Cryptophlebia*		fruit, seeds
						Crocidosema †	*lantana*	*Lantana camara*
	Xyloryctidae *†	6	12	0	0			decaying vegetation
	Gryllidae *	1	0	0	0	*Gryllus*	*bimaculatus*	various plants
Orthoptera	Tettigoniidae *	0	1	0	0	*Conocephalus*		various plants
	Trigonidiidae *	1	0	0	0	*Trigonidomorpha*	*sjostedti*	various plants

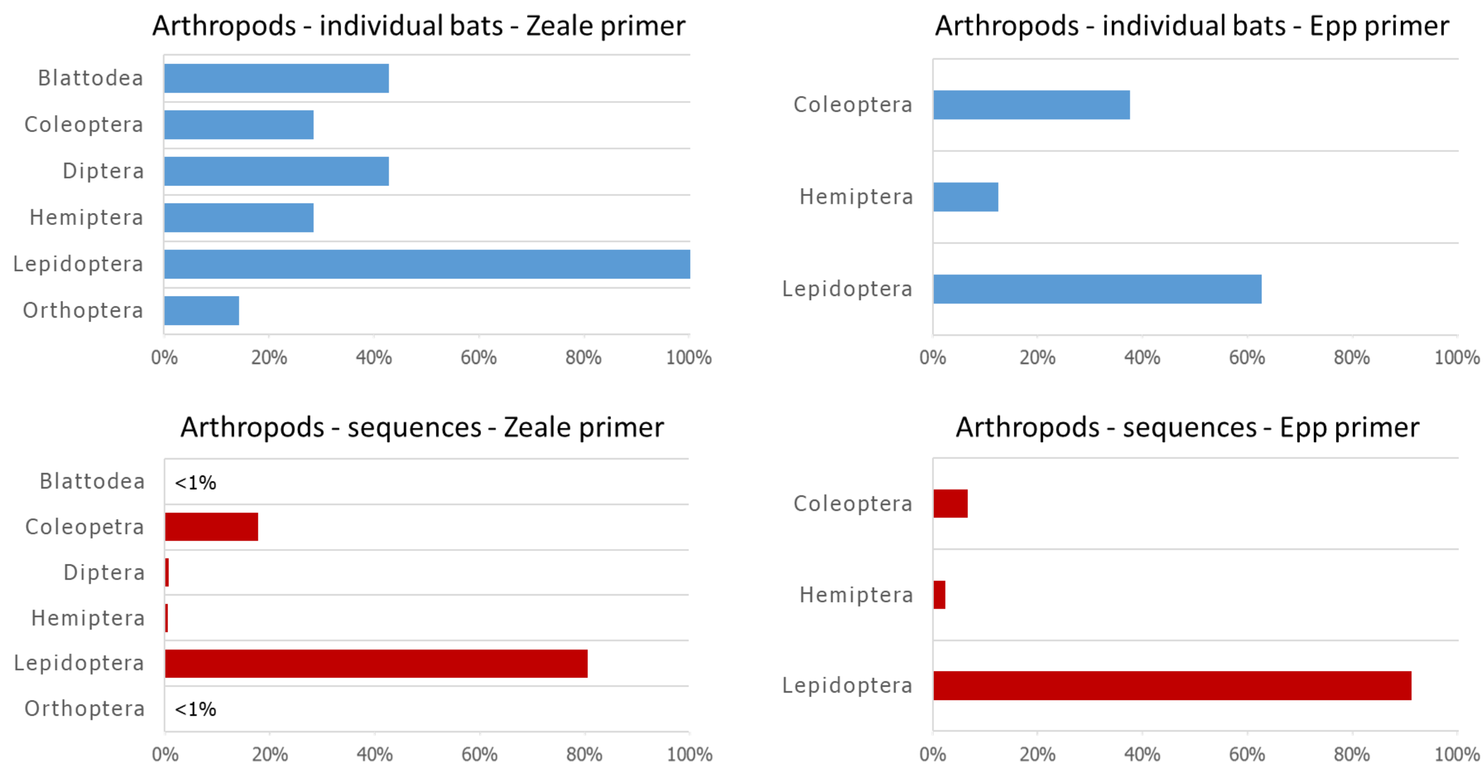

Figure 21. Proportion of arthropod orders identified in the Hawaiian hoary bat guano samples by prevalence (number of individual bats in which orders were detected; upper panels) and sequence occurrence (number OTUs; lower panels) using Zeale and Epp primers (left versus right panels). Values noted as "<1%" indicate non-zero counts.

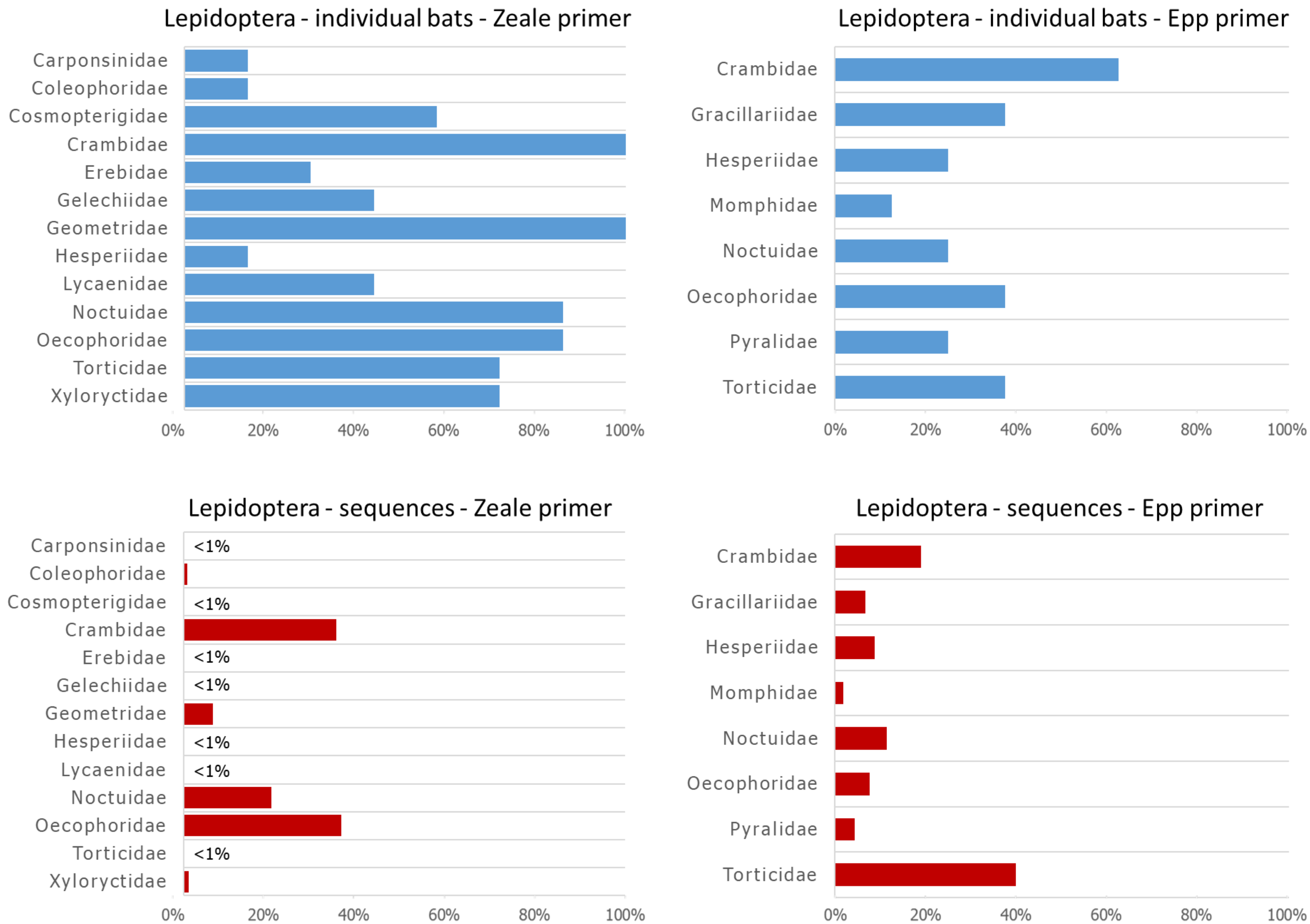

Figure 22. Proportion of Lepidoptera families identified in the Hawaiian hoary bat guano samples by prevalence (number of individual bats in which families were detected; upper panels) and sequence occurrence (number OTUs; lower panels) using Zeale and Epp primers (left versus right panels). Values noted as "<1%" indicate non-zero counts.

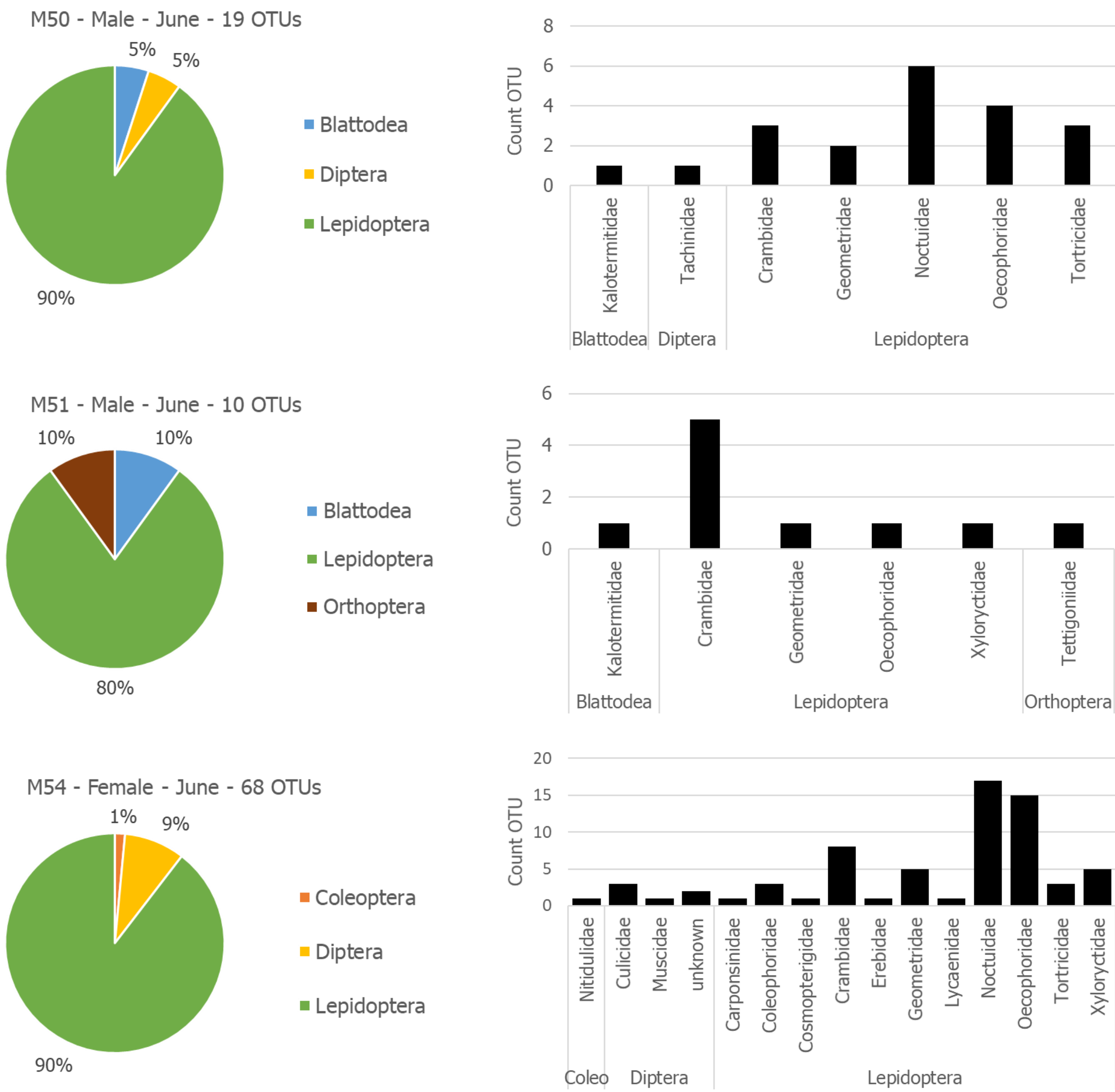

Figure 23. Diet composition and proportion of OTUs by order and family recovered from both members of Zeale primer samples for individual bats.

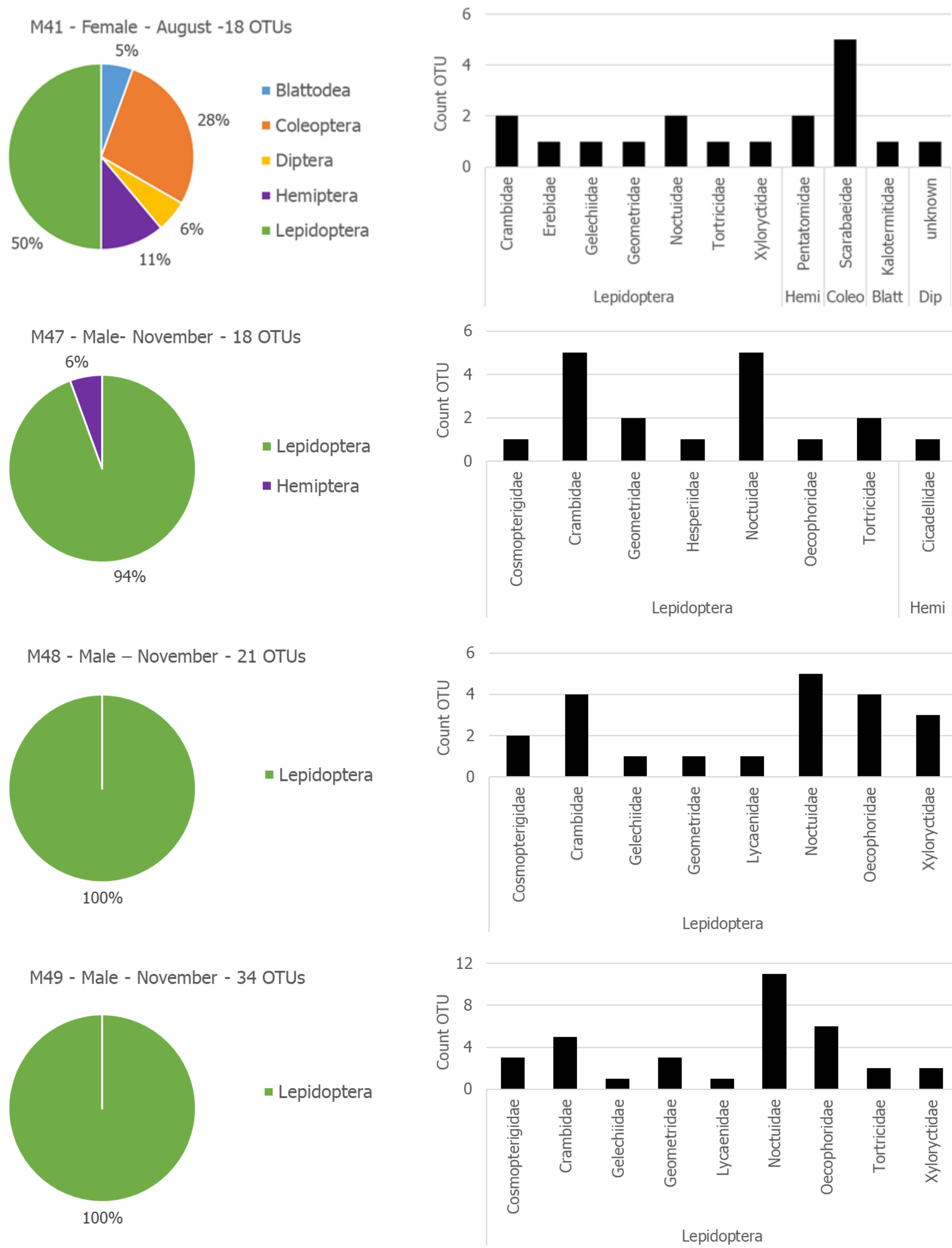

Figure 23 (continued).

Discussion

This study included a three-year acoustic survey of bat occurrence and seasonal activity obtained from sampling echolocation calls and provides information on the sex, age, and reproductive status of individual bats present in the Waihou Mitigation Area (inclusive of the Puʻu Makua Restoration Area). Additionally, this is the first study to report with genetic analysis, the diet of the Hawaiian hoary bat in relation to potential prey availability.

Acoustic surveys confirm the year-round occurrence of Hawaiian hoary bats in the Waihou Mitigation Area throughout the three years of sampling. Hawaiian hoary bats exhibited a seasonal pattern of presence similar to that previously observed on the islands of Hawaiʻi (Gorresen *et al.* 2013) and Oʻahu (Starcevich *et al.* 2019). These patterns showed peak acoustic activity between May and November, broadly encompassing the portion of the annual cycle that includes pregnancy, lactation, and fledging/post-lactation periods. During this time adult females can be expected to have their highest energy demands and efforts needed to forage to support reproductive activities. Thus, higher acoustic detection rates during those periods also may be attributable to increased foraging associated with greater insect availability, a trend indicated by the larger number of Lepidoptera trapped during summer and autumn. Acoustic detections during the autumn likely reflect the contribution of newly volant juveniles that accompany mothers in tandem flight during the first months of foraging (Hickey and Fenton 1990, Pfalzer and Kusch 2003).

Between-year comparisons demonstrated lower acoustic detection in 2017 relative to 2016 for all site and monthly metrics (i.e., mean call files recorded each night, percent of nights with at least one detection, percent of nights with at least one feeding buzz detected, and percent of nights with recordings of multiple bats). However, considerable inter-annual variability is typical of acoustic surveys (e.g., Gorresen *et al.* 2013, Rodhouse *et al.* 2012), and inference about trends are generally not possible from short-term datasets (i.e., <4 years). In addition, acoustic sampling is prone to imperfect detection for both methodological and biological reasons. For example, detection may be affected by factors associated with the propagation and detection of sound, cryptic foraging strategies, and conspecific presence (Gorresen *et al.* 2017). Furthermore, bat detectability may be affected by stochastic seasonal or weather related factors such as precipitation and wind velocity. Additional periodic or long-term acoustic monitoring of the Waihou Mitigation Area could more effectively assess resident bat trends and responses to management aimed at forest restoration and habitat enhancement.

Bat captures over an 8-month span confirmed 11 individuals, two of which were pregnant and one that was lactating, thus highlighting the importance of the area to resident and breeding individuals. The relatively high acoustic activity in the upper Waihou area at sites AUW6 and AUW7 also included a high proportion of nights with multiple bat detections. Moreover, the capture of eight adult males over two sampling periods spanning eight months and within the limited area suitable for netting bats, indicated a degree of co-occurrence as-yet not observed elsewhere. It is particularly notable given the typically agonistic behavior and structured use of foraging space by adult males (Bonaccorso *et al.* 2015), and the fact that agonistic interactions may occur among insectivorous bats when prey is scarce (Barlow and Jones 1997). The presence of multiple adult males suggests either that prey was not limiting during the period of survey, and/or the area supports a limited open water resource requiring a degree of mutual tolerance among bats, perhaps facilitated by a high rate of temporal-spatial turnover of individual bats (i.e., bats using the area for short periods of time).

The high acoustic activity recorded in the upper Waihou area is difficult to attribute to any single factor, as the area includes ponds, tall trees and is located close to larger tracts of contiguous forest at higher elevations. Although these features were largely absent in the immediate surroundings at the other acoustic sampling sites, the proximity of the sample sites and the broad extent of bat home ranges precludes any inference about selective use of relatively small areas such as the Puʻu Makua Restoration Area. However, the detection of feeding buzzes at all sampling sites does indicate that the entire area is used by foraging individuals.

The genetic analysis of Hawaiian hoary bat diet from samples collected in the study area confirms the major arthropod orders (Coleoptera, Lepidoptera, Diptera, Hemiptera, and Blattodea) found in previous studies that used dissection and microscopy of guano samples to identify prey items (Whitaker and Tomich 1983, Todd 2012, Bernard and Mautz 2016). However, genetic analysis of guano samples may afford greater taxonomic resolution and better prey identification of soft-bodied insects such as moths and flies than does morphological methods. For example, the hard carapaces of beetles may differentially survive digestion resulting in its over-representation in morphological analysis, while the taxa with soft parts are under-represented (Clare *et al.* 2009, 2014).

Genetic analysis showed Lepidoptera as the primary component in the diet of bats captured at the Waihou Mitigation Area, both in terms of its ubiquity among individuals (100%) and the mean proportion of Zeale sequence counts recovered (92%), the latter of which is potentially indicative of the amount of biomass consumed (Deagle *et al.* 2019). This finding was also supported by the results for Epp primer data. Two guano samples were entirely composed of moths, and the remaining four bats from this same area included only one to two other orders with relatively low OTU counts. A notable exception was the sample from bat M41, the fatality from the Auwahi Wind facility 7 km to the south and located in low elevation dryland habitat. The guano of M41 contained 50% moths but also included Coleoptera, Diptera, Hemiptera, and Blattodea. Although difficult to speculate about habitat-dependent effects on insect availability, it is possible that the feeding of bat M41 reflected either a more diverse local assemblage of insects, or its foraging over a large multi-habitat area on the night sampled. As the two fecal samples from females contain Coleoptera and Diptera, it may also indicate dietary preference for prey that are easier targets than fast flying moths. Previous studies have suggested that pregnant or lactating females (and juveniles) preferentially select less-maneuverable prey such as beetles (Anthony and Kunz 1977, Bellwood and Fenton 1976, Bellwood and Fullard 1984, Brack and LaVal 1985, Valdez and Cryan 2009). Moreover, some noctuid and geometrid moth species have evolved the capacity to hear bat echolocation calls and engage in evasive flight maneuvers to avoid bats (Fullard 2001). Moths in general may therefore be more difficult to catch compared to beetles, true bugs, and some and other insects. The preponderance of Lepidoptera in the diet of bats at the Waihou Mitigation Area may also reflect overall insect availability as our trapping in the area consisted almost entirely of moths. Other orders made up <0.1% of the insect sampled in late autumn and none were collected in early summer. This pattern of captures differs with the findings of Whitaker and Tomich (1983), which demonstrated a greater proportion of Coleoptera and Hemiptera in the diets of bats collected along the northeast coast of Hawaiʻi Island at elevations between sea level and 800 m. The pattern of insect composition also differs from that of Gorresen *et al.* (2018) that showed the abundance of Coleoptera (primarily dung beetles) to be significantly associated with areas in which Hawaiian hoary bats concentrated foraging activity at elevations <400 m on Oʻahu.

However, the high proportion of moths in our study is consistent with insects collected at high elevations (≥1,200 m) on windward Hawai'i Island (Todd 2012).

The dietary items of Hawaiian hoary bats sampled in this study share some similarities to that of hoary bats in North America (*L. cinereus cinereus*). Guano samples obtained from migrating hoary bats in New Mexico (Valdez and Cryan 2009) and those identified from stomach and intestinal contents of bats collected at wind energy facilities in Texas and New York (Valdez and Cryan 2013, Foo *et al.* 2017) also contain Lepidoptera as the predominant diet item. Other major items common to the diet of both subspecies include Coleoptera, Hemiptera, and Diptera. Orthoptera (specifically *Gryllus spp*.) were found in the stomachs of North American hoary bats (Foo *et al.* 2017), and *Gryllus bimaculatus* (two-spotted cricket) was detected in the Hawaiian hoary bat diet. Notable differences include Blattodea (likely the forest tree termite, *Neotermes connexus*) present in three of the seven Hawaiian hoary bat samples (albeit with a small amount of recovered OTUs), but was not noted in any of the North American studies. Conversely, Hymenoptera and Neuroptera were noted in the diet of *L. cinereus cinereus*, and appear in small proportions in other studies in Hawai'i (Jacobs 1999, Todd 2012), but were not apparent in our samples. The detection of Ephemeroptera (mayflies) and Ostracoda in the guano samples is interesting as these taxa are associated with fresh water, and most of the bats in our study were captured over ponds. The mayflies were likely captured by bats as these insects emerged from ponds, however the presence of ostracods could occur from drinking pond water.

Five dipteran families were present in three guano samples, and although OTU counts indicate that the volume consumed was relatively small, and Dipterans have been reported in the diet of Hawaiian bats, our samples include taxa not previously reported by either Jacobs (1999) or Todd (2012). Culicidae (mosquitos) and Cecidomyiidae (gall midges) found in our study are noteworthy since most species are usually <4 mm in length, a size that may approach the limit at which hoary bats can detect prey with echolocation (Barclay *et al.* 1999). The small size of these insects may be the reason they have been overlooked in previous studies. Although chironomid midges made up a negligible amount of the dipterans consumed by older juvenile or adult hoary bats in North America, it was a major component in the diet of conspecific juveniles during the 1st week of flight, apparently made more readily available to young juveniles due to their lower wing loading and greater maneuverability (Rolseth *et al.* 1994). *Lasiurus cinereus semotus* weighs almost half as much and has a considerably lower wing loading as does *L. cinereus cinereus* (Jacobs 1996). As such, Hawaiian hoary bats may be more maneuverable with the ability to capture and feed on smaller prey than their North American counterparts.

Our results confirm that the Hawaiian hoary bat is a feeding generalist. It feeds on a diverse range of insect taxa and on a large range in prey size. It is also a generalist in exploiting a range of habitats, being capable of foraging in both open grasslands and over ponds (e.g., Pu'u Makua parcel) and in vegetation-cluttered airspace (e.g., amongst trees in the upper Waihou Mitigation Area), and where it is active in the latter type of habitat, it tends to consume smaller prey (<15 mm; Jacobs 1999). The ubiquity of "micro-moth" families Crambidae, Oecophoridae, and Xyloryctidae in our Hawaiian hoary bat guano samples demonstrates that they often consume relatively small moths (although these families also include some larger species). However, the presence of families such as Noctuidae, Geometridae, and occurrence of Sphingidae (at low OTU counts), in the guano samples indicates these bats also consume large prey (>15 mm).

The overall diversity of Lepidoptera taxa (18 families) in the diet from bats sampled in the Waihou/Auwahi area indicates a wide breath of prey, averaging ~7 families (range 4 to 11) per bat based on Zeale primer sequencing. Twenty-four moth taxa identified compare similarly to the 20 moth species identified from stomach contents of hoary bats sampled in Texas (Foo *et al.* 2017). The prevalence of Noctuidae and Geometridae in the diet of *L. cinereus semotus* confirms a similar observation by Todd (2012), and its frequency in the diet of *L. cinereus cinereus* has been noted by Valdez and Cryan (2009, 2013). The families Crambidae, Oecophoridae and Tortricidae, showed recovered OTUs potentially indicative of a high volume of consumption, and were common to most of the bats sampled, and to our knowledge constitutes prey taxa for which no previous records exist for the Hawaiian hoary bat. These taxa were trapped seasonally at relatively high rates at various locations in the study area and likely constitute a prey base readily available to foraging bats.

The four species of Lepidoptera collected as caterpillars (*Scotorythra* sp., *Amorbia emigratella*, *Udara blackburni*, *Uresiphita polygonalis*) directly from vegetation did not appear in the diet of the bats sampled for guano in our study at the genus and species level, but OTUs associated with their families (Geometridae, Tortricidae, Lycaenidae, and Crambidae) were found in bat diet. Bat consumption of *Scotorythra* during moth outbreaks has been assumed on Hawaiʽi Island (Banko *et al.* 2014), and its occurrence in the diet of bats on Maui is also likely given the large numbers of Geometridae OTUs detected. Its prevalence on ʽaʽaliʽi, koa and naio indicates that reforestation that include these plant species may provide food for locally foraging bats. In addition, the indigenous moth *Uresiphita polygonalis* has been recorded in Hawaiʽi feeding on koa and māmane (Leen 1997), and its potential as bat prey may be enhanced by reforestation efforts.

Direct insect-plant associations are difficult to make at this time, as we were not able to identify many of the recovered OTUs to a genus- or species-level, largely because Hawaiian arthropods are not well represented in public barcode libraries. Zeale primers, although widely used in insectivorous predator studies, have been shown to poorly resolve family-level taxa within Lepidoptera (Brandon-Mong *et al.* 2015). To better understand if the Hawaiian hoary bat is moth specialist in some habitats, future studies should consider different primers in addition to Zeale, and development of reference libraries specific to Hawaiʽi and with a focus on Lepidoptera taxa.

Our results also indicate that Hawaiian hoary bats consume both native and non-native insect species. Identified in the bat's diet are agricultural pests in Hawaiʽi (Funasaki *et al.* 1988) and elsewhere that include the noctuid moths *Feltia subterranean (granulate cutworm) (*Prestes 2014*)*, *Peridroma saucia (variegated cutworm)* and *Pseudaletia unipuncta* (army worm). Another agricultural pest fed upon by Hawaiian hoary bats is *Nezara viridula* (southern green stink bug; Follett *et al.* 2009).

Items detected in the diet also include species deliberately introduced to Hawaiʽi as biological control agents, such as *Crocidosema lantana* (lantana tortricid moth) used to manage the highly invasive plant *Lantana camara* (Funasaki *et al.* 1988), and *Digitonthophagus gazella* (gazelle scarab) which was brought as an aid to agriculture and ranching because of the beetle's ability to recycle dung and reduce horn fly infestations (Markin and Yoshioka 1998). Given the high proportion of adventive insects introduced to Maui (e.g., 80%; Howarth *et al.* 2012) and elsewhere in the state, genetically evaluating the diet of bats in agricultural habitats may assist in the detection of new pest species (Maslo *et al.* 2017), as well as improve understanding of the role of bats in the biological suppression of pests (Boyles *et al.* 2011, McCraken *et al.* 2012, Maine and Boyles *et al.* 2015).

In conclusion, acoustic surveys confirm the year-round use of habitat by Hawaiian hoary bats in the Waihou Mitigation Area. Moreover, genetic analysis of the species' diet indicates that Hawaiian hoary bats feed on a diverse variety of insect prey items and range of habitats. Prey items include native and non-native insects, including agricultural pests, and indicate that the Hawaiian hoary bat is largely a food and habitat generalist. Genetic identification of guano samples has greatly expanded our understanding of the diet of this endangered species. Additional use of this technique will further enhance understanding of bat diet and contribute to planning habitat restoration across varied habitats in Hawai'i.

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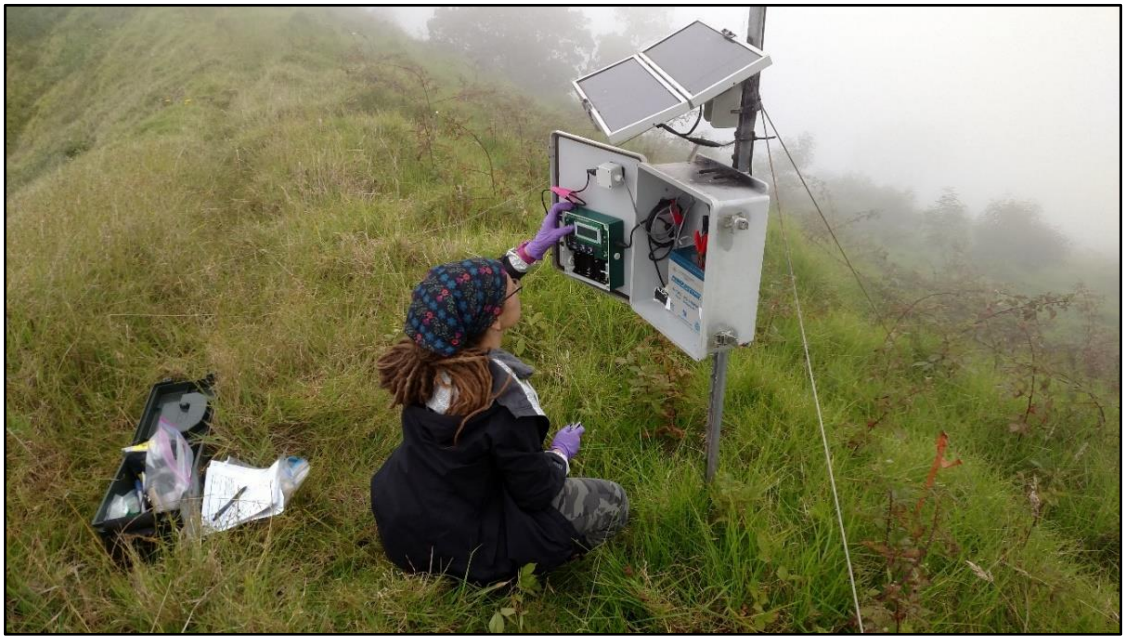
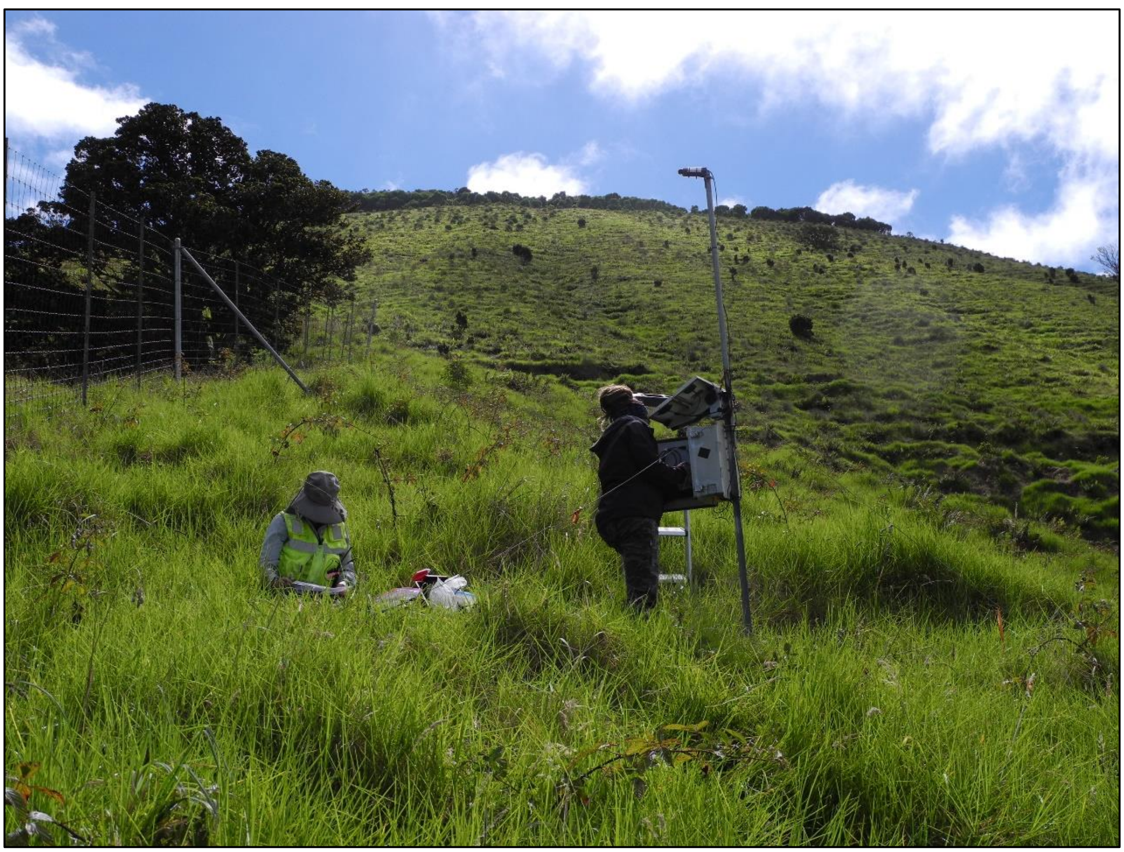
Appendix I. Bat Acoustic Recording Sites



Appendix I Figure 1. Puʻu Makua bat acoustic recording site AUW1.

Appendix I Figure 2. Puʻu Makua bat acoustic recording site AUW2.

Appendix I Figure 3. Pu‘u Makua bat acoustic recording site AUW4. The two microphone models (SMX-US and SMX-U1) are shown attached to the top of the pole, demonstrating comparison testing set up.



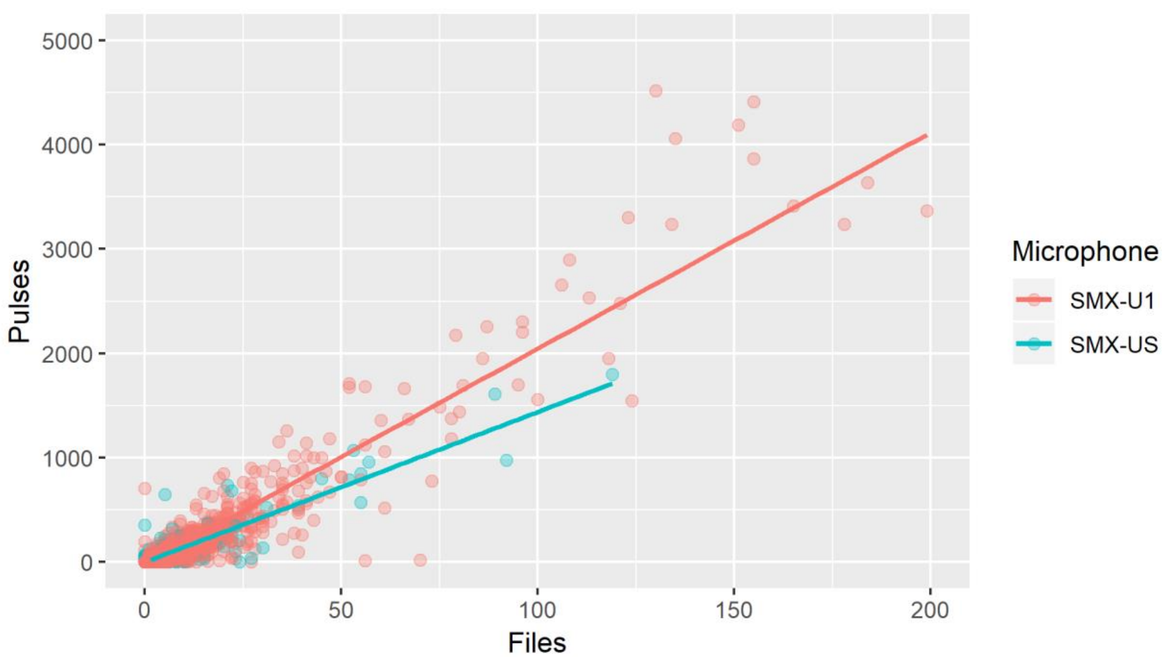
Appendix I Figure 4. Pu‘u Makua bat acoustic recording site AUW5.

Appendix I Figure 5. Pu‘u Makua bat acoustic recording site AUW6.

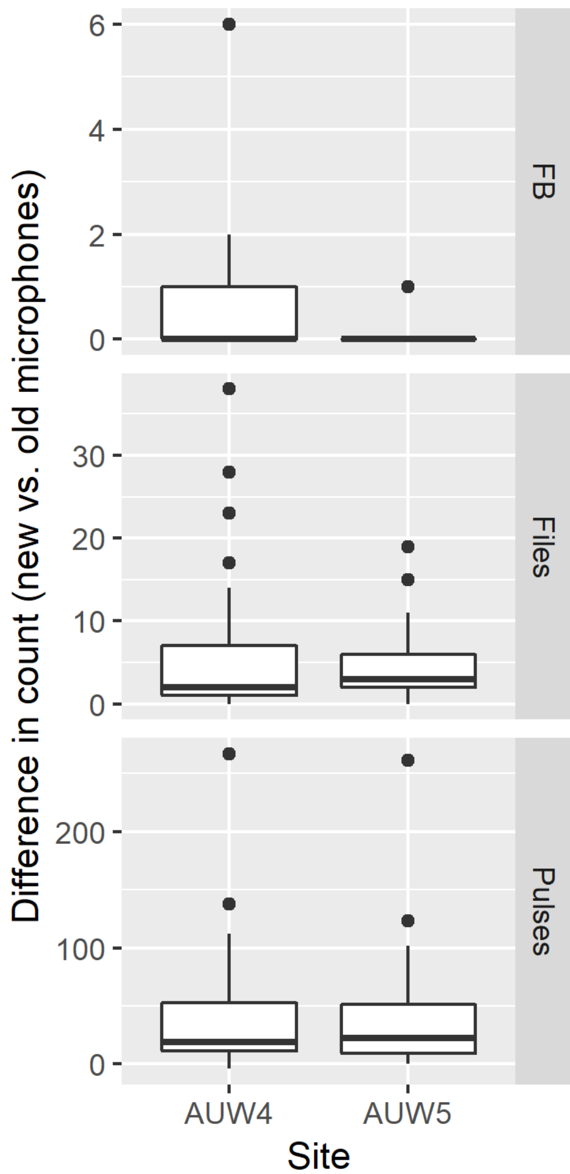
APPENDIX II. ACOUSTIC MICROPHONE COMPARISON

A comparison of simultaneous recordings between the SM2 acoustic detectors equipped with SMX-US and newer SMX-U1 ultrasonic microphones was performed to assess whether the detection data from the older SMX-US could be corrected and made comparable to that obtained from SMX-U1. The test was conducted at two stations (AUW4 and AUW5) from October 14 to November 27, 2016. The SM2 detector at each of the two stations were equipped with an SMX-US and an SMX-U1 positioned at the same height above ground and aimed into the same airspace (Appendix I Figure 3). Acoustic microphone comparison data are available at https://doi.org/10.5066/P9U0KRMY (Pinzari *et al.* 2019).

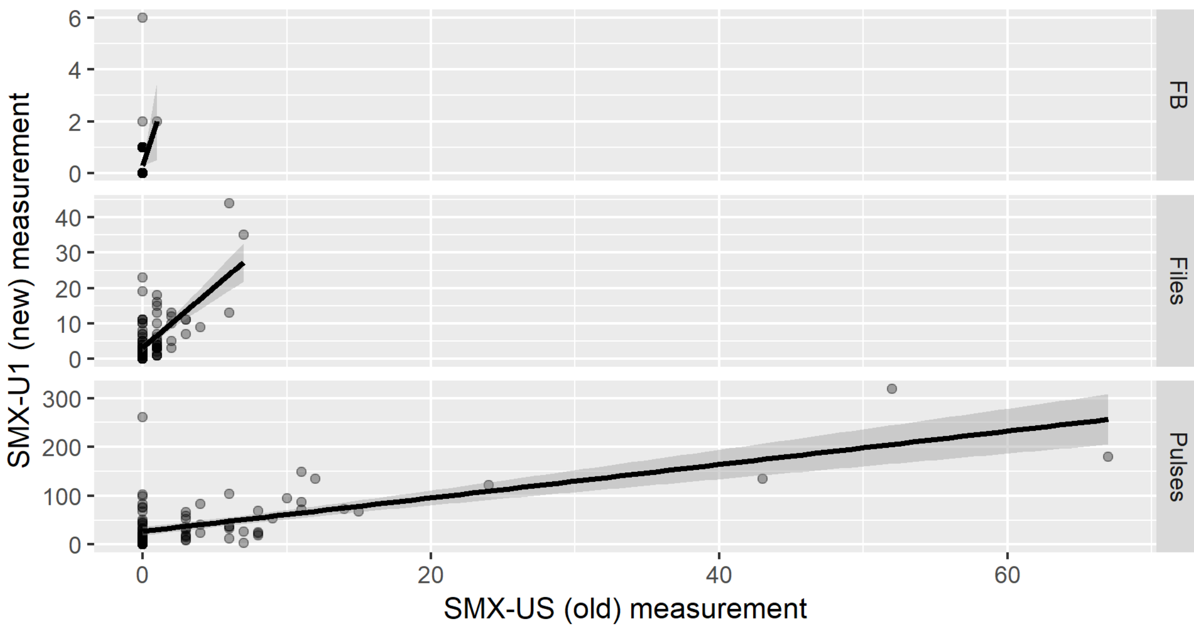
The SMX-U1 microphones samples detected more pulses, feeding buzzes, and generated more files than the SMX-US samples (Figures 1 & 2). In addition, the comparison of detections between microphone types demonstrated the following correlations for number of feeding buzzes ($r = 0.233$, $p = 0.027$), pulses ($r = 0.665$, $p < 0.0001$), and total files ($r = 0.652$, $p < 0.0001$) (Figure 3). A regression estimator of SMX-US to SMX-U1 file counts had a mean slope of 3.44 (95% confidence interval [CI]= 2.59-4.29) and an intercept of 3.13 (95% CI=1.84-4.43) (Figure 4). In general, a detector equipped with a SMX-US microphone detects about 1/3 the number of files of a detector with an SMX-U1 microphone. Although these data were obtained from only 2 acoustic stations over a 6-week sample period, the results indicate that the correlations between the microphone models were low and the confidence intervals around regression estimator were large. Consequently, applying the regression estimator with the objective of extrapolating and making comparable detections from SMX-US and SMX-U1-equipped detectors is not advisable.



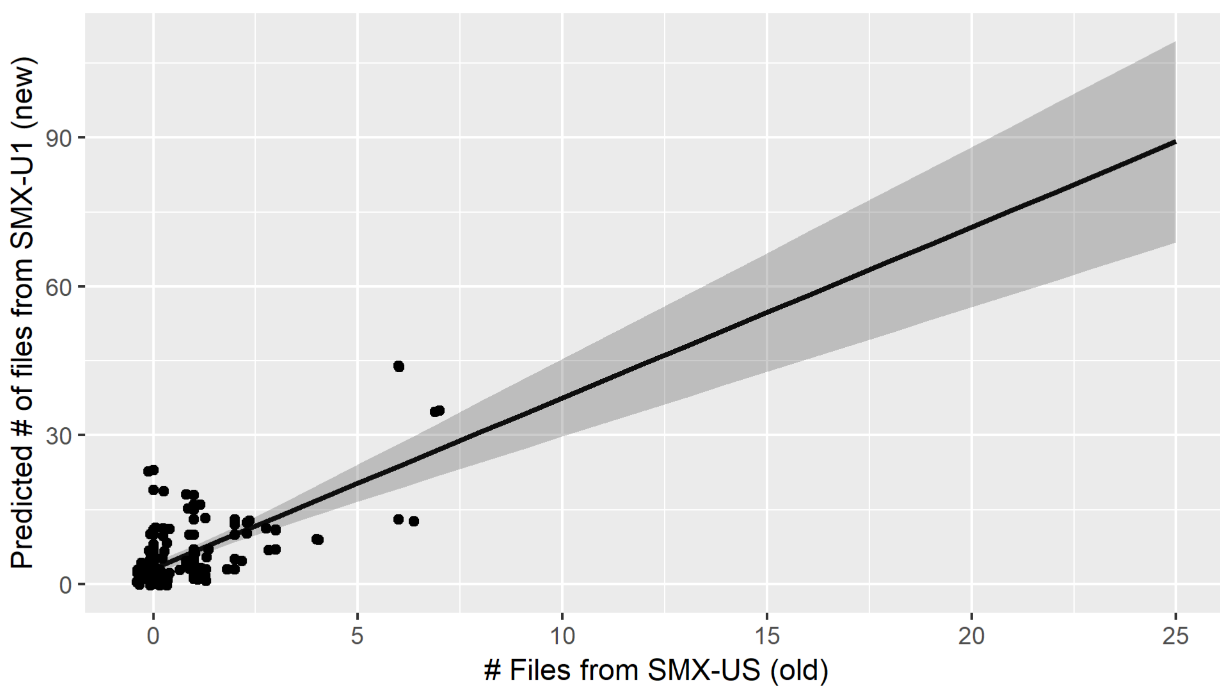
Appendix II Figure 1. Number of bat echolocation pulses relative to the number of files recorded from acoustic detectors equipped with SMX-US ("old") and SMX-U1 ("new") microphones at stations AUW4 and AUW5 from October 14 to November 27, 2016.



Appendix II Figure 2. Box plots demonstrating differences in count between SMX-U1 ("new") and SMX-US ("old") microphones from stations AUW4 and AUW5 for feeding buzzes (FB), number of files, and number of pulses.



Appendix II Figure 3. Correlation plots of simultaneous measurements between SMX-US ("old"; black dots) and SMX-U1 ("new"; grey dots) for feeding buzzes (FB), number of files and pulses from microphones at stations AUW4 and AUW5 from October 14 to November 27, 2016.



Appendix II Figure 4. Regression of detections obtained from SMX-US ("old") microphones relative to the number of files from detectors equipped with SMX-U1 ("new") microphones. It is important to note the lack of files generated from the SMX-US microphones, no more than 7 files were recorded on any given night during this test, whereas the number of files recorded from the SMX-U1 on a given night may be higher than 15 files.

Appendix III. Insect Capture Data

Appendix III Table A. Insect sample counts by season/year, trap type and site.

Light trap counts	PINE	MAM	PUU	REST
Late autumn (2016) totals	287	54	92	276
Crambidae	45	9	11	17
Erebidae	0	1	0	1
Geometridae	40	8	13	9
Noctuidae	58	3	32	201
Pterophoridae	13	0	0	0
Sphingidae	1	0	0	2
Tineidae	5	0	7	1
Tortricidae	9	2	9	17
Xyloryctidae	1	0	0	0
undetermined	115	31	20	28
Early summer (2017) totals	62	83	188	354
Carposinidae	0	3	0	0
Crambidae	6	13	2	0
Erebidae	2	2	1	78
Gelechioidea	6	2	7	0
Geometridae	10	8	39	13
Noctuidae	18	19	22	224
Sphingidae	0	0	0	1
Tineidae	4	2	3	1
Tortricidae	1	8	7	0
Xyloryctidae	1	0	0	1
undetermined	14	26	107	36
Malaise trap counts	PINE	MAM	PUU	REST
Late autumn (2016) totals	1,461	369	656	1,211
Crambidae	41	9	28	140
Geometridae	166	64	318	24
Lycaenidae	3	0	0	0
Noctuidae	8	5	4	7
Pterophoridae	2	4	2	2
Tineidae	287	23	57	40
Tortricidae	85	26	172	849
Xyloryctidae	7	0	0	0
undetermined	862	238	75	149
Early summer (2017) totals	450	303	412	191
Carposinidae	3	83	1	0
Cosmopterigidae	6	0	3	0
Crambidae	25	24	12	37
Erebidae	13	4	10	3
Gelechioidea	120	75	88	57
Geometridae	95	11	213	2
Gracillariidae	0	0	1	0
Lycaenidae	0	1	0	2
Noctuidae	2	2	8	6
Pterophoridae	0	0	0	2
Tineidae	67	11	10	27
Tortricidae	13	20	43	34
Xyloryctidae	1	1	0	0
undetermined	105	71	23	21

Appendix III Table B. Number of samples days per trap, season/year and site.

Number of light trap-days	PINE	MAM	PUU	REST
Late autumn (2016)	11	10	11	11
Early summer (2017)	6	5	6	6
Number of malaise trap-	PINE	MAM	PUU	REST
Late autumn (2016)	84	84	86	77
Early summer (2017)	47	54	54	54

Appendix III Table C. Capture rates (number per trap night) per season/year and site.

Late autumn (2016)	PINE	MAM	PUU	REST	Total	Proportion
Carposinidae	0.06	2.14	0.02	0.00	0.55	1.9%
Cosmopterigidae	0.00	0.00	0.00	0.00	0.00	0.0%
Crambidae	4.58	1.01	1.33	3.36	2.57	9.1%
Erebidae	0.00	0.10	0.00	0.09	0.05	0.2%
Gelechioidea	0.00	0.00	0.00	0.00	0.00	0.0%
Geometridae	5.61	1.56	4.88	1.13	3.36	11.9%
Gracillariidae	0.00	0.00	0.00	0.00	0.00	0.0%
Lycaenidae	0.04	0.00	0.00	0.00	0.01	<0.1%
Noctuidae	5.37	0.36	2.96	18.36	6.91	24.5%
Pterophoridae	1.21	0.05	0.02	0.03	0.33	1.2%
Sphingidae	0.09	0.00	0.00	0.18	0.07	0.2%
Tineidae	3.87	0.27	1.30	0.61	1.53	5.4%
Tortricidae	1.83	0.51	2.82	12.57	4.28	15.2%
Xyloryctidae	0.17	0.00	0.00	0.00	0.04	0.2%
undetermined	20.72	5.93	2.69	4.48	8.51	30.2%
Early summer	PINE	MAM	PUU	REST	Total	Proportion
Carposinidae	0.06	2.14	0.02	0.00	0.55	1.7%
Cosmopterigidae	0.13	0.00	0.06	0.00	0.04	0.1%
Crambidae	1.53	3.04	0.56	0.69	1.38	4.3%
Erebidae	0.61	0.47	0.35	13.06	3.75	11.6%
Gelechioidea	3.55	1.79	2.80	1.06	2.28	7.0%
Geometridae	3.69	1.80	10.44	2.20	4.58	14.1%
Gracillariidae	0.00	0.00	0.02	0.00	0.00	<0.1%
Lycaenidae	0.00	0.02	0.00	0.04	0.01	<0.1%
Noctuidae	3.04	3.84	3.81	37.44	12.39	38.2%
Pterophoridae	0.00	0.00	0.00	0.04	0.01	<0.1%
Sphingidae	0.00	0.00	0.00	0.17	0.04	0.1%
Tineidae	2.09	0.60	0.69	0.67	0.99	3.0%
Tortricidae	0.44	1.97	1.96	0.63	1.22	3.8%
Xyloryctidae	0.19	0.02	0.00	0.17	0.10	0.3%
undetermined	12.50	4.15	1.30	2.32	5.05	15.6%

APPENDIX IV. BAT ACOUSTIC DATA

Appendix IV Table A. Summary of bat presence and acoustic information recorded at detector sites in the Waihou Mitigation Area between March 17, 2015 and October 13, 2016. Recordings were made with model SMX-US microphones.

Site	Elevation (m)	Microphone model	Recording nights	Nights bats present	Percent nights with bats present	Number of files with bat activity	Feeding buzzes	Files with multiple bats
AUW1	1,611	SMX-US	576	131	23	1,452	88	59
AUW2	1,606	SMX-US	483	62	13	153	17	8
AUW3	1,607	SMX-US	183	152	83	734	146	4
AUW4	1,515	SMX-US	577	131	23	536	65	10
AUW5	1,396	SMX-US	520	79	15	236	15	0
AUW6	1,644	SMX-US	576	389	68	38,902	168	328

Appendix IV Table B. Summary of bat presence and acoustic information recorded at detector sites in the Waihou Mitigation Area and surrounding sites between October 14, 2016 and March 21, 2018. Recordings were made with model SMX-U1 microphones, which are more sensitive than the previously deployed microphones (SMX-US) to echolocation activity and feeding buzzes. Asterisk (*) indicates detector site with a 2017 start date, less than 12 months of calendar year sampling effort.

Site	Elevation (m)	Microphone model	Recording nights	Nights bats present	Percent nights with bats present	Number of files with bat activity	Feeding buzzes	Files with multiple bats
AUW1	1,611	SMX-U1	407	323	79	7,404	138	326
AUW2	1,606	SMX-U1	523	424	81	4,164	178	132
AUW3	1,607	SMX-U1	494	416	84	2,278	75	26
AUW4	1,515	SMX-U1	517	366	71	4,288	53	423
AUW5	1,396	SMX-U1	523	410	78	2,265	28	36
AUW6	1,644	SMX-U1	391	362	93	155,094	1,111	1,878
AUW7*	1,647	SMX-U1	337	246	73	12,110	1,334	178
AUW8*	363	SMX-U1	280	39	14	56	0	0
AUW9*	10	SMX-U1	219	61	28	136	0	1
AUW10*	150	SMX-U1	266	61	23	111	1	0

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Attachment 4

Status Update from the Leeward Haleakalā Watershed Restoration Partnership on Use of Funds for Blackburn's Sphinx Moth Mitigation

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Auwahi Forest Restoration Project quarterly report to Sempra
for forest restoration at Auwahi, ʻUlupalakua Ranch, Maui
Progress from May 1, 2018 through July 31, 2018

We are contacting you to update you on the progress of the goals outlined for the Auwahi Forest Restoration Project to conduct primary restoration in six acres and plant 1500 *ʻaiea* (*Nothocestrum latifolium)* and 10 *ʻiliahi* (*Santalum haleakalae var. lanaiense*). We have successfully conducted primary restoration in six acres of Auwahi, planted 1,086 *ʻaiea*, and more than 20 *ʼiliahi* in Auwahi exclosures. From May 1 through July 31, 2018 we have planted 93 *ʻaiea* including 3 larger saplings in 2 gallon pots into Auwahi forest restoration areas.

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Auwahi Forest Restoration Project quarterly report to Sempra
for forest restoration at Auwahi, 'Ulupalakua Ranch, Maui
Final report

This is s a final report for the goals outlined for the Auwahi Forest Restoration Project to conduct primary restoration in six acres and plant 1500 'aiea (*Nothocestrum latifolium)* and 10 'iliahi (*Santalum haleakalae var. lanaiense*).

We have successfully conducted primary restoration in six acres of Auwahi and planted 1500 'aiea and 20 'iliahi seedlings in appropriate and managed habitat for these species in all three Auwahi forest restoration exclosures.

Not only have the goals of this agreement been met but we are committed to the management of native habitat appropriate for this species as well as it's dry forest companion species and therefore do our best to ensure the survival of these young trees. The Auwahi project strives to manage Auwahi forest for the perpetuation of Hawaiian dry forest species.

When these funds were awarded in April of 2012, Auwahi was in the midst of a deep drought. Climate change is clearly impacting this dry forest habitat, apparent through the increasingly frequent droughts and the deeper and continuous wet or dry cycles. The wet cycles create conditions for the advance of habitat modifying weed invasions and atypical resource allocation during wet and dry cycles challenge native trees to provide sufficient resources for successful fruit development and seed set essential for regeneration of native trees. Over the last decade we have witnessed serious declines in the survival of dry forest trees. This population decline is due not only to drought stress, but also to invasive plants, invertebrates and ungulates in this habitat.

Obtaining seeds 'aiea proved to be extremely challenging and costly, much more than could have been predicted 7 years ago when the initial agreement was drafted. In Auwahi, 'aiea produces prolific flowers most years, however, for some reason, perhaps resource availability, most of these flowers fall off the tree or produce immature fruits that abort well before maturity.

Fortunately for this species, we recently collected hundreds more 'aiea fruit that were full developed and should lead to many hundred more 'aiea seedlings to be planted in Auwahi in the next few years.

Figure 1 and 2. Mature fruit on 'aiea trees in Auwahi. This recent collection of fruit is hopeful for the future of this species in Auwahi forest.

Figure 3. Healthy `aiea seedling planted in the understory of one of Auwahi's forest restoration areas. The native leaf litter at this site is deep providing `aiea trees protection from nematodes, organisms that directly damage `aiea roots and challenge the growth and survival of this species.

Attachment 5

FY 2020 Annual Work Plan and Timeline

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		2019						2020					
		July	Aug	Sept	October	November	December	January	February	March	April	May	June
PCMM	Fatality Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches	Weekly Canine Assisted Searches
	Searcher Efficiency Trials	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthly Trial	Monthl Trial
	Carcass Persistence Trials	Quarterly Trial			Quarterly Trial			Quarterly Trial			Quarterly Trial		
	Predator control	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check
	Acoustic/Thermal Monitoring	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check	Weekly Check
HAPE	HAPE Monitoring	Bi-Weekly Burrow Monitoring	Bi-Weekly Burrow Monitoring	Bi-Weekly Burrow Monitoring	Bi-Weekly Burrow Monitoring	Bi-Weekly Burrow Monitoring				Monthly Burrow Monitoring			
	Predator Control	Bi-Weekly Trap Checks					Trap Maintenance		Adjustments to Trap Grid	Bi-Weekly Trap Checks			
	Predator Assessment	Burrow Game Camera Review	Predator Activity Assessment	Burrow Game Camera Review	Burrow Game Camera Review	Burrow Game Camera Review			Predator Activity Assessment	Burrow Game Camera Review	Burrow Game Camera Review	Burrow Game Camera Review	Burrow Game Camera Review
	Predator Control trap monitoring trials using Reconyx Game Cameras	Deployment and Trials					Maintenance and repositioning			Deployment and Trials			
Bat	Ungulate Control	Quarterly Fence Inspection			Quarterly Fence Inspection			Quarterly Fence Inspection			Quarterly Fence Inspection		
	Vegetation Monitoring and Invasive Species Control	Target Weed Control					Annual Vegetation Monitoring			Target Weed Control			
	Tier 1	Plant filler Koas into outplanting units					Plant diversity of native plants into outplanting units						
Reporting	ITP & ITL Conditions		Annual HCP Report Submitted					Incidental Take Summary Tables Submitted	Semiannual Progress Report Submitted				
Tier 4 (Pending Approval of HCP Amendment)	Conservation Easement	Work with HILT to Identify Area and Draft Conservation Easement				Draft to DOFAW/USFWS	DOFAW/USFWS Approval						
	Fence Construction	Survey Fence Lines with Vendors						Fence Construction			Complete First Fenced Area	Fence Construction	
	Reforestation	Collect Seeds and survey planting areas						Grow Koas and Aalii in Nursery				Outplanting in Completed Fence	
	Pond Construction	Survey pond areas						Pond Construction			Quarterly Checks		
	Water Trough Modifications	Identify modifications acceptable to ranch						Water Trough Modification			Quarterly Checks		
	Bat Monitoring	Survey acoustic detector locations and purchase supplies						Deploy acoustic detectors			Quarterly Checks		
	Insect Monitoring	Survey insect sampling locations and purchase supplies						Deploy insect sampling equipment			Quarterly Checks		

Attachment 6

FY 2019 Expenditures for HCP Implementation

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	Tier, Ongoing, or One-time	Event	Proposed Costs	Total Costs Incurred to Date (up to July 2019)	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)
General Measures	Ongoing	Wildlife Education and Incidental Reporting Program	$5,000	$4,667	$3,000	$1,500	$167	N/A	N/A	N/A	N/A
	Ongoing	Downed Wildlife Post-Construction Monitoring and Reporting and Mitigation Monitoring	$1,810,000	$937,825	$100,000	$185,145	$152,901	$108,727	$96,700	$140,167	$154,185
	Ongoing	*DOFAW Compliance Monitoring (only if needed)	$200,000	$26,173	N/A	N/A	$2,423	N/A	4600	$8,100	$15,650
		Subtotal General Measures	*$1,815,000*	*$970,798*	*$103,000*	*$186,645*	*$155,324*	*$108,727*	*$101,300*	*$145,967*	*$169,835*
Hawaiian Hoary Bat	Tier 1	Retrofit fencing and restoration measures at the Waihou Mitigation Project	$522,000	$1,044,968	$314,900	$63,173	$128,410	$149,833	$126,463	$124,852	$137,337
	Tier 1	Acoustic Monitoring onsite	$40,000	$39,827	$5,000	$8,691	$14,663	$11,473	N/A	N/A	N/A
	Tier 2	Telemetry Research	$250,000	$249,999	N/A	$32,726	$8,308	$142,819	$66,146	N/A	N/A
	Tier 3	USGS Expanded Research	$250,000	$320,000	N/A	N/A	N/A	N/A	$234,360	$81,518	$4,122
		Subtotal Bats	*$812,000*	*$1,654,795*	*$319,900*	*$104,591*	*$151,381*	*$304,125*	*$426,969*	*$206,370*	*$141,459*
Hawaiian Petrel	Tier 1	Burrow Monitoring and Predator Control	$550,000	$684,265	$214,000	$74,572	$107,743	$56,410	$62,731	$83,880	$84,929
		Subtotal Petrels	*$550,000*	$684,265	*$214,000*	*$74,572*	*$107,743*	*$56,410*	*$62,731*	$83,880	$84,929
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
		Subtotal Nene	*$25,000*	*$25,000*	*$25,000*	*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
		Subtotal Moth	*$144,000*	*$144,000*	*$144,000*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
		Total HCP-related Expenditures	**$3,346,000**	**$3,478,860**	**$805,900**	**$365,808**	**$414,448**	**$469,263**	**$591,000**	**$436,218**	**$396,223**

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